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Thinking about Biology: Modular Constraints on Categorization and Reasoning in the Everyday Life of Americans, Maya, and Scientists*

1. Introduction

What follows is a discussion of four sets of set of experimental results that deal with various aspects of biological understanding among American and Maya children and adults. The first set of experiments shows that Yukatek Maya children do not have an anthropocentric understanding of the biological world; that is, children do not universally reason about nonhuman living kinds by analogy to nonhuman kinds. The fact that urban (but not rural) American children do show an anthropocentric bias appears to owe more to a difference in cultural exposure to nonhuman biological kinds than to a basic causal understanding of folkbiology *per se*. The second set of experiments shows that by the age of 4-5 years (the earliest age tested in this regard) rural Maya children as well as urban Brazilian (and American) children employ a concept of innate species potential, or underlying essence, as an inferential framework for projecting known and unknown biological properties to organisms in the face of uncertainty. Together, the first two sets of experiments indicate that folkpsychology cannot be the initial source of folkbiology.

They also suggest that to understand modern biological science, people must *unlearn* universal dispositions to view species essentialistically and to see humans as fundamentally different than other animals.

The third set of results shows that the same taxonomic rank is cognitively preferred for biological induction in two diverse populations: people raised in the Midwestern USA and Itza' Maya of the Lowland Mesoamerican rainforest. This is the generic species - the level of *oak* and *robin*. These findings cannot be explained by domain-general models of similarity because such models cannot account for why both cultures prefer species-like groups in making inferences about the biological world, given that Americans have relatively little actual knowledge or experience at this level. In fact, general relations of perceptual similarity and expectations derived from experience produce a "basic level"of recognition and recall for many Americans that corresponds to the superordinate life-form level of folkbiological taxonomy –the level of *tree* and *bird*. Still Americans prefer generic species for making inductions about the distribution of biological properties among organisms, and for predicting patterns in the face of uncertainty. This supports the idea of the generic-species level as a partitioning of the ontological domains of *plant* and *animal* into mutually exclusive essences that are assumed (but not necessarily known) to have unique underlying causal natures.

The fourth set of experiments shows that adult Maya, as well as American college students and various groups of biological experts (landscapers, parks workers, birdwatchers, professional taxonomists), spontaneously order generic species into taxonomies with higher and lower levels. Only the college students, however, consistently use their taxonomies to reason as science suggests they should: given a property found in two organisms (e.g., a turkey and an eagle) then it is reasonable to generalize that property to all and only those organisms that fall within the smallest taxon containing the original pair of organisms (e.g., birds). Moreover, only college students consistently project biological properties across taxa in accordance with similarity-based typicality or central tendency.

The implication from these experiments is that folkbiology may well represent an evolutionary design: universal taxonomic structures, centered on essence-based generic species, are arguably routine products of our “habits of mind”, which may be in part naturally selected to grasp relevant and recurrent “habits of the world”. The science of biology is built upon these domain-specific cognitive universals: folkbiology sets initial cognitive constraints on the development of macro-biological theories, including the initial development of evolutionary theory. Nevertheless, the conditions of relevance under which science operates diverge from those pertinent to folkbiology.

For the Maya, and arguably for others who subsist owing to their knowledge of the living world, folkbiological taxonomy works to maximize inductive potential relative to human interests. Here, folkbiological taxonomy provides a well-structured but adaptable framework. It allows people to explore the causal relevance to them –including the ecological relevance– of the natural world. Historically, for pragmatic reasons, the West’s development of a world-wide scientific systematics involved disregard of ecological relationships, and of the colors, smells, sounds, tastes and textures that constitute the most intimate channels of ordinary human recognition and access to the surrounding living world. For scientific systematics, the goal is to maximize inductive potential regardless of human interest. The motivating idea is to understand nature as it is “in itself”, independently of the human observer (as far as possible). From this standpoint, the species concept, like teleology, should arguably be allowed to survive in science more as a regulative principle that enables the mind to establish a regular communication with the ambient environment, than as an epistemic principle that guides the search for nomological truth.

Finally, these experiments suggest that standard undergraduate populations in major North American (or European) universities are often the “odd group out” in cross-cultural research on basic cognitive processes of biological categorization and reasoning. This has troubling implications for theoretical and methodological generalizations that are often based exclusively on such populations. This is especially problematic for claims about what is universal and what is not.

2. Four points of general correspondence between folkbiology and scientific systematics

In every human society, people think about plants and animals in the same special ways (Atran, 1998). These 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. The science of biology also treats plants and animals as special kinds of objects, but applies this treatment to humans as well. Folkbiology, which is present in all cultures, and the science of biology, whose origins are particular to Western cultural tradition, have corresponding notions of living kinds.

Consider four corresponding ways in which ordinary folk and biologists think of plants and animals as special.

2.1. First point

People in all cultures classify plants and animals into species-like groups that biologists generally recognize as populations of interbreeding individuals adapted to an ecological niche. We call such groups –like *redwood*, *rye*, *raccoon* or *robin* – "generic species". Generic species often correspond to scientific genera (e.g., oak) or species (e.g., dog), at least for the most phenomenally salient organisms, such as larger vertebrates and flowering plants. Generic species may also be the categories most easily recognized, most commonly named and most easily learned by children in small-scale societies (Stross, 1973). Indeed, 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 (Bartlett, 1940; Berlin, Breedlove & Raven, 1973; Bulmer, 1974; Hunn, 1982; Ellen, 1993). Ethnobiologists, historians of systematics and field biologists mostly agree "that species come to be tolerably well defined objects […] in any one region and at any one time" (Darwin, 1883 [1872], p.137) and that such local species of the common man are the heart of any natural system of biological classification (Diamond & Bishop, 1999).

