

The Case for Modularity: Sin or Salvation?

Introduction

The central thesis of PANKSEPP and PANKSEPP (2001, henceforth, P&P) is that there are no specially evolved, higher-order domain-specific cognitive mechanisms to speak of. Apart from the basic DARWINIAN emotions (fear, surprise, anger, sadness, joy, disgust), so-called cognitive 'modules' are more likely "the product of dubious human ambition rather than sound scientific reasoning". What evolutionary psychologists (as well as many cognitive and developmental psychologists) take to be modular structures are actually the epigenetic products of the ancestral emotional functions of the brain (rooted in what was once called "the limbic system," MACLEAN 1990) and more recent "general-purpose brain mechanisms". In more than a dozen places, P&P repeat as mantra that empirical evidence indicates the modern human mind was created through the dual functioning of subcortical mammalian emotions and a neocortical general-purpose computational device. Furthermore, this highly flexible, all-purpose intelligence probably emerged "more rapidly via group selection than by individual selection".

There is much to commend the cautionary tale that P&P tell regarding possible excesses of sociobiological speculation, including what are arguably 'just-so' stories about modularized adaptations for

Abstract

The case for evolved cognitive modules rests on several converging lines of evidence: Functional design (analogy), ethology (homology), universality, precocity of acquisition, independence from perceptual experience (poverty of stimulus), selective pathology (cerebral impairment), resistance to inhibition (hyperactivity), ease of cultural transmission. No factor may be necessary but evidence for all or some is compelling, if not conclusive, for domains like folkmechanics, folkbiology, folkpsychology. By contrast, no empirical evidence supports PANKSEPP and PANKSEPP's central thesis: that what evolutionary psychologists (and many cognitive and developmental psychologists) consider modular structures are actually epigenetic products of subcortical mammalian emotions and neocortical general-purpose computations. Arguably, no significant empirical discovery about language or other higher-order cognitive structures yet owes to inquiries about evolutionary origins and functions. Nevertheless, adopting evolutionary psychology's requirement that candidate exaptations and spandrels be described, as far as possible, in connection with evolved adaptations, opens new avenues for exploring and testing modular designs.

Key words

Modularity, domain-specificity, language, folkpsychology, folkbiology.

rape (THORNHILL/PALMER 2000), homicide (BUSS 1999) and emotional disorders such as depression (NESSE/LLOYD 1992). P&P's position on the derivative and epigenetic character of 'secondary' or 'social' emotions (guilt, love, empathy, etc.), is also defensible (e.g., DAMASIO 1994), although seriously debatable (cf. LEDOUX 1996; GRIFFITHS 1997). Finally, P&P's take on the current, overly-funded fad for neuroimaging (driven more by technological innovation and the industry it supports than by any theoretical insight) is credible. There can no more be a theory directly derived from observations of neuroimaging than there can be a theory derived directly from observations of meter readings; it is only in the service of some prior abstract theory that such observa-

tions can make sense. Nevertheless, there is no empirical evidence whatever to indicate that P&P's central thesis is true, and much to suggest it is false.

Evolutionary Psychology: No Explanatory Value for Higher-Order Cognition (Yet)

To-date, evolutionary psychology has not predicted or discovered any significant or surprising aspect of language or higher-order cognitive devices of the sort I describe below. But this does not mean that all

evolutionary psychology accounts are ‘just-so’ stories. The best account of language as an evolutionary adaptation centers on the claim that “language shows signs of design for the communication of propositional structures over a serial channel” (PINKER/BLOOM 1990). PINKER and BLOOM describe how specific syntactic structures conform to this language-specific design in ways that provide functional advantage: for example, through certain structure-dependent rules (phrase structure) and principles of embedding (recursion) that allow the formulation and expression of infinitely many discrete ideas by finite and few means. This enables the multiple thoughts of multiple individuals to be combined, tested in imagination and consequently included or excluded from having a role in some future action. A population whose individuals could contemplate alternative scenarios in any sequence and at any rate, benefit from the cognitive travails of others, and let conjectures die instead of themselves, would surely have had an evolutionary advantage over a population that couldn’t.

PINKER and BLOOM offer a well-reasoned and often nonobvious analysis of evolutionary tradeoffs involved in opting for linear communication through an auditory medium: visual displays better communicate highly complex topological relationships (“a picture is worth a thousand words”), gestures better convey emotion, and language is inefficient transmitting information about taste or smell. For all its insight and plausibility, though, PINKER and BLOOM’s account remains wholly backward-looking: no structural discovery, novel prediction or theoretical breakthrough ensues within the CHOMSKYEAN framework that the authors adopt.

According to Jerry FODOR (1998), whose reasoning is close to CHOMSKY’s (1988, p170), it is not likely that natural selection gradually produced an adaptive mutation for a language instinct. Rather, selection pressures unrelated to language simply made human brains a little larger and more complex. Unlike gradual and incremental adaptations, a little added complexity can go a long way fast to produce multiple novel structures:

“Make the giraffe’s neck just a little bit longer and you correspondingly increase, just by a little, the animal’s capacity to reach the fruit at the top of the tree... But make an ape’s brain just a little bigger (or denser, or more folded, or, who knows, grayer) and it’s anybody’s guess what happens to the creature’s behavioural repertoire”. (FODOR 1998).

