Adults across all cultures seem to think about biological phenomena in distinct ways that are not found in other domains of knowledge. Thought about the living world has its own particular nature that may be different from thought about artifacts and the nonliving natural world. Perhaps the most fundamental unit of that apparently special kind of biological thought is the concept of the species: the basic ontological kind around which so much of folk biology seems to be organized. If this is correct, it is in many ways quite extraordinary, for the phenomenal differences between plants and animals seem so enormous that it is remarkable that they nonetheless might be conceived as vastly more similar to each other than either is to other sorts of kinds. In this essay, we ask how it is that species might be thought of so differently and on what psychological basis.

At the most general level, two, nonmutually exclusive possibilities might explain this phenomenon: (1) there is something in the information about biological species that is structured so differently that it shapes learning differently and results in different kinds of cognitive structures for thinking about species; and (2) humans have certain intrinsic cognitive biases that lead them to think about species in very different ways. The task here is to explore the details of such possibilities and their relative roles. To frame the problem, it is useful to see how each possibility could be the only account.

For example, it might be that the informational patterns associated with biological kinds result in different kinds of knowledge structures being created by completely general learning capacities in humans. The kinds of features seen in living things and the patterns of correlation formed among them over time might result in knowledge of a distinctive type, but that knowledge reflects nothing about any a priori human expectations about living things. A variety of general learning devices, given the kind of information associated with living kinds, would tend to represent that information distinctively and then sequester that information into a coherent domain of biological thought.

Such an approach was implemented in a connectionist model by McRae, de Sa, and Seidenberg (1997). From a large body of feature norms, they found that living kinds had a greater density of intercorrelated features than
IV. Species in Mind and Culture

artifacts and that this distinction could explain the results of several priming studies that revealed latency differences between the two kinds. Furthermore, they claimed that an attractor network that had distributed knowledge of the empirically derived feature norms could simulate the same sort of behavior in priming tasks. Of course, priming results alone are hardly enough reason to suppose that the corresponding living kind concepts were fundamentally different in structure, but the work done by McRae and his colleagues illustrates how such an argument might proceed.1

Alternatively, it might be exceedingly difficult to specify any objective informational patterns that set aside plants and animals as a distinct kind with its own rich internal structure; instead, humans may carry with them certain cognitive biases to interpret information about species in highly distinctive and unique ways. Thus, extremely simple perceptual features shared by animals and plants (perhaps a kind of fractal structure seen more commonly in living things) might trigger a cascade of predetermined cognitive biases that make learning and the resulting concepts of biological kinds radically different from other concepts of kinds. There may be some real informational differences as well, such as differing densities of feature clusters, but this view would argue that those differences far underdetermine the nature and kind of specializations seen in biological thought.

We argue that there may be misleading assumptions and misconceptions about the nature of the distinctive information and about the biases that color our notions of what biological thought is like; also, the ensuing misconceptions about biological thought, especially as a kind of intuitive theory, may obscure the true nature of species concepts and how they are embedded within the broader system of biological knowledge. Several new lines of empirical work are suggested.

Much of our discussion examines how biological thought in general and species concepts in particular develop in the child. We take such a developmental perspective because (1) it tells us what sorts of information might be most salient to the naive mind, and (2) it suggests what might be the most fundamental biases that we all have in thought about the living world.

Between the empiricist and nativist extremes there are many gradations and combinations. Our goal here is not to allocate responsibility to these two extremes as much as it is to explore what each may contribute to a more complex interactive model of where species concepts come from and what makes them special. We do so by trying to clarify what informational patterns might be both distinctive to living kinds and salient to humans, and by asking what sorts of cognitive biases might interact with that information, even if those biases themselves are not always reserved exclusively for biological phenomena.

THE GENERAL NATURE OF FOLKBIOLOGICAL THOUGHT

Any notions of species are embedded within broader systems of belief about biological kinds. One cannot understand what a dog is without also knowing
something about animal life cycles, nutritional needs, and the like. For that reason, it is helpful to consider how views of intuitive biological thought have changed in recent years (e.g., Medin and Atran 1999). It has become commonplace to argue that lay people throughout the world possess richly structured beliefs about the living world that might be thought of as intuitive or naive theories about biological processes and systems—such as growth, reproduction, digestion, disease, and death (Medin and Atran 1999).

Characterizations of these beliefs as theories or mental models, however, may carry with them somewhat misleading ideas about how that knowledge is represented in the mind of the individual. It might seem that the knowledge must be an explicit set of beliefs connected together in the tightly coherent manner of a formal scientific theory and that the models must contain concrete, imagelike components whose interactions can be clearly visualized. Folk theories would then be said to differ from formal scientific ones only in terms of the particular sets of beliefs they embrace and not so much in terms of their general format. Thus, a belief that demonic possession causes disease contagion might have very much the same kind of mechanistic set of lawful relations as a belief that germs cause disease contagion (Keil et al. 1999).