The term "generic species" is used here, rather than "folk genera/folk generic or "folk species/folk species" because a principled distinction between biological genus and species is not pertinent to most people around the world. For humans, the most phenomenally salient species (including most species of large vertebrates, trees, and evolutionarily isolated groups such as palm s and cacti) belong to monospecific genera in any given locale. Closely related species of a polytypic genus may be hard to distinguish locally, and often no readily perceptible morphological or ecological "gap" can be discerned between them (Diver, 1940).[i]

Generic species are usually as obvious to a modern scientist as to local folk. Historically, the generic-species concept provided a pre-theoretical basis for scientific explanation of the organic world in that different theories –including evolutionary theory – have sought to account for the apparent constancy of "common species" and the organic processes that center on them (Wallace, 1901 [1889], p.1).

2.2. Second point

There is a commonsense assumption that each generic species has an underlying causal nature, or essence, which is uniquely responsible for the typical appearance, behavior and ecological preferences of the kind. People in diverse cultures consider this essence responsible for the organism's identity as a complex, self-preserving entity governed by dynamic internal processes that are lawful even when hidden. This hidden 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 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 (Ghiselin, 1998). Nevertheless, biologists have traditionally interpreted this conservation of identity under change as due to the fact that organisms have separate genotypes and phenotypes.

2.3. Third point

In addition to the spontaneous division of local flora and fauna into essence-based species, such groups have "from the remotest period in […] history […] been classed in groups under groups. The structure of these hierarchically included groups, such as *white oak*/*oak*/*tree* or *m ountain robin*/*robin*/*bird*, is referred to as "folkbiological taxonomy". Especially in the case of animals, these nonoverlapping taxonomic structures can often be scientifically interpreted in term s of speciation (related species descended from a common ancestor by splitting off from a lineage).

In all societies that have been studied in depth, folkbiological groups, or taxa, are organized into hierarchically-organized ranks. Most folkbiological systems have between three and six ranks (Berlin, 1992). Taxa of the same rank are mutually exclusive and tend to display similar linguistic, biological and psychological characteristics. Ranks and taxa, whether in folkbiological or scientific classification, are of different logical orders, and confounding them is a category mistake. 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. Ranks are intended to represent fundamentally different levels of reality, not convenience.[ii]

2.4. Fourth point

Such taxonomies not only organize and summarize biological information; they also provide a powerful inductive framework for making systematic inferences about the likely distribution of organic and ecological properties among organisms. For example, given the presence of a disease in robins one is "automatically" justified in thinking that the disease is more likely present among other bird species than among nonbird species. In scientific taxonomy, which belongs to the branch of biology known as systematics, this strategy receives its strongest expression in "the fundamental principle of systematic induction" (Warburton, 1967; Bock, 1973). On this principle, given a property found among members of any two species, the best initial hypothesis is that the property is also present among all species that are included in the smallest higher-order taxon containing the original pair of species. For example, finding that the bacteria *Escheriehia coli* share a hitherto unknown property with robins, a biologist would be justified in testing the hypothesis that all organisms share the property. This is because *E. coli* link up with robins only at the highest level of taxonomy, which includes all organisms. This or any general-purpose system of taxonomic inference for biological kinds is grounded in a universal belief that word naturally divides into the limited causal varieties we commonly know as (generic) species.

These four principles provide the backbone and background for studying the role of culture and experience in cognizing nature. That is, they suggest candidates for universals as well as variations that may derive from limited contact with plants and animals or from different cultural lenses for perceiving biological kinds. In the next sections of this paper we review four case studies that illustrate these themes.

3. Folk biology doesn't come from folk psychology:

Experimenta1

One influential model of conceptual development in folkbiology is Carey's (1985) notion that young children's understanding of living things is embedded in a folkpsychological, rather than folkbiological, explanatory framework, and that until age10, it is based on their understanding of humans. Carey reports three major findings to bolster the claim that children's conceptions of the biological world are anthropocentric. First, projections from humans are stronger overall than projections from other living kinds. 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, 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.

This research has had a powerful impact on psychological theory and educational practice; but it suffers from a serious limitation. It 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 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. Indeed there is evidence that the onset of the industrial revolution was associated with a sharp and continuing drop in cultural interest in and support for learning about biological kinds (e.g. Wolff, Medin & Pankratz, 1999), at least in industrialized nations. Over the past few years we have been testing the generality of Carey's finding. We have examined biological induction in rural USA majority culture children, rural USA Native American children, and in Yukatek Maya children living in rural Mexico. Here we concentrate on our findings in Mexico (See Atran, Medin, Lynch, Vapnarsky, Ucan Ek' & Sousa, 2001 for full details).

Our participants were nearly 100 Yukatek Maya-speaking children (ages 4-5 and 6-7) and adults from rural villages in southcentral Quintana Roo, Mexico. By and large, younger children were monolingual, older children had begun learning Spanish, and almost all of the adults understood Spanish as a second language. All testing was done in Yukatek Maya.

Detailed color drawings of objects represented base and target categories. Four bases were used: 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).

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, and bases and targets were presented in random order for each participant.

The first result of interest is that humans were not the only useful inductive base for the young children. All groups show generalization as a function of biological affinity (similarity) between base and target for bases like dog, bee and peccary. Furthermore, the young children were actually more likely to generalize from dog to other animals than to generalize form humans to other animals.