Much ink has spilled and acrimony vetted in the debate between evolutionary psychologists and the

scientists who criticize them. In the case of language, however, no empirical issue has yet to turn on the debate. Despite very different evolutionary stories, CHOMSKY, FODOR, PINKER and BLOOM fundamentally agree on the specific computational structures that characterize language, on its innateness, on its highly specialized mode of operation (modularity) and on the fact that all of this is uniquely the product of evolution, whether adaptation or by-product.

The Language Module

From a purely logical standpoint, if a mind is able to take fragmentary instances of 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, then the inferential structure responsible for this prediction cannot possibly derive from the experience. As Hume noted, the structure must be prior to experience, just like the cranes and architects used for constructing buildings must exist prior to initial construction: a building does not just build itself. There is no other possibility. What, then, are the physical possibilities for a mental structure to be “prior to experience”?

One could hold with SOCRATES or BUDDHA that people are born with a past-life ‘memory’ for the structure of experience they will encounter later in life; or, one could hold with Thomas Aquinas or Kant that God put structure in people’s minds. If, however, one accepts humans as biological creatures whose species attributes emerged through the same evolutionary processes that govern the emergence of all other species, then there appears to be no alternative to a priori mental structures being evolved biological structures (whether as adaptations or by-products of adaptations). 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 channel development, but do not determine it—like mountains that channel scattered rain into the same mountain–valley river basin (WADDINGTON 1959).

P&P might grant all this, but argue that an all-purpose, domain-general computational device suffices to give the mind/brain inferential power beyond the information given. As an empirical claim, this entails that one should be able to deduce the structural principles and parameters governing any specific domain from general purpose-structures acting under the constraints of experience in the rele-

vant domain. For example, P&P offer that language “may be closely linked to anterior cingulate and adjacent frontal lobe tissues which appear to mediate certain types of pain, feelings of separation distress and thereby social sensitivities” (MACLEAN 1990). But there is nothing in what we know of general intelligence (e.g., conditioning, association, etc.), pain, distress, social sensitivity, or the structures of anterior cingulate and adjacent frontal lobe tissues, to even remotely hint at the highly structured, and structurally peculiar, principles and parameters of human language. This includes: anaphora (the structural constraints on how even widely separated parts of an expression co-refer), quantification (the structural constraints that ‘who,’ ‘many,’ ‘few,’ etc. impose on the syntactic behavior of subjects and objects), negation (it is literally impossible to learn negation through perceived experience or ‘interaction,’ as one cannot perceive or interact with something that isn’t), word order (all languages have a specified *linear* order linking *arguments to predicates*), and so forth.

Briefly, the central tenet of CHOMSKY’S (2000) approach is that there is a language system, LS, of the human brain. LS reflexively discriminates and categorizes parts of the flux of human experience as ‘language,’ and develops complex abilities to infer and interpret this highly structured, and structurally peculiar, type of human production. In a general sense, there is nothing intrinsically different about LS—in terms of innateness, evolution or universality—than the visual system (VS), immune system (IS), respiratory system (RS), or any other complex biological system. Learning syntactic structure through ‘social interaction’ is no more plausible an alternative than learning by ‘osmosis’. If a child is initially deprived of linguistic input, the child may never come to acquire, or ‘know,’ much in the way of language, just as a kitten initially deprived of normal exposure to the visual world may never come to ‘know’ much by way of object recognition (HUBEL 1988). Still, emotion and social interaction no more ‘create’ language in the child’s mind than lighting and object patterning ‘create’ vision in the kitten.

Interacting Modules

LS 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, in humans, linguistic and other cognitive systems of meaning, MARR 1982). LS 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 LS 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 language. There is little doubt that the sound system is highly structured for access (psycholinguistic experiments with neonates and even fetuses, dichotic listening experiments, comparative phonology, and so forth are compelling). The interface between syntactic and semantic systems is much more obscure. Speculation is rampant, debate is furious, and critical experiments are few, as might be expected from a relatively new and dynamically changing science. But progress is being made, slowly and laboriously, as intense research by teams of well-trained investigators continues.

Cognitive and developmental psychologists and psycholinguistics have identified a number of structural principles in human cognitive systems that relate to the interface between LS and these other systems. Among the principles discovered is “the whole-object constraint” (CAREY 1985). Children, whatever their culture or language, apparently assume as a default that nouns in general apply to whole objects (e.g., a rabbit) and not to parts of the object (e.g., a piece of a leg, a patch of fur, or spatially separated patches of fur and pieces of leg), or the object-and-its-environment. Children actually have to learn that this is not always the case (just as children have to learn that the shadow of an object is not itself an object, SPELKE et al. 1995). This apparently ‘innate bias’ helps to solve the problem of radical indeterminacy of translation. Consider an anthropologist who visits an exotic tribe for the first time and sees a member of that tribe pointing to something that the anthropologist immediately identifies as a running deer. The anthropologist is fairly safe in assuming that the informant also thought of pointing to a running deer (and not a moving piece of deer, a shifting pattern of deer fur and grass, etc.). This is so even if the informant also believes that the deer is some other person’s ancestor. If this were not the case—if radical indeterminacy were an omnipresent possibility—then anthropology would be impossible and ethnography could be *only* fiction.