But a closer look at intuitive biological theories and perhaps at many theories in the more formal sciences reveals something quite different from an explicit set of propositions all linked together in a tightly connected, logically consistent, and coherent set of inferences. Most people have strikingly little knowledge of the detailed mechanisms at work in their own bodies, let alone in other animals and plants. An exceedingly simple gloss may be all that is known, such as food contains energy and that the body uses that energy as a kind of fuel to power muscles, which make us move. This simple functional schemata may then occasionally get filled with local mechanisms and gradually become interconnected in somewhat larger and more coherent structures, but only the smallest percentage of people in any culture can tell you much of anything about the full causal chain that goes from the ingestion of food to the production of a motor movement based on the energy in that food.

Yet people seem to have far more than a set of functional schemata. They seem to have general and often abstract ways of choosing among classes of explanations about biological phenomena, even though these explanations may be equally satisfactory from a functional point of view. An explanation of mechanisms of digestion in terms of a mechanism in which food particles are converted to light that is routed around the body before being transformed into muscle energy would be vastly less plausible to most adults than a mechanism that invoked transformation of food into a kind of fluid "fuel," even if both mechanisms were ultimately wrong.

There are several sorts of things, above the level of specific mechanisms, that adults and possibly children know and believe about biological kinds and that nonetheless might be distinctive to those kinds and thereby make biological thought different:

Keil and Richardson: Species, Stuff, and Patterns of Causation
1. We know that certain kinds of properties and relations tend to be central to explanations in biology and to the stability of various biological phenomena (cf. Boyd, chapter 6 in this volume). For example, (a) color is likely to play a more important causal role in explaining functions of most living kinds than in explaining functions of most artifacts; (b) size variation might matter less for most living kinds than for most artifacts; (c) difficulty of finding instances may be more important for artifacts; (d) sensitivity to temperature is more important to living kinds, as is (e) their age or stage of development.

2. We know that certain kinds of causal patternings might be distinctive to living kinds and to explanations about their nature. Patterns of causal homeostasis may appear to be richer and more interconnected (Boyd, chapter 6 in this volume). Causal mechanisms may change more dramatically as one goes from “inside” a biological kind to its outside, but not for artifacts and nonliving natural kinds. We may expect the time course of bounded causal events for biological systems to have a certain duration that is distinctive in comparison to the time course for either artifacts or nonliving natural kinds. Artifacts tend to have immediate cause and effects, whereas living things can have a far more delayed reaction to events; for example, a plant may not yield fruit now because it wasn’t watered enough a month ago.

3. We know that living kinds may have certain causal powers even if we don’t know the mechanisms for these powers or their functions. For example, we might know that humans tend to sneeze when they go rapidly from dim light to bright light, but we may have absolutely no idea how that happens or for what possible reason. The specific causal powers of living things may be quite different in nature and kind from the causal powers of other sorts of things and could thereby give a distinctive structure of biological thought without knowledge of mechanisms.

4. We may also carry distinctive biases about aspects of biological entities and events—biases that may not be correct, but that powerfully constrain our beliefs and explanations about biological phenomena nonetheless. These biases might include the notions that living kinds have fixed inner essences that guide the expression and maintenance of many of their phenomenal properties and that their properties are likely to be present for functional adaptive reasons. The “essentialist bias” for living kinds becomes particularly important later when we examine the developmental course of naive folk biology.

5. We may have notions of how aspects of biological knowledge might be distributed in the minds of others such that we believe that there are people who know certain things about living kinds and thus can answer our questions. Because we cannot understand all the details of most mechanisms, we all learn to divvy up knowledge responsibilities, and part of our understanding of a phenomenon becomes knowing how to access relevant areas of expertise that others have generated. Biological knowledge and most other
areas of scientific understanding have this critical social component (Wilson and Keil 1998). Notice, however, that historically and in most cultures even today, the richness of and social apportionment of knowledge about the biological world far exceeds the richness of knowledge about the rest of the natural world, such as elements and compounds or weather systems or the stars. The cognitive division of knowledge responsibilities may therefore be far and away the most developed in the biological realm.

It is possible that we may have different expectations about how such knowledge is distributed for biological kinds than we do about how it is distributed for other sorts of kinds. For example, it may be that we expect natural kind expertise to be more tied to species or types and artifact expertise to be related to mechanisms or processes. Thus, we have vets, gardeners, pediatricians, and entomologists, on the one hand, and electricians, plumbers, and carpenters, on the other. It seems plausible that this distinction is because knowledge of living kinds has historically begun with the organism and analyzed inward, whereas expertise about nonliving things would consist of grasping a process or mechanism and learning to exploit it for functional means across types. Moreover, as science progresses and we learn more about biological mechanisms, we can analyze them more in terms of processes. This distinction may therefore be dissolving as “cross-type” domains of living kind knowledge develop, such as microbiology or evolutionary biology.