With humans as a base, 4-5-year-olds generalize broadly in an undifferentiated manner – they show no reliable effect of similarity. In contrast, adults show characteristically sharp gradients with humans as a base. The 6-7-year-olds show a very weak similarity gradient. In short, the clearest developmental change is in determining the role of humans in the folktaxonomic system (seeFigure1a). A second major result is that the children did not show reliable human-animal asymmetries**.** For inferences involving the bases Human and Dog, the data are inconsistent with Carey because only adults show the asymmetry favoring Human to mammal over Dog to human (see Figures 1a-1d).

<insert Figures 1a-1d about here>

Using the same experimental set-up as in Yucatán, Ross, Medin, Coley and Atran (2003) studied projection patterns for over 200 USA children from the urban Boston area and from rural Wisconsin. They found that the young urban children 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 generalized in terms of biological affinity but showed a strong asymmetry in reasoning between humans and other animals. Overall, these data from urban children provide a rough replication of Carey's original results.

Studies with rural children revealed a different pattern. The youngest children 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 Johnson, Mervis & Boster (1992) suggest.

Young Yukatek Maya children and young rural American children do not show commitment to an anthropocentric understanding of the living world. This suggests that folkpsychology is not a necessary or universal source for folkbiology. Carey's results m ay derive from the fact that humans are the only animal that urban children k now much about and so they generalize from them. Consistent with this view, Inagaki (1990) presents evidence that experience influences children's biological reasoning (cf.Inagaki & Hatano, 1991). She found that kindergarteners who raised 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.

4. Childhood conceptions of species essences:

Experiment 2

Young individuals 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 it's birth parent) rather than the environment in which it was raised (i.e. the species of it's 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.

This study has been criticized 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, it does not address the question of how the children identify to which species the baby belongs in the first place (Johnson & Solomon, 199 7).

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 being a member of a certain species *causes* a cow to *be* a cow (Carey, 1996).

Hickling and Gelman (1995) addressed this criticism in a later experiment; our focus has been on evaluating the generality of their results. Our studies are designed to test the extent to which children's assumptions about innate species potential govern projection of both known and unknown properties, and to avoid the problems noted above. Our research team has studied children and adults in rural Wisconsin, Brazil, and Mexico. Here, we concentrate on our results in Mexico and Brazil (for details see Atran, Medin, Lynch, Vapnarsky, Ucan Ek' & Sousa, 2001) but our findings are quite general.

Participants in Mexico were some 100 Yukatek Maya-speaking children and adults. All testing was done in Yukatek Maya. In a forced choice task, children 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 associated 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, mahogany vs. cedar tree) were shown to participants. The sketches did not indicate the species to which the traits belonged. Subjects chose birth or adoptive parent species in response to the probes by pointing to the relevant parent sketch.*

The story was followed by two comprehension controls: a birth control (*Who gave birth to the baby? Go ahead and point out the drawing of who gave birth to the baby*.) and a nurture control (*Who did the baby grow up with?*). Children then were presented with the four experimental probes. For example: *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?* For each set, the
four probes (counterbalanced in order across children) 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?*

<insert Tables 1a-1b about here (see PDF file enclosed,
showing these tables as published in *Mind& Society*)>

Overall, the results show a systematic and robust preference for attributions from the birth parent (Table1a). This preference was observed for all age groups and for known and unknown behavior and physical properties. The trend is somewhat stronger in older children and adults and slightly stronger for known than unknown properties. Means for all probes were significantly different from 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.

A similar study with over 100 urban Brazilian children and adults revealed almost the same pattern of results (Sousa, Atran & Medin, 2002). One minor difference was that several of the

6-7 year-old Brazilian children based their responding on an explicit analogy with the Disney movie, *Tarzan*, which was widely shown at the time of the study (Table1b). They evinced a ~~a~~ marginally weaker birth bias than did 4-5 year-olds, consistent with Tarzan’s mixed human/ape characteristics.

Summary Results of these studies indicate that Yukatek Maya children and adults as well as urban Brazilian children and adults reliably 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 young Maya and Brazilian children use the notion of underlying essence as an inferential framework for understanding the nature of biological species. These findings, together with Gelman and Wellman’s (1991) earlier results for urban American children, suggest that such an essentialist bias in children is universal. Bloch, Solomon, and Carey (2001) report an apparent counter-example among (older) Zafimaniry children but they did not counter-balance properties across birth and adoptive parents (and birth and adoptive parents differed markedly in social status) so it is difficult to assess their findings.

5. Essence (generic species) vs. appearance (basic levels) in folkbiology:

Experim ent 3

In a justly celebrated set of experiments Rosch and her colleagues set out to test the validity of the notion of a psychologically preferred taxonomic level (Rosch, Mervis, Grey, Johnson & Boyes-Braem, 1976). Using a broad array of converging measures they found that there is indeed a “basic level” in category hierarchies of “naturally occurring objects”, such as “taxonomies” of artifacts as well as living kinds. For artifact and living kind hierarchies, the basic level is where: (1)many common features are listed for categories, (2)consistent motor programs are used for the interaction with or manipulation of category exemplars,(3)category members have similar enough shapes so that it is possible to recognize an average shape for objects of the category, (4)the category name is the first name to come to mind in the presence of an object (e.g., “table” versus “furniture” or “kitchen table”).