Before learning to talk, children first learn to follow gaze, engage in joint attention, contingently interact with others to achieve goals, and so forth.

Those who argue that language is acquired through social interaction might be tempted to claim that these facts undermine the modular model of language (SHANKER 2001). Yet, most of the work in this area—called the child’s ‘theory of mind’ or ‘folkpsychology’—focuses on many of the same sorts of questions and approaches that generative grammarians do: How is the child able to reliably *infer* such rich mental structures about *other minds* from a few gestures and without mastery of language? And how is it that children also infer that people’s mental structures (intentions) can cause others to act a distance (without any physical contact)? The emerging consensus in the field is that children are biologically endowed with a ‘theory of mind’ (ToM) that matures in predictable ways over the first three years of life (LESLIE 1994; BARON-COHEN 1995; SPELKE et al 1995). Some features of developing ToM interface with maturing features of developing LS in systematic ways that are only now being experimentally studied. This is one of the most exciting and productive research areas in cognitive and developmental psychology (to judge from journal publications and grant funding), and also one of the most thoroughly ‘modular’.

Interactions between modular cognitive systems are complex and difficult to tease apart, perhaps more so than interactions among various bodily systems. For example, belief in supernatural agents, which characterizes all religions in all societies, involves a host of modular expectations and interfacing: folkmechanics, folkpsychology, folkbiology, primary and secondary emotions, predator–prey schema, and so forth (BOYER 1994; BARRETT/NYHOFF 2001; ATRAN in press). Nevertheless, predictive theories are being proposed and empirically tested.

Are Modules Adaptations or Evolutionary By-Products of Adaptations?

Leading evolutionary biologists, such as Stephen GOULD and Richard LEWONTIN (1979) describe the products of higher-order human cognition as evolutionary ‘by-products’ or ‘spandrels’. This is a stance P&P adopt. A spandrel is an architectural term for the structural form or space that arises as a necessary concomitant to another decision in design, and is not designed to have any direct utility in itself. For example, the space beneath a flight of stairs is a by-product of constructing an inclined stairway rather than a vertical ladder. The fact that people might subsequently use this ‘leftover’ space for storage does not entail that the space was designed to be a storage space.

For GOULD and LEWONTIN, higher-order human cognitive structures originated as functionless spandrels that have been subsequently modified under cultural selection rather than natural selection. Biologically functionless, or nearly functionless, spandrels supposedly include: religion, writing, art, science, commerce, war and play. These evolutionary by-products are cultural ‘mountains’ to the biologically ‘adaptive molehill’ (GOULD 1991, pp58–59; WILLIAMS 1992, pp77–79). On this account, evolutionary psychology would have little to reveal about the emergence and structure of such culturally-elaborated spandrels: “The number and complexity of these spandrels should increase with the intricacy of the organism under consideration. In some region within a spectrum of rising complexity, the number and importance of useable and significant spandrels will probably exceed the evolutionary import of the primary adaptation” (GOULD 1997, pp10754–10755; cf. FODOR 1998).

GOULD’s account of the emergence of distinctly human cognitions as spandrels of a big brain is hardly convincing. The very notion of a ‘big’ or ‘large’ or ‘complex’ brain is too vague to empirically constrain the evolutionary story about how it might have evolved. The big brain is taken as an adaptation from which all cognitive spandrels arise. But an adaptation to what? A design for what? What are its evolutionary-relevant computational structures? Big brain stories tend to be even broader in scope and handwaving than language–evolution stories. Human brains supposedly broke away from ape brains under selection pressures that run the gamut from runaway social competition (ALEXANDER 1989), to gut reduction (AIELLO/WHEELER 1995), to hunting large game (HILL 1999), to niche construction (LALAND et al. 2000), to runaway sexual selection (MILLER 2000), and so on. Alternatively, the big brain primarily evolved as a conduit for culture (HARRIS 1975), as a vehicle for language (JERISON 1976), or as a host for the independently evolving ideas, or ‘memes,’ that compete to colonize it (DENNETT 1995; BLACKMORE 1999). Finally, the big brain may have evolved under any number ‘positive feedback’ pathways involving some or all of the factors mentioned.