There are many forms of implicit knowledge one could have of living things. Explanatory knowledge of most phenomena can, by necessity, capture only part of the richness and complexity of causal structure in a domain. We therefore cannot ever have full mechanistic knowledge, but at the same time we have more than a collection of surface impressions or skeletal functional schemata. That our knowledge and understanding might be largely organized in these different forms, however, is not always appreciated, and part of the reason it is difficult to see may be that we all tend to have a vividness illusion regarding our own understandings. People may often assume they have complete or extensive mechanistic understanding of a domain when they do not. They might have observed the inner workings of a car engine or a heart or a bicycle derailleur and be convinced that they have an imagelike mental model of how that system works. They might confidently predict their ability to explain exactly what happens in each step of the causal event sequence that characterizes the entity in question; yet when queried about such mechanisms, they might reveal glaring ignorance and inconsistencies. They seem to think that understanding arises from clockwork kinds of vivid concrete steps, and because they have a strong sense of understanding, they assume they have that kind of clockwork knowledge.

Later, we discuss how the vividness illusion may help us understand why knowledge does not always develop from concrete images of interacting components to more abstract notions about property types and their interactions.
Just as we tend to overestimate the centrality of such clockwork mechanisms in our adult understandings, we may tend to overestimate their seminal role in development.

In the end, any notions of species must be powerfully influenced by how we view adult biological knowledge in general. If, for example, we believe that having an essence is a critical part of a species concept, then we must be able to say how we could have a notion of essence without any sort of concrete understanding of what is inside animals and plants. And if we think species are entities with properties that help maintain the survival and integrity of that kind, we must be able to say how we know those patterns of maintenance without knowing many of the details. Almost any way one tries to flesh out the nature of species concepts is powerfully influenced by this view of biological knowledge in general. The species concepts cannot be understood without understanding how it fits into a larger system of folk biology.

**CHILDREN, FOLK, AND SCIENTISTS**

Lay people are not children relative to scientists; thus, the study of children’s biological concepts is not equivalent to studying biological concepts in people who don’t work in the science of biology. All adults have many interactions with the biological world. Even the most nature-phobic and jaded urban dweller thinks about the food and drink he consumes and their consequences on his bodily functioning, or about the diseases he encounters in others and how they might influence his own biological state. Adults have spent thousands of more hours having such thoughts than a young child has, and they have surely developed much richer and more elaborate systems of knowledge. As we look across many different cultures, however, we turn to development as highlighting emerging and invariant universal properties of biological thought, for those properties that seem to emerge the earliest might well be the most universal. They may have much more elaborated forms in adults, but examining acquisition may help uncover a core form.

Views of the emergence of biological thought have changed dramatically in recent years. Older accounts described children as going through general stages of cognitive development that would make completely unavailable to them any real notions of biology. Piaget (1954), for example, thought of young children as having “animistic” tendencies in which they endowed a great many things, living and not, with beliefs and desires and explained their properties and actions in such terms. They did not have any notion of plants and animals as forming a common kind of biological things. But these stage views of cognitive development fell from grace in the late 1970s and early 1980s as closer and more systematic examinations of knowledge acquisition did not reveal such stages in which children progressed from having one sort of representational and computational capacity to a qualita-
tively different one (e.g., Gelman and Baillargeon 1983). Alternative conceptions focused on developmental patterns in specific bounded domains—such as biological thought, theory of mind, naive physical mechanics, and number. This domain specificity approach found a natural affinity with the notion of concepts as embedded in larger systems of explanation or intuitive theories. Despite occasional talk of “theories of everything,” the notion of theory tends to imply a bounded domain of phenomena explained by that theory with little reason to think that theoretical knowledge in one domain should necessarily extend to all other domains. Within that framework, two main themes emerged with respect to the emergence of biological thought.

One theme argued that younger children (e.g., before age seven) really did not have an appreciation of biology as a coherent set of phenomena and that they often explained biological phenomena in social and psychological terms (Carey 1985). Thus, they might see sleeping as caused by feeling tired and wanting to sleep, and they might see its function as satisfying those needs. Similarly, they might explain eating in terms of the sensory pleasures of ingesting food and in terms of the social interactions that happen at meal times. They would completely ignore the physiological aspects of these processes. In these accounts, the children would then undergo radical conceptual changes in which an intuitive biology emerged, and now they would explain the same phenomena in completely different terms. An alternative account has emerged from several laboratories (Keil 1992, 1998; Hatano and Inagaki 1996; Wellman and Gelman 1998), however, that suggests that even young preschoolers do have some sense of the domain of biology and have a distinctive mode of biological thought. Their failures on many tasks concerning biological knowledge are attributed to their not knowing specific mechanisms and to sometimes misunderstanding which frame of reference (social versus biological) is being asked for in a task (Gutheil, Vera, and Keil 1998) rather than to a complete lack of an intuitive biology, which is seen as couched in the more implicit forms discussed earlier.