There is a problem, however: The basic level that Rosch, Mervis, Grey, Johnson & Boyes-Braem (1976) had hypothesized for artifacts was confirmed (e.g., *hammer*, *guitar*); however, the hypothesized basic level for living kinds (e.g., *maple*, *trout*), which Rosch initially assumed would accord with the generic-species level, was not. For exam ple, instead of *maple* and *trout*, Rosch etal. 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 the life-form level, which is superordinate to the generic-species level (seeZubin & Köpcke, 1986 for supporting evidence involving the German language). In short, the level assumed to be psychologically-salient based on ethnobiological studies, generic species, did not prove to be privileged for Berkeley undergraduates. How can one reconcile these differences?

To explore the apparent discrepancy between preferred taxonomic levels in small-scale and industrialized societies, and the cognitive nature of ethnobiological ranks in general, we used inductive inference. Inference allows us to test for a psychologically preferred rank that maximizes the strength of any potential induction about biologically relevant information, and whether or not this preferred rank is the same across cultures. If a preferred level carries the most information about the world, then categories at that level should favor a wide range of inferences about what is common among members (for detailed findings under a variety of lexical and property-projection conditions, see Atran, Estin, Coley & Medin, 1997; Coley, Medin & Atran, 1997).

The prediction is that inferences to a preferred category (e.g., *white oak* to *oak*, *tabby* to *cat*) should be much stronger than inferences to a superordinate category (*oak* to *tree*, *cat* to *mammal*). Moreover, inferences to a subordinate category (*swamp white oak* to *white oak*, *short-haired tabby* to *tabby*) should not be much stronger than or different from inferences to a preferred category. What follows is a summary of results from one representative set of experiments in two very diverse populations: Midwestern American adults and lowland Maya elders. The Itza' are Maya Amerindians living in the Petén rainforest region of Guatemala. Until recently, men devoted their time to shifting agriculture, hunting and silviculture, whereas women concentrated on the myriad tasks of household maintenance. The Americans were college students, self-identified as people raised in Michigan, and recruited through an advertisement in a local newspaper.

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" (*puksik'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 over 50 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. L =bird), generic-species (e.g. G =vulture), folk-specific (e.g. S =black vulture), or varietal (e.g. V =red-headed black vulture). The conclusion category was drawn from a higher-level category, either kingdom (e.g. K =animal), life-form (L), generic-species(G), or folk-specific(S). Thus, there were ten possible combinations of premise and conclusion category levels. For example, a folk-specific-to-life form (S->L) 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 seeDougherty, 1979). The properties used in questions for the Michigan 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.

<insert Figures 2a-2b about here>

Figure2a 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(S) rank (e.g., red squirrel) and a conclusion category of generic-species(G) 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. Results were obtained by totaling the proportion of "all or virtually all" responses for each kind of question (e.g., the proportion of times respondents agreed that if red oaks had a property, all or virtually all oaks would have the same property). A higher score represented more confidence in the strength of the inductive inference. Figure2b summarizes results of Michigan response scores for all life forms and biological properties.

Following the main diagonals of Figures2a and 2b 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 (i.e., V->S, S->G, G->L, L->K), 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 Michigan patterns are nearly identical.

Moving horizontally within each graph corresponds to holding the premise category constant and varying the level of the conclusion.[iii] We find the same pattern for "all" responses for both Itza' and Americans as we did along the main diagonal. However, in the combined response scores ("all" + "few") there is evidence of increased inductive strength for higher-order taxa among Americans versus Itza'. Both Americans and Itza' show the largest break between inferences to generic species versus life forms, but 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: G->K vs. G->L, S->K vs. S->L, and V->K vs. V->L.

These results indicate that both the ecologically inexperienced Americans and the ecologically experienced Itza' prefer taxa of the generic-species rank in making biological inferences. These findings cannot be explained by appeals either to cross-domain notions of perceptual "similarity" or to the structure of the world "out there", as most ethnobiologists contend (Berlin, 1992; Hunn, 1976; Boster, 1991). If inferential potential were a simple function of perceptual similarity then Americans should prefer life forms for induction (in line with Roschetal.). Yet Americans prefer generic species as do Maya. Unlike Itza', however, Americans perceptually discriminate life forms more readily than generic species (although one might expect that having less biodiversity in the American environment allows each species to stand out more from the rest). This lack of convergence between knowledge and expectation on the part of the USA participants may represent devolution associated with diminished contact with nature. If this view is correct, evidence that biological experts treat the generic-species level as privileged on perceptual, feature listing and naming tasks (e.g. Tanaka & Taylor, 1991; Johnson & Mervis, 1997) may represent the natural byproduct of experience with nature. In other words, performance of people in less industrialized contexts and USA experts may reflect "normal development" with so-called "USA nonexperts" reflecting the cognitive consequences of diminished contact with nature. In this sense it is all the more remarkable that our non-expert USA adults privileged the generic-species level on the induction task.[iv] We see that as reflecting the robust presumption of essence focused on this level.

The findings suggest that root categorization and reasoning processes in folkbiology owe to domain-specific conceptual presumptions and not exclusively to domain-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 *oak* / *red oak*). Our experiments, however, still show reliable results in the absence of clear linguistic cues (e.g., *oak* /*white oak* /*swamp white oak* vs. *dog* /*poodle* /*toy poodle*).

6. Cultural and expertise effects in taxonomic inference

An important function of taxonomic classification is enabling generalizations between categories. Osherson, Smith, Wilkie, Lopez and Shafir (1990) identify a set of phenomena that characterize category-based inferences in adults, and formalize a model that predicts the strength of those inferences. Consider argument (i) below:

(i)H yenas have an ileal vein

Cows have an ileal vein

Wolves have an ileal vein.