But even if true, and even if we knew the reasons (selection pressures responsible for) why, we are unlikely to learn anything of particular interest from all this about how the mind works. The notion of a big brain is as uninformative about cognitive structures and functions cognition as the notion of big body is about bodily structures and functions. Never mind exaptations, such as chins, or spandrels, such as

palm lines. From the fact of a bigger body, what could one possibly deduce about hearts, livers, kidneys, hands, faces, placentas and so on? And never mind exaptations, such as language, or spandrels, such as religion. From the fact of a bigger (or denser, or more folded, or grayer) brain, what could one possibly deduce about perception, emotion, categorization, inference or any of the other capabilities humans share with apes but in more vastly elaborated form? Probably nothing at all.

It may well be true that little insight is to be gained into higher-order human cognitive structures by considering possible evolutionary origins and functions. Adopting the hypothesis of GOULD and LEWONTIN or P&P, which assumes this truth, is practically guaranteed to block insight, whether or not it is true. By contrast, adopting evolutionary psychology's requirement that candidates for exaptations and spandrels be described, as far as possible, with reference to evolved adaptations, then it might be possible to find out if the hypothesis is true or not. If it is true, then evolutionary psychology would have provided the empirical evidence that shows it to be a significant and surprising scientific insight, and not one that depends entirely on intuition, analogy, eloquence or wishful thinking. If it is not true, then evolutionary psychology will have helped to discover something new about human nature.

Three Examples of Modularity: Naïve Mechanics, Theory of Mind, Folkbiology

Ever since CHOMSKY jump-started the 'cognitive revolution,' successors to the behaviorists who believed in an all-powerful general thinking device have tried to reconcile CHOMSKY's insights with faith in flexible intelligence by reluctantly granting *some* specificity to language, and language alone. But cognitive psychology today concentrates more on discovery and exploration of domain-specific mechanisms than on general-purpose computation. Each such device has a particular 'content-bias' in that it targets some particular domain of stimuli in the world ('set of inputs'): for example, the edges and trajectories of rigid three-dimensional bodies that move by physical contact between them (mechanics), the contingent motion a self-propelled actors that can coordinate interactions without having physical contact (agency), or the behaviors and appearances of nonhuman living creatures (species relations). The particular inferential structure of each domain-specific processor then takes the isolated exemplars (or relatively poor

samples) of the stimulus-set actually encountered in a person's life, and spontaneously projects these relatively fragmentary instances onto richly-structured categories ('classes of output') of general relevance to our species: for example, the objects and kinds of folkphysics (naïve mechanics), folkpsychology (ToM) and folkbiology. Much work on domain-specificity has developed, and now develops, independently of sociobiology or evolutionary psychology (ATRAN 1989; HIRSCHFELD 1996; KEIL 1989; LESLIE 1994; CAREY/SPELKE 1994; SPERBER 1985).

Within the emerging paradigm of cognitive domain-specificity, there is much speculation and controversy—again, as might be expected in any newly emerging science. For example, there are competing accounts of how human beings acquire basic knowledge of the everyday biological world, including the categorical limits of the biological domain and the causal nature of its fundamental constituents. One influential view of conceptual development in folkbiology has been articulated by Susan CAREY and her collaborators (CAREY 1985; CAREY/SPELKE 1994; JOHNSON/CAREY 1998). On this view, young children's understanding of living things is embedded in a folkpsychological, rather than folkbiological, explanatory framework. Only by age 7 do children begin to elaborate a specifically biological framework of the living world, and only by age 10 does an autonomous theory of biological causality emerge that is not based on children's understanding of how humans think and behave. A competing view is that folkbiology and folkpsychology emerge early in childhood as largely independent domains of cognition that are clearly evident by ages 4 or 5, and which may be innately differentiated (ATRAN 1987; KEIL 1989; GELMAN/WELLMAN 1991; HATANO/INAGAKI 1999).

To address this issue, my colleagues and I carried out a series of cross-cultural experiments (LÓPEZ et al. 1997; MEDIN et al. 1997; ATRAN et al. 2001). One set of experiments shows that by the age of 4–5 years (the earliest age tested in this regard) urban American and Yukatek Maya children employ a concept of innate species potential, or underlying essence, as an inferential framework for understanding the affiliation of an organism to a biological species, and for projecting known and unknown biological properties to organisms in the face of uncertainty. Another set of experiments shows that the youngest Maya children do not have an anthropocentric understanding of the biological world. Children do not initially need to reason about nonhuman living

kinds by analogy to human kinds. The fact that American children show 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*. Together, the first two sets of experiments suggest that folkpsychology can't be the initial source of folkbiology. They also indicate that to master biological science, people must learn to inhibit activation of universal dispositions to view species essentialistically and to see humans as inherently different from other animals (ATRAN 1990, 1998).

A third set of results show 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 (ATRAN et al. 1997; COLEY et al. 1997). 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, although 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* (ROSCH et al. 1976). Still, Americans prefer generic species for making inductions about the distribution of biological properties among organisms, and for predicting the nature of the biological world 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 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'.

Evidence for Modularity

The evolutionary argument for a naturally-selected cognitive disposition, such as folkbiology, involves converging evidence from a number of venues: Functional design (analogy), ethology (homology), universality, precocity of acquisition, independence

from perceptual experience (poverty of stimulus), selective pathology (cerebral impairment), 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.

