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Do houseflies think? Patterns of induction and biological beliefs in development[1]

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Abstract

A current debate within the cognitive development literature addresses how best to characterize conceptual change. Within one proposal, development primarily consists of a series of radical conceptual shifts or restructurings in which the most current understanding is inexplicable within (incommensurate with) prior conceptual structure. Alternatively, development is discussed as more gradual enrichment of multiple existing early explanatory systems, allowing for commensuarability over time and change. This paper examines the literature in this debate with specific focus on naive biological understanding, and discusses a series of studies on preschoolers' inductive inferences across biological and non-biological kinds. Children were taught a series of biological properties for a human being (e.g. eating, sleeping etc.), and asked to generalize these properties to both biological (e.g. dogs, worms) and non-biological kinds (e.g. clouds, tables). The results of these studies support the gradual-enrichment proposal. Specifically, 4-year-olds seem to possess a limited, but coherent and independent biological theory which may form the basis of mature understanding of biological kinds. These results are discussed in terms of multiple explanatory systems which both preschoolers and adults can employ across development to effectively guide their decisions within a given domain. © 1998 Elsevier Science B.V.

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1. Introduction

Houseflies clearly don't 'think' in the folk-psychological sense of having beliefs and desires and a set of mental computations that links their beliefs and desires to those of other houseflies. This is presumably why most of us would not credit them with more complex psychological activities such as puzzlement, angst or cynicism. Houseflies do, however, 'think' in a different, functional biological sense that refers to their ability to register information, perform computations on what is registered and act on the results of those computations. As adults, we easily understand these two different senses of thinking as being grounded in two very different systems of explanation: one for intentional agents and one for functional biological systems. Furthermore, any inductive judgments we make can only be correctly understood in the context of the specific system of explanation that we consider relevant for a particular situation.

The state of affairs with the earliest origins of understanding and thinking is less obvious. Young children's expectations might at first be strikingly different (incommensurate) from those of adults, requiring radical conceptual shifts or restructuring to account for development (e.g. Inagaki and Hatano, 1993). In addition, rather than possessing multiple explanatory systems for a given class of phenomena, as adults seem to, young children may first be restricted to a single explanatory framework from which others must develop (e.g. Carey, 1985, but see also Spelke et al., 1992; Leslie, 1995, for discussion of multiple frameworks in infancy). In this paper, we argue for a more gradual enrichment of multiple early explanatory systems allowing for commensurability over time, and change. Specifically, we propose that, like adults, preschoolers have access to multiple explanatory systems which they can employ across different situations to effectively guide their decisions within a given domain.

The structure of knowledge about living things has become a focal point in this debate, in part due to its status as a large, complex and cross-culturally significant domain of knowledge (e.g. Carey, 1985; Keil, 1992; Atran, 1994, 1995). Some argue that (in contrast to adults), preschoolers rely mostly on a system of psychological and behavioral explanation to understand the properties of living things (Carey, 1985, 1991); thus, all biological phenomena are initially interpreted in psychological and behavioral terms. Only later does distinctly biological thought emerge from psychological concepts.

In a landmark series of studies, Carey (1985) asked young children whether animals such as dogs, fish, flies and worms had the human properties of eating, sleeping, having bones, having hearts, having babies and thinking. If children initially construe biological properties within a psychological framework, they should not generalize these properties to animals that seem different from humans with respect to psychological roles (Carey, 1985). Four-year-olds in Carey's studies showed a steep drop in property generalization as animals became more psychologically and behaviorally distinct from humans (i.e. from dogs to worms). In contrast, 7-year-olds' inferences showed a much smaller drop off, and significantly greater property generalization across all animals. These results were interpreted as evidence that 4-year-olds' inductions about biological kinds were governed by a single psychological/behavioral framework, and that a qualitatively distinct biological theory, incommensurate with the understanding of younger children, started to emerge at about age seven.

Younger children clearly know less than older ones and acquire major new insights in biology as they age. However, rather than radical restructuring, development could consist of gradual enrichment with strong, fundamental similarities between the naive biological theories of preschoolers and adults. In this view, psychological expectations may be the default system which children employ, but children possess both biological and psychological expectations that organize information about living things throughout the preschool years. The relative difficulty preschoolers have in moving beyond the default (psychological) framework could give the illusion of radical restructuring, but biological knowledge is never distorted and absorbed into another domain of explanation, and radical restructuring is not necessary.