This argument is strong to the extent that belief in the premises leads to belief in the conclusion. There are two components to Osherson, Smith, Wilkie, López & Shafir's (1990) similarity-coverage model (SCM). Participants may infer that wolves have an ileal vein because they are similar to hyenas, or they may infer it because they have inferred that all mammals share the property given that hyenas and cows do. Thus, the first component of the model, *similarity*, calculates the maximum similarity of the premise categories to the conclusion category; the greater this similarity, the stronger the argument. In this example, hyenas are more similar to wolves than cows are, hence similarity is calculated for hyenas. The second component – *coverage* – calculates the average maximum similarity of premise categories to members of the "inclusive category" –the lowest category that includes both premise and conclusion categories. For argument (i), the inclusive category is presumably *mammal*. In our research, the inclusive category is simply the conclusion category. The greater the coverage of the inclusive category by the premise categories, the stronger the argument.

For present purposes we will focus on the phenomenon of diversity. Diversity is a measure of category coverage. The diversity phenomenon predicts that an argument will be inductively strong to the degree that categories mentioned in its premises are similar to different instances of the conclusion category. For example, consider arguments in (ii): (iia) Jaguars have protein Y

Leopards have protein Y

All mammals have protein Y.

(iib)Jaguars have protein Y

Mice have protein Y

All mammals have protein Y.

The SCM predicts that the categories mentioned in the premise of (iib) provide greater *coverage* of the conclusion category *mammal*–i.e., are more similar to more mammals – than the categories mentioned in the premises of (iia), thus making (iib) the stronger argument. Indeed, most subjects agree that the (iib) is stronger than (iia) (Oshersonetal., 1990). Diversity predicts that an argument with more diverse premises will be evaluated as stronger than an argument with more similar premises.

Lopez, Atran, Coley, Medin & Smith (1997) used the similarity-coverage model to investigate inductive reasoning about mammals among U.S.college students and Itza' Maya elders. They found that the groups differed markedly in the extent of their use of diversity. U.S.participants demonstrated powerful diversity effects whereas the Itza' were reliably below chance in the selection of arguments with more diverse premises. Itza' reasoned on the basis of specific knowledge of the species in question, which was often ecological in nature.

Consider the following scenario: Suppose we know that River Birch and Paper Birch trees can get some new diseaseA and that White Pine and Weeping Willow can get some new diseaseB. Which disease is more likely to be able to affect all kinds of trees? According to the "diversity principle" that underlies taxonomic sampling and inference in science one would choose disease B on the grounds that White Pines and Weeping Willows are more different (diverse) than River Birch and Paper Birch. Undergraduates overwhelmingly pick the argument with the more diverse premises as stronger. Taxonomists show diversity but not nearly to the extent of undergraduates. Landscapers show even less diversity, whereas parks maintenance workers show *negative* diversity (Proffitt, Medin & Coley, 2000). Justifications for judgments reveal these tree experts engaging in causal/ecological reasoning. For instance, in the above example, 13 of 14parks maintenance personnel selected the disease associated with birches. Their reasoning was as follows: "Birches are found all over the place and incredibly susceptible to disease so that if one of them gets it, they all will get it. Then there will be many opportunities for the disease to spread".

American birdwatchers and Itza' Maya also show causal ecological/ reasoning and relatively little diversity-based responding (Bailenson, Shum, Atran, Medin & Coley, 2002). By contrast, American undergraduates, who are relative novices with respect to the birder expertise of the other two groups, again appear to be 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 (Table2). 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.

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showing this table as published in *Mind& Society*)>

Work in progress in Wisconsin shows a similar focus on causal and ecological relations among freshwater fishermen (Medin, Ross, Atran, Burnett & Blok, 2002). Only when there is clear disregard for ecological context (from relative ignorance in the case of college students, from a scientific tradition of de-contextualized comparisons in the case of taxonomists) do taxonomic inductions follow the diversity principle. In short, although people may use folk taxonomies in reasoning, there are often more compelling strategies linked to ecological relations. Only novices appear to resort to abstract, similarity-based reasoning strategies on a consistent basis.

Only USA novices (i.e., undergraduates) show patterns of judgment consistent with current models of category-based taxonomic inference and universal claim s about similarity-based notions of diversity and typicality in natural categorization and reasoning. This has troubling implications given the fact that USA 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. It is hard to imagine a more culturally-limited subject pool as a basis for generalization to humankind as a whole.

Take the case of typicality. In our reasoning studies, typicality strategies are also reliably used only by US nonexperts (undergraduates). Consequently, models invoking such principles may apply solely to situations where novices are reasoning about stimuli with which they have limited knowledge. Those models tend to support the view that similarity-based structures (e.g., central tendency, family resemblance) are the primary predictors for typicality in taxonomic categories, in general, and folkbiological categories, in particular (Rosch & Mervis, 1975; Barsalou, 1985). In this view, the mind's similarity judgments about typicality and the world's correlational structure are closely linked: typical members of categories capture the correlational structure of identifiable features in the world better than do atypical members. This capacity to recognize correlated similarity structures in the world, such as other species types, seems to be a built in part of human and well as non-human species (Cerella, 1979; Lorenz, 1966; Herrnstein, 1984; Brown & Boysen, 2000; cf.Smith & Medin, 1981). From these considerations Boster (1988, p.258) predicts a biological, cognitive and cultural universal: "Passerines appear to be densely and continuously spread through the bird similarity space […] non-passerines are m ore sparsely and discontinuously distributed, leading to the choice of passerines as both more typical and more difficult to categorize than non-passerines".