1. Functional Design. All organisms must function to procure energy to survive, and they also must procure (genetic) information for recombination and reproduction (ELDRIDGE 1986). The first requirement is primarily satisfied by other species, and an indiscriminate use of any individual of the other species (e.g., energy-wise, it does not generally matter which chicken or apple you eat). The second requirement is usually only satisfied by genetic information unique to individual conspecifics (e.g., genetically, it matters who is chosen as a mate and who is considered kin). On the one hand, humans recognize other humans by individuating them with the aid of species-specific triggering algorithms that 'automatically' coordinate perceptual cues (e.g., facial recognition schemata, gaze) with conceptual assumptions (e.g., intentions) (BARON-COHEN 1995). On the other hand, people do not spontaneously individuate the members of other species in this way, but as exemplars of the (generic) species that identifies them as causally belonging to only one essential kind.

Natural selection basically accounts only 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, p140), having "very much the appearance of design by an intelligent designer... on which the wellbeing and very existence of the organism depends" (WALLACE 1901, p138). Plausibly, the universal appreciation of generic species as the causal foundation for the taxonomic arrangement of biodiversity, and for taxonomic inference about the distribution of causally-related properties that underlie biodiversity, is one such functional evolutionary adaptation. But a good story is not enough.¹

2. 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. Some nonhuman species can clearly distinguish several different animal or plant species (CERELLA 1979;

LORENZ 1966; HERRNSTEIN 1984). Vervet monkeys even 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 have rudimentary hierarchical groupings of biological groups within groups (BROWN/BOYSEN in press). To be sure, the world itself is neither chaos nor flux: species are often locally self-structuring entities that are reproductively and ecologically isolated from other species through natural selection. 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 (e.g., it makes little difference *which* tiger could eat a person or *which* mango a person could eat). And the adaptive functions of organisms rarely, if ever, evolve or operate in nature as all-purpose mechanisms.

3. 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 (BERLIN et al. 1973; BERLIN 1992; ATRAN 1990, 1999). These striking cross-cultural similarities suggest that a small number of organizing principles universally define folkbiological systems. Basic aspects of folkbiological structure (e.g., taxonomic ranking, primacy of generic-species) seem to vary little across cultures as a function of theories or belief systems.

4. 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 1994; HATANO/INAGAKI 1999; ATRAN et al. 2001).

5. Independence from Perceptual Experience. Experiments 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 (ATLAN et al 1997; COLEY et al 1997).

6. Pathology. Cerebral impairments (WILLIAMS syndrome, brain lesions caused by certain types of herpes virus, etc.) suggest selective retention or loss of folkbiological taxonomies or of particular taxonomic ranks. Neuropsychological studies have reported a pathological performance in recognition at the life-form and generic-species levels (e.g., recog-

nizing an item as an animal but not as a bird or robin), and dissociation at the life-form level (e.g., not recognizing items as trees). Existing studies, however, do not say anything about the generic-species rank as the preferred level of representation for reasoning, perhaps because of methodology (linked to averaging over items and failure to include sets of generic species) (WARRINGTON/SHALLICE 1984; SARTORI/JOB 1988; JOB/SURIAN 1998).

7. 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. For example, the essentialist bias to understand variation in terms of deviance is undoubtedly a hindrance to evolutionary thinking. In some everyday matters, the tendency to essentialize or explain variation in terms of deviation from some essential ideal or norm (e.g., people as mental or biological 'deviants') can be an effortlessly 'natural' but wrong way to think.

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 for 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).

8. Cultural Transmission. Human cultures favor a rapid selection and stable distribution of those ideas that: 1) readily help to solve relevant and recurrent environmental problems, 2) are easily memorized and processed by the human brain, and 3) 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 everywhere in orienting themselves and surviving in the natural world. Its content tends to be stable within cultures (high interinformant agreement, substantial historical continuity) and its structure isomorphic across cultures (BERLIN et al. 1973; LÓPEZ et al. 1997). Folkbiological taxonomy also 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, 1998).

Consider, for example, the spontaneous emergence of totemism—the correspondence of social groups with generic species—at different times and in different parts of the world. Why, as LÉVI-STRAUSS (1963) aptly noted, are totems so “good to think”? In part, totemism uses representations of generic species to represent groups of people; however, this pervasive metarepresentational inclination arguably owes its recurrence to its ability to ride piggyback on folkbiological taxonomy. Generic species and groups of generic species are inherently well-structured, attention-arresting, memorable and readily transmissible across minds. As a result, they readily provide effective pegs on which to attach knowledge and behavior of less intrinsically well-determined social groups. In this way totemic groups can also become memorable, attention-arresting and transmissible across minds. These are the conditions for any idea to become culturally viable (see SPERBER 1996 for a general view of culture along the lines of an ‘epidemiology of representations’). A significant feature of totemism that enhances both memorability and its capacity to grab attention is that it violates the general behavior of biological species: members of a totem, unlike members of a generic species, generally do not interbreed, but only mate with members of other totems in order to create a system of social exchange. Notice that this violation of core knowledge is far from arbitrary. In fact, it is such a pointed violation of human beings’ intuitive ontology that it readily mobilizes most of the assumptions people ordinarily make about biology in order to better help build societies around the world (ATRAN/SPERBER 1991).