The possible presence of several explanatory systems in young children's thinking about living things is suggested by a recent study in which children were presented with a set of animals that formed two orthogonal categories: taxonomic groups (i.e. mammals, birds, reptiles, fish), and dispositional groups (i.e. predators and prey/domestic animals). Six-year-olds attributed the biological properties to all animals, but attributed domestic psychological properties more often to the prey/domestic animals than to the predatory animals (e.g. both guinea pigs and tigers have bones and can be angry, but guinea pigs are more likely to be happy and scared (Coley, 1995).

Some restructuring might well occur *within* an autonomous domain of biology. Six-year-olds seem to have a coherent biological theory based on vitalism, in which individual organs or organ systems are endowed with agency; organs guide biological functioning independently of the intention or control of the person who possesses them. Eating is neither an exclusively behavioral (e.g. eating as a family interaction), nor a purely biological process concerning only digestion and physiology. Instead, the stomach/digestive system is seen as an autonomous agent that works in some way to transfer energy or 'vital power' from food to the rest of the body. In contrast, mature biological theory focuses accurately on the mechanistic action of bodily processes. The stomach is not an autonomous agent, but a mechanism of digestion. Vitalistic biology is seen as qualitatively different from the mechanistic biology of older children and adults (Inagaki and Hatano, 1993).

Although vitalistic biology and mechanistic biology might appear strikingly different, the difference may largely lie in a lack of specific knowledge of biological processes and organ systems (Inagaki and Hatano, 1993). Six-year-olds do not know how food is digested, or blood is circulated. Young children may possess a common framework for understanding the biological nature of living kinds, into which they incorporate specific information over time (Simons and Keil, 1995). As children gain concrete details concerning biological mechanism, this understanding becomes more mechanistic in nature, but is not necessarily restructured into a qualitatively different biological theory (see also Au and Romo, 1998).

In summary, by age six children seem to possess a distinctly biological theory that guides their understanding of biological phenomena (see also Hatano and Inagaki, 1994). They may also possess multiple explanatory systems within this domain (Coley, 1995). Evidence that biological understanding emerges from naive psychology is equivocal. The need for radical restructuring to account for development (especially below age six) remains an open question.

If preschoolers can use multiple frameworks to structure their understanding of living kinds in ways similar to older children, developmental discontinuities and radical restructurings of biological thought become less appealing. The availability of such multiple frameworks would be suggested if contrasting contexts could switch children's inductions about biological kinds between behavioral/psychological and biological frameworks. In particular, it should be possible to reproduce Carey's (1985) results with no context, or elaborations that invoke a psychological form of explanation, and to make 4-year-olds look like 6- or 7-year-olds with elaborations that invoke biological/functional forms of explanation.

These hypotheses were first investigated in a preliminary study in which children ($n = 16$ per condition, mean age = 4–2 years) were told that humans possess a set of specific biological properties (e.g. eating, having bones etc.) and then asked to decide whether dogs, fish, flies and worms have these properties as well. The properties were accompanied by two different types of description (context) that were intended to highlight a specific domain of explanation for children. If children are capable of assessing the animal/property relationships from multiple theoretical perspectives, then their patterns of property attribution should be differently affected by each context provided. The biological context described the property in terms of its physiological role and its consequences for the person's survival. The psychological context described the property in terms of its effects on a person's psychological state or her interactions with other people. In the no-context condition children were simply told the person had the property and then asked about the other animals (see Table 1). If the psychological belief system is children's default mode of reasoning about biological properties, then their responses in the no-context condition should be similar to both those found in Carey (1985), and those found in the psychological-context condition[2].

There was a strong effect of the context provided on children's responses. When given a psychological context or no context, children's responses were similar to past studies. In contrast, when given a biological context, children were more willing to generalize the properties to all the animals regardless of those animals' degree of behavioral-psychological similarity to humans (see Fig. 1).

Children attributed properties to animals more often in the biological condition than in any of the other conditions or than in prior studies (Carey, 1985). Given the proper context, 4-year-olds base their inductions on something other than psychological/behavioral similarity. Fig. 2 shows that the preschoolers in the biological

[2]The results of this study are reported in an abbreviated form due to the loss of the original data while the second author was in transit to Hong Kong. All of the results reported are statistically significant, however, we felt it better to summarize these results as a preliminary study and conduct replications as the primary focus of the paper.