But for Itza' Maya, passerines are not very typical at all.

Work on direct 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. 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, 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.

Consistent with these results, Lynch, Coley and Medin (2000) found that tree experts based their typicality judgments on ideals (e.g. height, absence of undesirable characteristics) and that central tendency was uncorrelated with judgments. They found no effects of type of expertise. The fact that US experts and Itza' both show effects of ideals undermines concerns about the wording of the typicality instructions in Itza' Maya somehow conveying a different notion of typicality. Lynchetal. used instructions that followed verbatim those by Rosch and Mervis (1975) in their original studies showing central-tendency based typicality effects.[v] Bailensonetal. (2002) also found that typicality judgment were correlated with central tendency only among novices.

No doubt similarity structures and similarity-based typicality and diversity are important determinants in natural categorization and reasoning. Our findings suggest that, at least 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 example, Bailensonetal. (2002) found that Itza' Maya rely less on passerines than do USA informants on reasoning tasks. American subjects tended to pick small songbirds as generalizing to the population of all birds while Itza' preferred larger, more perceptually striking birds. 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, then the information provided by their ideal birds 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. For Americans, whose interest in, and interaction with, behavioral ecology is of a much reduced and different order (game birds are not considered palpably crucial to survival of the human habitat), correlated perceptual information may be more relevant by default.

Such concerns also may be critical to the way the Maya and perhaps other peoples in small-scale manage to live and survive with nature. If so, then it is practically impossible to isolate folkecological orientation from other aspects of cultural knowledge. Thus, previous studies indicate that Itza' share with other cultural groups (e.g., Spanish -speaking Ladino immigrants, highland Q'eqchi' Maya immigrants) an identical habitat and a similar taxonomic understanding of its flora and fauna; nevertheless, these different cultural groups cognitively model species relationships (including humans) and socially interact with the same local ecology in fundamentally different ways (Atran, Medin, Ross, Lynch, Coley, Ucan Ek' & Vapnarsky, 1999; Atran et al., 2002). Such findings strongly simply that culture-specific cognitions and practices –and not just biotic, demographic or other material features of the environment– reliably determine population differences in ecological orientation and folkbiological understanding.

Most compellingly, we found patterns of expertise in natural categorization and reasoning that selectively transcend cultural boundaries: Itza' Maya 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 entirely on feral children.

7. Th e general-purpose nature of folk biological taxonom y

These experimental results in two very different cultures –an industrial Western society and a small-scale tropical forest society– indicate that people across cultures organize their local flora and flora in similarly structured taxonomies. Yet they may reason from their taxonomies in systematically different ways. With their ranked taxonomic structures and essentialist understanding of species, it would seem that no great cognitive effort is additionally required for the Itza' or USA experts to recursively essentialize the higher ranks as well, adopt the diversity principle, and thereby avail themselves of the full inductive power ranked taxonomies provide. But contrary to earlier assumptions (Atran, 1990), our studies show this is not the case. Itza', and probably other traditional folk, do not essentialize ranks: they do not establish causal laws at the intermediate or life-form levels, and do not presume that higher-order taxa share the kind of unseen causal unity that their constituent generic species do.

There seems, then, to be a sense to Itza' "failure" in turning their folk taxonomies into one of the most powerful inductive tools that humans may come to possess. To adopt this tool, Itza' would have to suspend their primary concern with ecological and morpho-behavioral relationships in favor of deeper, hidden properties of greater inductive potential. But the cognitive cost would probably outweigh the benefit (Sperber & Wilson, 1996). For this potential, which science strives to realize, is to a significant extent irrelevant, or only indirectly relevant, to local ecological concerns. The only USA experts to consistently show diversity effects are those with a great deal of training in scientific taxonomy. For expertise organized around m ore practical goals it is seldom necessary to go above the level of family.

Scientists use diversity-based reasoning to generate hypotheses about global distributions of biological properties so that theory-driven predictions can be tested against experience and the taxonomic order subsequently restructured when prediction fails. For scientific systematics, the goal is to maximize inductive potential regardless of human interest. The motivating idea is to understand nature as it is "in itself", independently of the human observer (as far as possible). For Itza', people from other small-scale societies and practical experts, folkbiological taxonomy works to maximize inductive potential relative to human interests. Here, folkbiological taxonomy provides a well-structured but adaptable framework It allows people to explore the causal relevance to them –including the ecological relevance– of the natural world. Maximizing the human relevance of the local biological world –its categories and generalizable properties does not mean assigning predefined purposes or functional signatures to it. Instead, it implies providing a sound conceptual infrastructure for the widest range of hum an adaptation to local cultural and environmental conditions.

For scientific systematics, folk biology may represent a ladder to be discarded after it has been climbed. But for an increasingly urbanized and formally educated people, who are often unwittingly ruinous of the environment, no amount of cosmically valid scientific reasoning skill may be able to compensate the local loss of ecological awareness upon which human survival may ultimately depend. Because folk in industrialized societies often lack aspects of folkbiological knowledge as well as scientific theory, reliance on diversity-based induction and other scientific strategies at the expense of ecologically-based folkbiological strategies may discourage, rather than encourage, better understanding of the world.

8. Science and comm on sense

Much of the history of systematics has involved attempts to adapt locally relevant principles of folkbiology to a more global setting, such as the taxonomic embedding of biodiversity, the primacy of species, and the teleo-essentialist causality that makes sense of taxonomic diversity and the life functions of species. This process has been far from uniform (e.g., initial rejection of plant but not animal life form s, recurrent but invariably failed attempts to define essential characters for species and other taxa, intermittent attempts to reduce teleological processes to mechanics, and so forth) (Atran, 1990).