In brief, modularized structures—such as those which produce folkmechanical, folk-

psychological and folkbiological concepts—are special players in cultural evolution. Their native stability derivatively attaches to more variable and difficult-to-learn representational forms, thus enhancing the latter’s prospects for regularity and recurrence in transmission within and across cultures. This includes knowledge that cumulatively enriches (e.g., to produce folk expertise), overrides (e.g., to produce religious belief) or otherwise transcends (e.g., to produce science) the everyday ontology prescribed by our evolved cognitive modules.

Conclusion: Neither Sin nor Salvation, but a Promissory Note.

Despite the initial independence of work in domain-specificity, 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). In the computer lingo that now dominates the field, the ‘computational mind’ consists of a variety of distinct, task-specific information-processing devices. Nothing from work on subcortical emotions or neocortical principles of general association has provided, or hints at providing, the slightest insight into the cognitive structures and processes discovered so far in these emerging fields.

Evolutionary psychology is still in its infancy and is not yet the new scientific paradigm some would love and others hate. Some find the idea of ‘Stone Age Minds for a Space Age World’ bold and irreverent, many find it false and demeaning, others find it ridiculous. As the field stands now, all may garner uncertain support for their position.

This new field surely will not solve all of the problems its fervent supporters say it will. But neither will it face the massive road blocks to understanding that its unrelenting detractors see at every turn. At present, the field is a promissory note, much as DARWIN’S theory was at its beginning.

Author’s address

Scott Atran, CNRS-Institut Jean Nicod, 1 bis, avenue de Lowendal, F-75007 Paris, France, and School of Natural Resources and Environment, Dana Building, 430 East University, Ann Arbor, Michigan 48109-1115, USA. Email: satran@umich.edu

Little by little, biologists were able to deliver on DARWIN's promises. This process has speeded up considerably—almost irreversibly—thanks to access at the molecular level. There is still a long way to go. Through recent advances in cognitive science, evolutionary psychology has gained entrance to mental structure, and so potentially to the brain's evolved neural architecture. It has an even longer way ahead: much less is currently known about how the mind/

brain works than how body cells function. Perhaps, in the end, evolutionary psychology's interpretations of complex mental designs as telltale signs of ancient environments will prove no truer than phrenology's readings of bumps and other conformations of the skull as indications of mental faculties and character (phrenology was a very serious and hotly debated discipline a century ago). Then again perhaps not, which makes the effort worthwhile.

Note

1 Although the adaptive relationship of structure to function is often manifest, as with the giraffe's neck or the rhinoceros's horns, often it is not. In such cases, evolutionary theorists adopt a strategy of 'reverse engineering'. Reverse engineering is what military analysts do when a weapon from an enemy or competitor in the arms market falls into their hands and they try to figure out exactly how it was put together and what it can do. Reverse engineering is easiest, of course, if the structure contains some signature of its function, like trying to figure out what a toaster does given the telltale sign of toasted bread crumbs left inside. But in many cases recognizing the appropriate signs already requires some prior notion of what function the structure may have served. Thus, after a century and a half of debate,

it is only now that scientists clearly favor the hypothesis that bipedality was primarily selected to enhance field of view. Comparative studies of humans with bipedal birds and dinosaurs, as well as experiments comparing energy expenditure and running speed in two-footed versus four-footed running and walking, appear to exclude the competing hypotheses that bipedality evolved for running or energy conservation. For most higher-order human cognitive faculties, however, there may be little useful comparative evidence from elsewhere in the animal kingdom. This is because of their apparent structural novelty, poor representation in the fossil record (e.g., stone tools tell little of language or theory of mind) and lack of surviving intermediate forms. The moral is that reverse engineering can be helpful, and occasionally successful, but success is by no means guaranteed even in the richest of evidentiary contexts.