In addition to preferring some mechanisms more than others, young children also often know how knowledge of a specific mechanism is likely to be related to understanding of another mechanism, even when they have no direct knowledge of either mechanism. For example, in one study in progress in our laboratory, children as young as five years of age often respond in an adultlike manner to the following question:

Louise knows all about why kids get a second set of teeth. Cathy knows all about why babies can get afraid of strangers. Who knows why teenagers like to listen to so much music?

Many five-year-old children judge that knowledge about behavioral mechanisms is more likely to “hang together” in the minds of experts (e.g., Cathy is more likely to know about the teenagers predilection for music) than will a mixture of biological and behavioral mechanisms (e.g., where Louise would know more about the teenagers) even though they usually
have no explicit notions of the mechanisms whatsoever. Indeed, when asked about the mechanisms, most of them will quickly say they have no idea. Yet, at some level these children are aware that the kinds of processes involved in stranger fear and positive feelings toward music are more similar to each other conceptually than those processes involved in explaining deciduous teeth. The converse also seems to hold—namely, if there are two questions about biological mechanisms and one about behavioral mechanisms, an expert in one of the biological questions is judged more likely to know more about the other biological question than about the behavioral one. These sorts of results raise the question, What do young children know about biology that guides their judgments in such tasks?

More generally, it seems that we do not want to think of young children as only capable of having “concrete” impressions of biological processes wherein specific mechanisms or models are explicitly visualized. Contrary to many decades of claims that younger children are bound to think in concrete terms and can grasp more abstract relations only later, it often seems that knowledge can shift from the abstract to the concrete in development (Simons and Keil 1995). We adopt here the view that even preschoolers have an intuitive sense, often at a highly implicit level, of biological phenomena as being distinct from one another, and we ask what that perspective suggests about species concepts and how they develop. One of the most robust findings of that developmental story has been the discovery of very early beliefs in essences for living kinds.

How might a child come to believe more strongly in essences for living kinds than for other sorts of things? We’ve seen that such a strong belief might arise not only from real informational differences between the causal structures responsible for biological kinds and those structures responsible for other sorts of kinds, but also from cognitive biases that might be related to those differences. Yet another source of information might be parents, but in a surprisingly subtle and implicit manner. Parents do not tell children that things have essences, but they do talk about living kinds quite differently from the way they talk about artifacts and in ways that would seem to suggest a hidden structure with greater richness for living kinds (Gelman et al. 1998). Parents do not provide didactic explanations of hidden properties and their causal consequences. Instead, they seem to indicate in more abstract ways—through different patterns of reference—what sorts of things are kinds and that some kinds are likely to have richer essences. They also provide hints as to what sorts of things are more likely to be taxonomically embedded.

We do not yet know how much influence this subtle pattern of language has on the child’s conceptual development, but it does point out a third dimension that might interact with cognitive biases and intrinsic informational differences. We now need to examine the content of this essence concept that adults and children readily attach to living kinds.
All of us may succumb to essentialist biases that compel us to assume and look for those critical aspects of kinds that allow us to make powerful inferences. Gelman and Hirschfeld (1999) contrast three types of "psychological essentialism": sortal, ideal, and causal. Sortal essence refers to critical defining features or, in other words, singly necessary and jointly sufficient sets of features for determining category membership—an account that seems to work for only a small set of real-world concepts, however. Ideal essence refers to nonexistent perfect cases. The ideal essence of parallel lines has no real counterparts because no physical system can perfectly embody parallelism. Finally, causal essence refers to something about a kind that results in its having many of its most typical and stable properties. The nature of that "something" is critical. Most commonly, it seems to be thought of as a fixed inner entity that has multiple causal effects. That entity might be a kind of substance (the essence of gold being atoms with gold's number of protons) or an informational code (the DNA sequence corresponding to tigers) or a process.