Historical continuity between universal aspects of biological common sense and the science of biology should not be confounded with epistemic continuity or use of folk knowledge as a learning heuristic for scientific knowledge. Scientists have made fundamental ontological shifts away from folk understanding in the construal of species, taxonomy and underlying causality. For exam ple, biological science today rejects fixed taxonomic ranks, the primary and essential nature of species, teleological causes ‘for the sake’ of species existence, and phenomenal evidence for the existence of taxa (e.g., trees do not constitute a scientifically valid superordinate plant group, but bacteria alm ost assuredly should).

Nevertheless, from the vantage of our own evolutionary history, it may be more important that our ordinary concepts be adaptive than true. Relative to ordinary human perceptions and awareness, evolutionary and molecular biology's concerns with vastly extended and minute dimensions of time and space has only marginal value. The ontological shift required by science may be so counterintuitive and irrelevant to everyday life as to render inappropriate and maladaptive uses of scientific knowledge in dealing with ordinary concerns. Science can't wholly subsume or easily subvert folkbiological knowledge.

9. Conclusion: Cultural em ergence in an evolutionary landscape

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, induction experiments regarding 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.

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 distinctly different notions of modules so we will take a few paragraphs to provide a definition and characterization of 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. It has its own proprietary database, and may not draw on information produced by other conceptual modules or processes. A perceptual module is usually associated with fairly fixed 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, p.285).[vi] Examples include folkmechanics, folkbiology and folkpsychology. The argument for conceptual modules involves converging evidence from a num ber 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 (Atran, 2001). Consider these criteria of evidence for modularity in the case of folkbiology:[vii]

Functional Design**:** Natural selection may account for the appearance of complexly well-structured biological traits that are designed to perform important functional tasks of adaptive benefit to organisms. In general, naturally selected adaptations are structures functionally “perfected for any given habit” (Darwin, 1883 [1872], p.140), having “very much the appearance of design by an intelligent designer […] on which the wellbeing and very existence of the organism depends” (Wallace, 1901 [1889], p.138). The universal appreciation of generic species m ay be one such functional evolutionary adaptation. Moreover, the pigeonholing of generic species into a hierarchy of mutually exclusive taxa arguably allows the incorporation of indefinitely many species and biological properties into an inductively coherent system that can be extended to any habitat whatsoever, thus facilitating adaptation to any habitat (a hallmark of *Homo sapiens*). And so:

> 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, p.431).

Ethology**:** One hallmark of adaptation is a phylogenetic history that extends beyond the species in which the adaptation is perfected: for example, ducklings crouching in the presence of hawks, but not other kinds of birds suggests dedicated mechanisms for something like species recognition. But there is no a priori reason for the mind to always focus on categorizing and relating species *qua* species, unless doing so served some adaptive function.

For example, it makes little sense to know the individual differences between lions that can eat you and bananas you can eat, but allot of sense to know that *lions* can eat you and *bananas* you can eat (cf. Eldredge, 1986).

Universality**:** Ever since the pioneering work of Berlin and his colleagues, evidence from ethnobiology and experimental psychology has been accumulating that all human societies have similar folkbiological structures (Berlinetal., 1973; Berlin, 1992; Hunn, 1977; Hays, 1983; Brown, 1984; Atran, 1990, 1999). These striking cross-cultural similarities suggest that a small number of organizing principles universally define folkbiological system s.

Ease of acquisition**:** Acquisition studies indicate a precocious emergence of essentialist folkbiological principles in early childhood that are not applied to other domains (Gelman & Wellman, 1991; Keil, 1995; Hatano & Inagaki, 1999; Atranetal., 2001).

Independence from perceptual experience**:** Experim ents on inferential processing show that that humans do not make biological inductions primarily on the basis of perceptual experience or any general similarity-based metric, but on the basis of imperceptible causal expectations of a peculiar, essentialist nature (Atranetal., 1997; Coley etal.,1997).

Inhibition and hyperactivity**:** One characteristic of an evolved cognitive disposition is evident difficulty in inhibiting its operation (Hauser, 2000). Consider beliefs in biological 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 biological 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**:** H um an 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 readily aids humans to orient themselves and survive in the natural world. Folkbiological taxonomy serves 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, 2002).

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, 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.

In sum, folkbiology plays a special role in cultural evolution in general, and particularly in the development of totemic tribal religions and Western biological science. To say an evolved mental structure is "innate" is not to say that every important aspect of its phenotypic expression is "genetically determined". The particular organisms observed, actual exemplars targeted, and specific inferences made can vary significantly from person to person. Much as mountain rain will converge to the same mountain-valley river basin no matter where the rain falls, so each person's knowledge will converge on the same cognitive "drainage basin" (Waddington, 1959; Sperber, 1996). This is because:(1)inputs naturally cluster in causally redundant ways inasmuch as that's the way the world is (e.g., where there are wings there are beaks or bills, where there are predators there are prey, where there are fruit-eating birds there are fruit-bearing trees, etc.); and (2)dedicated mental modules selectively target these inputs for processing by domain-specific inferential structures (e.g., to produce natural taxonomies).