References

- Aiello, L./Wheeler, P. (1995) The expensive-tissue hypothesis. *Current Anthropology* 36:199–221.
- Alexander, R. (1989) Evolution of the human psyche. In: Stringer, C. (ed) *The human revolution*. The University of Edinburgh Press: Edinburgh.
- Atran, S. (1987) Ordinary constraints on the semantics of living kinds: A commonsense alternative to recent treatments of natural-object terms. *Mind and Language* 2: 27–63.
- Atran, S. (1989) Basic conceptual domains. *Mind and Language* 4: 7–16.
- Atran, S. (1990) Cognitive foundations of natural history: Towards an anthropology of science. Cambridge University Press: Cambridge.
- Atran, S. (1998) Folkbiology and the anthropology of science: Cognitive universals and cultural particulars. *Behavioral and Brain Sciences* 21: 547–609.
- Atran, S. (1999) Itzaj Maya folk-biological taxonomy. In: Medin, D./Atran, S. (eds) *Folk biology*. MIT Press: Cambridge MA.
- Atran, S./Estin, P./Coley, J./Medin, D. (1997) Generic species and basic levels: Essence and appearance in folk biology. *Journal of Ethnobiology* 17: 22–45.
- Atran, S./Medin, D./Lynch, E./Vapnarsky, V./Ucan Ek', E./Sousa, P. (2001) Folkbiology doesn't come from folkpsychology: Evidence from Yukatek Maya in cross-cultural perspective. *Journal of Cognition and Culture* 1: 3–43.
- Atran, S. (in press) In gods we trust: The evolutionary landscape of religion. Oxford University Press: New York.
- Atran, S./Sperber, D. (1991) Learning without teaching: Its place in culture. In: Tolchinsky-Landsmann, L. (ed) *Culture, schooling and psychological development*. Ablex: Norwood NJ.
- Barrett, J./Nyhof, M. (2001) Spreading non-natural concepts: The role of intuitive conceptual structures in memory and transmission of cultural materials. *Journal of Cognition and Culture* 1: 69–100.
- Baron-Cohen, S. (1995) *Mindblindness*. The MIT Press: Cambridge MA.
- Berlin, B./Breedlove, D./Raven, P. (1973) General principles of classification and nomenclature in folk biology. *American Anthropologist* 74: 214–242.
- Berlin, B. (1992) *Ethnobiological classification*. Princeton University: Princeton.
- Blackmore, S. (1999) *The meme machine*. Oxford University Press: Oxford.
- Boyer, P. (1994) *The naturalness of religious ideas*. University of California Press: Berkeley.
- Brown, D./Boysen, S. (in press) Spontaneous discrimination of natural stimuli by chimpanzees (*Pan troglodytes*). *Journal of Comparative Psychology*.
- Buss, D. (1999) *Evolutionary psychology*. Allyn & Bacon: Boston.
- Carey, S. (1985) Constraints on semantic development. In: Mehler, J./Fox, R. (eds) *Neonate cognition*. Erlbaum: Hillsdale NJ.
- Carey, S./Spelke, E. (1994) Domain-specific knowledge and conceptual change. In: Hirschfeld, L./Gelman, S. (eds) *Mapping the mind*. Cambridge University Press: New York.
- Cerella, J. (1979) Visual classes and natural categories in the pigeon. *Journal of Experimental Psychology Human perception and performance* 5: 68–77.
- Chomsky, N. (1982) *Lectures on government and binding*.