Despite much talk about essence in recent years, it still is not clear how most lay people actually conceive of essences or whether the biases are much stronger in younger children and in thought about some sorts of kinds rather than about others. Medin and Ortony (1988) have suggested that we can often believe in an essence without any idea of what the essence actually is—that we have an essence "place holder" concept without the concept of the essence itself. This sense of essence makes clearer how it could be a bias without specific content. But the place holder notion may overlook a related set of beliefs, for even as people commonly believe in essences without knowing any details about those essences, they still might prefer some sorts of future details to others. Thus, there might be a physicalist bias, whereby people prefer essences to be seen as objects or "stuff" rather than kinds of processes. Teaching that photosynthesis is the essence of green plants might be less compelling than teaching that it is a certain DNA sequence, even though the process of photosynthesis may be much more directly connected causally to a far greater range of phenomenal properties of plants.2

For species concepts, then, notions of essence may be absolutely essential, yet we have little idea of what sorts of constraints there might be on notions of essence. Some theorists have argued that notions of essence have had extraordinary limiting effects on how we think about species in the context of evolutionary thought. Hull (1965), for example, talks about how Aristotelian essentialism caused a "2,000 year stasis in evolutionary thought" because it assumed that species had fixed essences and thereby could not explain how new species could evolve through natural selection. The notion of species as a probabilistic concept, a distribution of types, seemed to be foreclosed by the essentialist bias even though that notion of distribution is
critical to understanding how evolution through natural selection could actually occur. But what notions of essence were involved in Aristotelian essences? Hull’s reference to Aristotle suggests something like the sortal essence, yet for much of folk biology, the causal essence seems more appropriate. A causal essence, however, is not on its own incompatible with a probability notion. Indeed, Boyd’s notion of causal homeostasis (see chapter 6 in this volume), a process wherein species properties are maintained in stable configurations, fully allows for species themselves to change over time as a consequence of natural selection, yet that kind of process might well be a form of causal essence. The fixedness of essence would seem to arise from a cognitive bias toward not appreciating a process such as causal homeostasis, either because processes in general are not preferred or because any probabilistic components to such processes are not allowed.

The problem of an essence is that it seems indirectly or probabilistically related to the features of an organism, but directly related to its categorization. That is to say, an organism with a leopard “essence” will resemble a leopard ceteris paribus, but not if some freak dietary anomaly prevents it from developing a certain pigmentation pattern: it will nevertheless be a leopard under an essentialist conception. The question, then, is what features license this ascription of an essence of a certain type, since an essence is also a basis for ignoring features?

The riddle about causal essence is that unlike both sortal and ideal essences, causal relations in the real world are rarely strictly necessary. Because the entities within a folk theory are usually loosely framed, there can be no necessary causal laws holding between the entities as there can be between entities in a more rigid scientific framework. Therefore, some degree of probability always seems to be associated with causal relations occurring in the real world, even if in some cases that probability is exceedingly high. Are lay notions of causality ignorant of such probabilities, or does probability somehow otherwise get ignored as notions of cause and essence become intertwined? People often seem to know that an event may cause a particular effect, but not always. Eating rotten meat usually causes one to feel sick, but not always. Sexual relations cause the emergence of babies sometime later, but certainly not always. These probabilistic relations are part of how all of us talk every day: why, then, cannot there be a kind of causal essence that is probabilistic? It would seem that the psychological constraints on causal essence strongly discourage certain forms. Perhaps the psychologically appealing sense of causal essence ultimately requires the notion of fixed stuff, rather than a process, as the initial cause, and even if that stuff has only probabilistic causal consequences, its very nature is not at all probabilistic.

Given these considerations, there is the additional problem of the scope of an essence: how it is seen to vary within living kind hierarchies. Is the “essence” a type—the DNA sequence varying by “product type and brand” like a supermarket bar code—or is it a token, an essence as individual as a fingerprint? Or is it the case that the hypothesized essentialist bias easily
admits gradations of similarity between tokens that can be used to categorize them into types? Although it may be more correct to think of a continuum of DNA similarity that is, perhaps arbitrarily, divided up into species, cognitive bias may pull us away from this idea.

In their pioneering studies on prototype concepts, Rosch and Mervis (1975) asked subjects to grade the typicality of various living kinds. For example, a robin was graded as a more typical bird than a duck, and these ratings predicted speed on tasks such as lexical decision. Furthermore, Rips (1975) found that the typicality gave rise to asymmetric judgments: subjects thought it more likely that a duck could catch a disease from a robin than that a robin could catch a disease from a duck. This asymmetry could be interpreted as pointing toward an essentialist bias. Rather than being the case that robins and ducks simply have a certain degree of similarity, it seems to be the case that we conceive of robins as having a “stronger bird essence” than ducks, so if something affects a robin as a typical bird, it seems more likely to affect a duck than vice versa.

An essentialist folk theory may suggest that biological factors such as susceptibility to a certain disease attach not only to robins, but to their essence as birds; these factors are hence, more likely to extend to a duck. Can the same sense of essence that gives us the concept of species also make one species more central than another in a higher-level category, such as bird?