In this way, the mind is able to take fragmentary instances of a person's experience (relative to the richness and complexity of the whole data set) and spontaneously predict (project, generalize) the extension of those scattered cases to an indefinitely large class of intricately related cases (of larger relevance to our species and cultures). Thus, many different people, observing m any different exemplars of dog under varying conditions of exposure to those exemplars, all still generate more or less the same general concept of *dog*. Within this evolutionary landscape of medium-sized objects that are snapshot in a single lifespan of geological time, biologically-poised mental structures channel cognitive development but do not determine it. Cultural life, including religion and science, can selectively target and modify parts of this landscape but cannot simply ignore it or completely replace it.

The full expression of the folkbiology module may require natural environmental triggering conditions (akin to those of ancestral environments) and cultural support perhaps lacking for certain groups in industrialized societies, including the usual subjects in most cognitive psychology experiments. These subjects, then, would be prime candidates for studies of knowledge devolution – at least in the domain of folkbiology.

<Figure captions>

Figure1a. Maya projections from humanFigure 1b. Maya projections from dogFigure 1c. USA projections from human (after Carey, 1985)Figure1d. USA projections from dog (after Carey, 1985)

Figure2a. Combined Itza' results for all six life formsFigure2b. Combined Michigan results for all six life forms

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<Tables (see PDF file enclosed, showing these tables as published in *Mind& Society*)>

Table 1a. Percent birth parent choice for each probe type for each age group (rural Maya)

Know n Unk now n

GROUP beh avior ph ys feat beh avior ph ys feat

Bias Control

(Food)

4-5 year olds 0.74** 0.68* 0.69 ** 0.68* 0.06***

6-7 year olds 0.96***0.97***0.82***0.83***0.01*** *Adults*

1.00***0.96***0.90***0.93***0.00***

p < .05*, p < .01**, p < .001***

Table 1b. Percent birth parent ch oice for each probe type for each age group (urban Brazil)

Know n Unk now n GROUP beh avior ph ys feat beh avior Bias ph ys feat
(Play) *4-5 year olds* 0.9 0***0.9 2***0.78***0.85***0.06*** *6-7* Control
year olds 0.77***0.85***0.75***0.79 ***0.00*** *Adults*
1.00***1.00***0.83***0.87***0.00***

p < .05*, p < .01**, p < .001***

Table 2. Summary of reliable main effects found for typicality and diversity trial justifications in bird study.

Justification Category	Typicality Trials		Diversity Trials	
	Subject Type	Stim ulus Set	Subject Type	Stim ulus 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.

Subject groups are represented by USnonexperts (N), USexperts (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.

<Footnotes>

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[i] In a comparative study of Itza’ Maya and rural Michigan college students, we found that the great majority of m amm al taxa in both cultures correspond to scientific species, and m ost also correspond to m onospecific genera: 30 of 40 (75%) basic Michigan mammal terms denote biological species, of which 21 (70%, or 53% of the total) are monospecific genera; 36 of 42 (86%) basic Itza’ mammal terms denote biological species, of which 25 (69%, or 60% of the total) are monospecific genera (López, Atran, Coley, Medin, & Smith, 1997). Similarly, a Guatemalan

government inventory of the Itza' area of the Peten rainforest indicates that 69% (158 of 229) are monospecific (AH G/APESA, 1992) the same percentage of monospecific tree genera (40 of 58) as in our study of the Chicago area (Medinetal., 1997). [ii] Generalizations across taxa of the same rank thus differ in logical type from generalizations that apply to th is or th at taxon. *Termite*, *pig* and *lemon tree* are not related to one another by a simple class-inclusion under a common hierarchical node, but by dint of their common rank –in this case the level of generic species. A system of rank is not simply a hierarchy, as some suggest (Rosch, 1975; Carey, 1996). Hierarchy, that is, a structure of inclusive classes, is common to many cognitive domains, including the domain of artifacts. For exam ple, *chair* often falls under *furniture* but not *vehicle*, and *car* falls under *vehicle* but not *furniture* . But there is no ranked system of artifacts: no inferential link, or inductive framework, spans both *chair* and *car*, or *furniture* and *vehicle*, by dint of a common rank, such as the artifact *species* or the artifact *family*. [iii] Moving vertically within each graph corresponds to changing the premise while holding the conclusion category constant. This allows us to test another domain-general model of category-based reasoning: The Similarity-Coverage Model (Oshersonetal., 1990). In this model, the closer the premise category is to the conclusion category, the stronger induction should be. Our results show only weak evidence for this general reasoning heuristic, which fails to account for the various "jumps" in inductive strength that indicate absolute privilege.

[iv] In nature walks, undergraduates at Northwestern University and the University of Michigan identify the overwhelming majority of trees and birds they encounter as simply "tree" or "bird", that is, at the life-form level. In contrast, Itza' Maya identify the overwhelming majority of trees and birds at the generic-species level (cf.Coley etal., 1999; Bailensonetal., 2002). [v] 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 home during a fire, camping equipment), although central tendency still supposedly predicts typicality in "taxonomic" categories (furniture, vehicles), including folkbiological categories (birds). [vi] 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, p.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 a computational theory of mind would not tell us very m uch about conceptual categorization and reasoning. For Sperber (2001), Fodor's pessim ism is unwarranted because it ignores the fact that privileged access to an input set

depends on the competition for mental resources. Evolutionary task dem ands com petitively favor certain naturally-selected m odular structures for processing certain types of input (*ceteris paribus*), although contingent circumstances can occasionally favor other ways of functionally processing the same inputs. [vii] Paul Griffiths (2002) argues that because the items on any such symptomatic list do not necessarily co-occur in any given case, and cannot 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 an evidential claim, not a causal claim about innateness or modularity. It provides a family of heuristics rather than a causal diagnosis.