- Foris Publications: Dordrecht. ***NOT_MENTIONED***
- Chomsky, N. (1988) *Language and problems of knowledge*. MIT Press: Cambridge MA.
- Chomsky, N. (2000) Minimalist inquiries: The framework. In: Martin, R./Michaels, D./Uriagereka, J. (eds) *Step by step*. MIT Press: Cambridge MA.
- Coley, J./Medin, D./Atran, S. (1997) Does rank have its privilege? Inductive inferences in folkbiological taxonomies. *Cognition* 63: 73–112.
- Damasio, A. (1994) *Descartes' error: Emotion, reason, and the human brain*. Avon Books: New York.
- Darwin, C. (1883) *On the origins of species by means of natural selection*. 6th edition. Appleton: New York. Originally published 1872.
- Dennett, D. (1995) *Darwin's dangerous idea: Evolution and the meaning of life*. Simon and Schuster: New York.
- Eldredge, N. (1986) Information, economics, and evolution. *Annual Review of Ecology and Systematics* 17: 351–369.
- Fodor, J. (1998) The trouble with psychological Darwinism. *London Review of Books* 20(2): ***PAGE_NUMBERS***
- Gelman, S./Wellman, H. (1991) Insides and essences. *Cognition* 38: 214–244.
- Gil-White, F. (2001) Are ethnic groups biological "species" to the brain? *Current Anthropology* 42(4): ***PAGE_NUMBERS_MISSING***
- Gould, S. (1991) Exaptation: A crucial tool for evolutionary psychology. *Journal of Social Issues* 47: 43–46.
- Gould, S. (1997) The exaptive excellence of spandrels as a term and prototype. *Proceedings of the National Academy of Sciences USA* 94: 10750–10755.
- Gould, S./Lewontin, R. (1979) The spandrels of San Marco and the Panglossian paradigm. *Proceedings of the Royal Society of London B*. 205: 581–598.
- Griffiths, P. (1997) *What emotions really are*. University of Chicago Press: Chicago.
- Harris, M. (1975) *Culture, people, nature: An introduction to general anthropology*. 2nd edition. Thomas Crowell: New York.
- Hatano, G./Inagaki, K. (1999) A developmental perspective on informal biology. In: Medin, D./Atran, S. (eds) *Folk biology*. MIT Press: Cambridge MA.
- Hauser, M. (2000) *What animals really think*. Henry Holt & Company: New York.
- Herrnstein, R. (1984) Objects, categories, and discriminative stimuli. In: Roitblat, H. (ed) *Animal cognition*. Erlbaum: Hillsdale NJ.
- Hill, K. (1999) Evolution of the human life course. Paper presented to The Evolution and Human Adaptation Program, Institute for Social Research, The University of Michigan, Ann Arbor, February 9, 1999.
- Hirschfeld, L. (1996) *Race in the making*. MIT Press: Cambridge MA.
- Hubel, D. (1988) *Eye, brain, and vision*. Scientific American: New York.
- Jerison, H. (1976) The paleoneurology of language. In: Harnad, S./Steklis, H./Lancaster, J. (eds.) *Origins and evolution of language and speech*. *Annals of the New York Academy of Sciences* 280: 370–382.
- Job, R./Surian, L. (1998) A neurocognitive mechanism for folk biology? *Behavioral and Brain Sciences* 21: 577–578.
- Johnson, S./Carey, S. (1998) Knowledge enrichment and conceptual change in folkbiology: Evidence from people with Williams Syndrome. *Cognitive Psychology* 37: 156–200.
- Keil, F. (1989) *Concepts, kinds, and cognitive development*. MIT Press: Cambridge MA.
- Keil, F. (1994) The birth and nurturance of concepts by domains. In: Hirschfeld, L./Gelman, S. (eds.) *Mapping the mind*. Cambridge University Press: New York.
- LeDoux, J. (1996) *The emotional brain*. Simon and Schuster: New York.
- López, A./Atran, S./Coley, J./Medin, D./Smith, E. (1997) The tree of life: Universals of folk-biological taxonomies and inductions. *Cognitive Psychology* 32: 251–295.
- Laland, K./Olding-Smee, J./Feldman, M. (2000) Niche construction, biological evolution and cultural change. *Behavioral and Brain Sciences* 23: 131–146.
- Leslie, A. (1994) ToMM, ToBy, and agency. In: Hirschfeld, L./Gelman, S. (eds) *Mapping the mind: Domain-specificity in cognition and culture*. Cambridge University Press: New York.
- Lévi-Strauss, C. (1963) The bear and the barber. *The Journal of the Royal Anthropological Institute* 93: 1–11.
- Lorenz, K. (1966) The role of gestalt perception in animal and human behavior. In: White, L. (ed) *Aspects of form*. Indiana University Press: Bloomington.
- MacLean, P. (1990) *The triune brain in evolution*. Plenum Press: New York.
- Marr, D. (1982) *Vision*. W. H. Freeman: New York.
- Medin, D./Lynch, E./Coley, J./Atran, S. (1997) Categorization and reasoning among tree experts: Do all roads lead to Rome? *Cognitive Psychology* 32: 49–96.
- Miller, G. (2000) *The mating mind: How sexual choice shaped the evolution of human nature*. Doubleday Books: New York.
- Nesse, R./Lloyd, A. (1992) The evolution of psychodynamic mechanisms. In: Barkow, J./Cosmides, L./Tooby, J. (eds) *The adapted mind*. Oxford University Press: New York.
- Panksepp, J./Panksepp, J.B. (2001) The seven sins of evolutionary psychology. *Evolution and Cognition* 6(2): 108–131.
- Pinker, S./Bloom, P. (1990) Natural language and natural selection. *Behavioral and Brain Sciences* 13: 707–727.
- Rosch, E./Mervis, C./Grey, W./Johnson, D./Boyes-Braem, P. (1976) Basic objects in natural categories. *Cognitive Psychology* 8: 382–439.
- Sartori, G./Job, R. (1988) The oyster with four legs: A neuropsychological study on the interaction of semantic and visual information. *Cognitive Neuropsychology* 5: 105–132.
- Shanker, S. (2001) What a child knows when she knows what a name is: The non-Cartesian view of language acquisition. *Current Anthropology* 42(4): ***PAGE_NUMBERS_MISSING***
- Spelke, E./Phillips, A./Woodward, A. (1995) Infants' knowledge of object motion and human action. In: Sperber, D./Premack, D./Premack, A. (eds) *Causal cognition: A multidisciplinary debate*. Clarendon Press: Oxford.
- Sperber, D. (1985) Anthropology and psychology: Towards an epidemiology of representations. *Man* 20: 73–89.
- Sperber, D. (1996) *Explaining culture: A naturalistic approach*. Blackwell: Oxford.
- Thornhill, R./Palmer, C. (2000) *A natural history of rape*. MIT Press: Cambridge MA.
- Waddington, C. (1959) Canalisation of development and the inheritance of acquired characteristics. *Nature* 183: 1654–1655.
- Wallace, A. (1901) *Darwinism*. Macmillan: New York. Originally published 1889.
- Warrington, E./Shallice, T. (1984) Category specific impairments. *Brain* 107: 829–854.
- Williams, G. (1992) *Natural selection: Domains, levels and challenges*. Oxford University Press: New York.