These issues make obvious the need for an extensive set of psychological studies that ask what constraints there might be on different notions of essence. We can further ask how those notions might change over the course of cognitive development in the child—of moving from novice to expert knowledge—and how they vary across kinds. In addition, they may vary across kinds from the earliest points in conceptual development, or they may start as a more common vague notion that gradually differentiates with increasing knowledge in each domain. In short, people do seem to have an essentialist bias and perhaps especially so for living kinds, a bias that powerfully influences their concepts of species, but we have only begun to understand the real psychological nature of this bias.

THE VIVID ILLUSION OF SPECIES

So far we have put forward several claims about the nature of our concepts of living kinds, and it seems that there might be a common underlying cognitive explanation. Given that folk-biological thought seems both void of specific mechanisms and inclined toward certain types of explanation, and that we have a strong bias toward essences in living kinds, it now seems plausible to seek an account of the type of illusion discussed earlier, whereby people have a tendency to assume that they have a vivid, clockwork knowledge of certain mechanisms.

This illusion is similar to one that has been repeatedly demonstrated in recent years in studies of visual memory and indeed may arise from common
mental sources. In those studies, people look at scenes, often quite simple ones, and assert that they have a clear memory of what it contained. Yet when tested, they can be strikingly ignorant of the details of the scene they just observed. They not only mistakenly remember different colors, textures, and surface patterns on objects, but also often fail to notice in a recognition task when completely different objects are in the scene (e.g., Simons 1996). They do, however, have quite good memories for the spatial layout of the objects in the scene—the general relational topology of objects—even when they forget the details. With dynamic objects and systems, people seem to retain good understandings of the functional “layout” while often losing all the details of particular discrete components in that layout.

The vividness illusion in the mechanisms of folk biology might be seen in terms of a misleading dispositional bias: a variant of the “fundamental attribution error” (Nisbett and Ross 1980) whereby folk tend to think dispositionally about other people, assuming that inner essences, more than situational factors, explain the behaviors of others (Miller 1996). This bias has been shown to extend beyond concepts of people to concepts of other entities in the world, such as a chip of wood in a turbulent stream (Peng and Nisbett forthcoming). It may be that living kinds are far more powerful triggers of the bias than are most other kinds.

A very general cognitive bias may be at work here as well: the tendency to focus on what are known in statistics as main effects and not on interactions. It may be simpler and more cognitively compelling to think of a kind being created by either intrinsic essential properties or environmental forces, rather than by an interaction between the two. Therefore, being aware of some salient endogenous factors may lead to an overzealous assumption of almost exclusively endogenous forces.

The reasons for these illusions or biases are not clear, but they may well have cognitive benefits at some level. For scenes, they perhaps help build the impression of a continuous flow of experience; for systems, they may help build an impression of a continuous chain of understanding without explanatory gaps.

The question with regard to species and essentialism is whether a kind of illusion is created wherein patterns of causal homeostasis result in the relative stability of property clusters, which are then mistakenly assumed to be stable not because of that homeostatic process, but rather because of a fixed physical causal source. That is, causal homeostasis causes stable property clusters, which in turn cause the impression of a fixed physical essence. We know that people succumb to a vividness illusion in several ways. There may be the corresponding assumption that stable property clusters must have stable physical sources. The relative stability of property clusters that emerge through causal homeostasis, as opposed to those clusters that do not, may be so great in relative terms that it leads to the erroneous assumption of absolute stability. Then, the cognitive bias toward essences might
consist of positing a stable property for living kinds as a kind of simplifying heuristic.

Many argue that living kinds have a much richer causal structure—that they are causally more complex (Gelman et al. forthcoming). That causal complexity is then thought perhaps to trigger impressions of causal essence. But complexity is notoriously difficult to define and measure, and a little reflection makes one worry about any absolute differences between artifacts and living kinds in terms of causal complexity. To be sure, the vast majority of living kinds have more complex causal internal processes that give rise to surface processes and to activities. When one includes external social and cultural factors that help explain why artifacts are as they are, however, artifacts have vastly more causal complexity connected to such cultural and social properties than most living kinds have.

Again, more subtle and more interesting differences may be at work. The sociocultural causal factors for artifacts may not be nearly as bounded as are the other causal factors for most living kinds. That is, they do not neatly circumscribe the artifact. To know why chairs are the way they are, one has to look at economics, body shapes, and physiological needs in a vastly extended causal network that does not cluster tightly around chairs.

Whereas artifacts may have causal factors that are distributed across sociocultural factors, living kinds seem to have a more bounded, visceral pattern of causal homeostasis. Perhaps living kinds are different in the respect that the causal cluster for each one is more of a dense island in a sea of weaker and less causally complex interconnections. Again, there is a strong intuition here, but it needs to be examined in an experimental manner to see if people see living kinds as forming more dense and distinct clusters (See also Ahn, 1998 on why different features are central for artifacts and natural kinds.).

We all accept that the notion of essence is not unique to thought about living kinds, but its strength and power seem strongest for living kinds even when it may be least correct as a kind of fixed entity in such cases. Thus, at the cognitive level and perhaps also because of the special nature of living things, essences of living kinds seem to have a different character, one that may be more cognitively compelling.

Artifacts are not normally thought of as having essences, but again that notion depends on notions of essence that remain largely unanalyzed. Certain physical constraints make only some two-wheeled pedaled devices physically stable and thereby useful as bicycles (Olson and Kyle 1990). The angle of the front fork can be changed so that the “bicycles” are completely unridable as they start to oscillate in an unstable manner. Thus, a pattern of causal homeostasis makes a stable functional unit, and only certain properties qualify in the pattern for that unit. Are such causal patterns part of the essence of bicycle? If not, what makes their case so different from the patterns for some animals? At a psychological level, the difference may lie in the belief that for living kinds, there is some sort of fixed stuff that gives rise to the patterns of homeostasis, a belief that seems counterintuitive for most artifacts.
A species concept is a kind of categorization. It treats a class of living things as equivalent in important respects, and that equivalence then licenses powerful inductions, which is presumably why species concepts are so useful. But inductive power is said to be a key motivation for almost all cognitively natural categories; what else, beyond essence, is distinctive about species concepts as opposed to other concepts? There appear to be many qualitative distinctions between living kinds and artifacts, including how taxonomies, teleology, and exemplars are construed, yet the question remains whether or not these differences are due to quantitative differences in the spread of causal homeostatic patterns.

Living kinds are said to be much more deeply embedded in taxonomies than are other sorts of kinds, and throughout the world, all peoples seem to realize this taxonomic character very early in development (Atran, chapter 9 in this volume and 1998). Abundant evidence now shows that this taxonomic assumption is very powerful for living kinds and probably not nearly as powerful for other sorts of kinds (although the latter have not been nearly as carefully or systematically studied). However, what is it about living kinds that leads to this taxonomic assumption? As with essences, it is not so clear what “triggers” the assumption. Thus, it is not so objectively obvious that living kinds occur in more deeply embedded hierarchies. There are, after all, quite deep hierarchies for many naturally occurring compounds (kinds of rocks, soils, gems, etc.). For example, the United States Department of Agriculture gives a four-layered basic taxonomy of soil types—categorizing, to take one instance, from histolsols to fibrists to sphagnofibrists that are pergelic. Therefore, depth of hierarchy is not evidently a cue. Similarly, there are very rich hierarchies for many classes of artifacts. The U.S. Patent Office has more than five hundred classes of artifacts: meandering down the scheme, of these five hundred, the class “Surgery” has forty divisions, within which “Prosthetics” has twenty, within which “Leg” has nine, and of these “Socket” has six categories. Even if the hierarchies of living kinds are generally deeper, it is not at all clear that their depth in itself is responsible for their being seen taxonomically. Thus, there is no evidence to support the intuition that deeper hierarchies are more taxonomically compelling. If depth doesn’t predict a sense of taxonomy for the nonliving world, why should it be a factor in the living world?

Do these species-related taxonomies provide the only apparent ways to classify living kinds even though there are multiple ways for other sorts of kinds? No. Animals can be classified as predators or prey, as domesticated or wild, or as edible or not, or they can be classified within theories that focus on phylogenetics, ecology, and so on. It is difficult to know how to count the ways, but it is not obvious that living kinds are different in this respect. Even in folk biology, we see trees and non-trees as one way of sorting plants.
that is at intrinsic odds with sorting by more common species names (Dupré 1981).

Do taxonomies for living kinds have more salient properties at each level of the hierarchy? Perhaps that is the case in comparison to nonliving natural kinds, but many artifacts have powerful sets of distinctive features at many levels, and those features license powerful inductions. Perhaps there is a more subtle difference here. Basic-level concepts (Rosch et al. 1976) turn out to be much more robust for some artifacts—such as furniture, clothing, and vehicles—than they do for most living kinds. That is, the basic level for artifacts (e.g., chair) represents a vastly richer feature cluster than is present at the superordinate level (e.g., furniture); the basic level also offers correspondingly many more inductions. With living kinds, however, the superordinate level, such as mammal, is much richer in nature and more full of distinctive properties than it is for most artifact kinds. This difference may suggest more taxonomic continuity between levels of living things because there is less of a jump in feature density as one moves up or down a level. For that reason, the basic level tends to stand out in much sharper relief for artifact categories, with most experimental data demarcating that level more strongly and unambiguously when artifacts are used as stimuli (Rosch et al. 1976).

Another contrast between species categories and categories for other kinds is said to revolve around teleology, the argument being that teleological interpretations work only with living kinds. In a simple form, however, this argument is clearly wrong. Artifacts have purposes, as do their parts. In a more subtle form, however, this view may offer an important contrast. One does not normally ask about the purposes of animals as whole entities, but only about the purposes of aspects of them (the exception is highly domesticated functional species, such as hunting dogs). Such questions are completely normal about artifacts, however. Thus, species categories are different in terms of where teleological questions are directed and when they are legitimate. Why this difference exists and how universal it is remain unclear, however.

Detailed analyses of teleological understandings and some characterization of what it is about living kinds that blocks such holistic teleological interpretations are needed for the contrast between living and nonliving kinds to work (cf. Bloom 1996). With artifacts, human intention guides the holistic teleological account, but why should intention be needed for the holistic account when it is not needed for more local explanations for living kinds (for example, that webbed feet help an animal swim better)?

A final contrast may circle around the nature of the category structure in terms of best exemplars and well definedness. With some natural kinds, the best exemplar would be something like its sortal essence, to use Gelman’s terminology: “pure” water is nothing but H₂O molecules, for example. The best exemplar of an artifact would be closer to some ideal essence framed in terms of its function, so the exemplar of computer would be cheap, fast, easy to use, compatible with all platforms, and so on. However, determining the
best exemplar becomes more difficult when the function is not easily framed: What is the one-line functional definition for *church* or the *internet*?

How do we think of the exemplars of living kinds? In some cases, living kinds have functional value for human beings and can be evaluated on that dimension: the best trees are those with the highest fruit yield, for example. Or we might frame the best exemplar as that which fulfills its “purpose”: the best butterfly is camouflaged from predators, can extract nectar efficiently, lay a large number of eggs, and so on. But this framework brings in all the problems of teleology discussed above. In addition, how do we evaluate how “doglike” a dog is? It could be the case that we have some prototype or idealized average of all dogs. Does this average equate with a dog essence? Alternatively, we may have some notion that goes beyond the typicality of perceptual features to a representation of a homeostatic cluster of causal properties that are seen to be significant. It becomes difficult, however, to draw a firm distinction between living and nonliving kinds on this criteria of well definedness because there is considerable variation within both classes.

Well definedness in itself may therefore not be the cut between artifacts and living kinds because they both have fuzzy aspects, but the fuzziness may occur in different ways for the two kinds. Furthermore, it seems that when more rigid criteria are applied in the evaluation of living kinds, those kinds are being measured in relation to some functional goal, even the seemingly hollow purpose of winning a dog show. In short, species concepts may be importantly different from other sorts of concepts that categorize kinds, but the dimensions and degrees of difference are still unclear.

It seems, therefore, that species concepts may be distinct in several ways that go beyond notions of essence and that are not closely related to patterns of causal homeostasis. The details of the psychological differences between these ways are just beginning to be uncovered, however.

**CONCLUSIONS**

Species concepts seem indeed to reflect a special kind of categorization. Several cognitive biases may interact with some very distinctive informational patterns of living kinds, such as a disposition toward certain types of properties and relations, as well as a tendency to discretize these homeostatic patterns into an essence of some sort. But it is clear that all of these psychological contrasts are just beginning to become apparent. The nature of a species concept is mostly a place holder at present and is framed by only the softest and vaguest of constraints. We therefore do not really know much about how it is that species concepts arise, but this lack of knowledge should not be discouraging because for the first time we are now in a position to learn a great deal more about how those concepts emerge in development and become used by adults. The rapid growth of work on biological thought, especially in cross-cultural and developmental perspectives, has helped set up a framework in which it is now possible to pose highly
detailed questions about species concepts—such as how children have them early on, even though they have few concrete details of what an essence might be. We now see more clearly the different ways in which folk biology is likely to be mentally represented and especially how it is not. Even more important, we now see how these issues can be better understood through empirical study of both children and adults. Very different patterns of results are possible in such studies, and those patterns will make a profound difference in our understanding of what it means psychologically to have the concept of a species.

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NOTES

1. As an aside, it is interesting to note the similarities between McRae and colleagues' (1997) discussion of an attractor space as a way of describing a cognitive mechanism representing concepts and Goodwin and Webster's (1996) claim that the concept of species should be understood in biology theory in terms of an attractor space or a “morphonogenic field” (see Griffiths, chapter 8 in this volume).

2. Some sort of cognitive bias may be favoring the notion of DNA in lay thinking about living kinds and appropriating it as the essence of living kinds. As argued elsewhere in this volume, DNA is not a sufficient tool with which to divide species because there can be more variability within species than between them. However, it appears as if the scientific term DNA has been equated with some intuitive, folk notion of essence, even though essence and DNA divide up the world in very different ways. We discuss the possible psychological grounds for this bias, but for now we might make the observation that when people misunderstand the notion of DNA—as probably all but a few do—the mistakes they make commonly belie an underlying essentialist belief.

REFERENCES


Species Begone!