Table 1
Functions given with each property in the biological and psychological conditions of the preliminary study

Biological	
Eats	This person eats because he needs food to live and grow. The food gives him energy to move. If he doesn't eat, he will die.
Sleeps	This person sleeps because his body needs to rest and build up energy for the next day. If he didn't sleep, he would get very tired and would not be able to do anything.
Has bones	This person has bones so that he can walk, run and move. If he didn't have bones, he would be a bag of skin.
Has a heart	This person has a heart that pumps blood around his body. The blood carries food and air to all the parts of the body and the person would die without the heart pumping.
Has babies	This person has babies when he grows up because people grow old and die and without babies there would be no more people.
Thinks	This person thinks so that he can know where his home is and how to find food. He also thinks so that he can know who his family and friends are.
Psychological	
Eats	This person eats because he loves to be at meals with his family and friends. Meals bring the family together to eat and have fun. If he didn't eat he would never see his family all together.
Sleeps	This person sleeps because everyone in his family goes to bed at night. If he didn't sleep he would be up all alone and might wake up the rest of the family and make them mad.
Has bones	This person has bones so that he can play and dance with his friends. If he didn't have bones, he wouldn't be able to hug his family.
Has a heart	This person has a heart that pounds when he is happy and excited. The pounding helps keep him more excited when he plays with his friends.
Has babies	This person has babies so that he can have a big fun family and more people to play with.
Thinks	This person thinks so he can have fun with people. He and his friends like to play thinking games and work out problems together.

condition are giving responses that are quite similar to the results of 7-year-olds in Carey's (1985) studies[3]. By contrast, in the no-context (and psychological-context) conditions, see Fig. 1, the preschoolers perform just as in earlier studies, showing a marked drop-off after dogs. This drop is also present to a lesser degree in the biological condition. As in earlier studies, children clearly see the dog as morphologically and behaviorally most similar to humans. Biological context provides a framework that enables children to go beyond this similarity, and thereby produce more generalization across animals.

This preliminary study, however, is open to alternative interpretations. Children may have a general explanatory system of natural kinds, say, as distinct from artifacts, but no specific biological system. A study that does not compare biological and non-biological natural kinds might mistakenly attribute the pattern of inductions to a biological theory instead of to the more general theory of natural kinds (cf.

[3]Carey (1985) did not present a complete data set for plants and inanimate objects. Her data were consequently not included for comparison in the figures in the main studies.

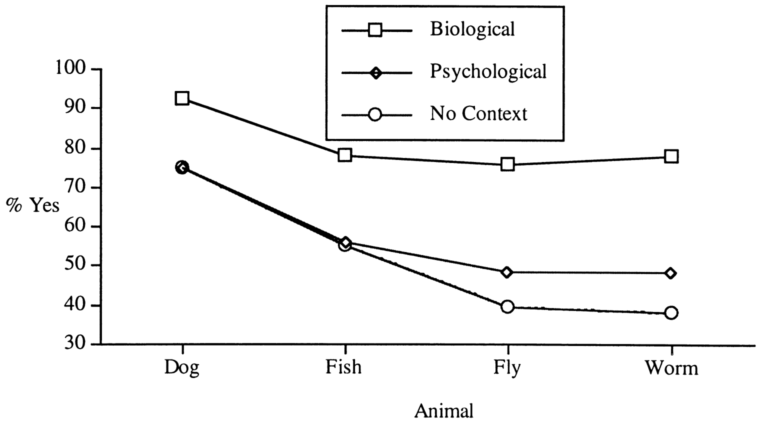

Fig. 1. Percent of positive response across conditions in the preliminary study.

Gelman, 1988). We therefore expanded the items to include plants, artifacts and non-living natural kinds as well as animals.

The biological contexts also contained some subtle behavioral cues. For example, movement is mentioned in the biological context for ‘bones’ (see Table 1). Perhaps the overall pattern of induction in the biological condition is improved by those contexts because they make other organisms more behaviorally similar to humans (This explanation was suggested by Susan Carey). We therefore altered the context stories to remove all behavioral cues. Finally, given the similarity of responses in the psychological and the no-context conditions, we focused on the differentiation between the biological and the no-context conditions as the strongest contrast in our design of Study 1.

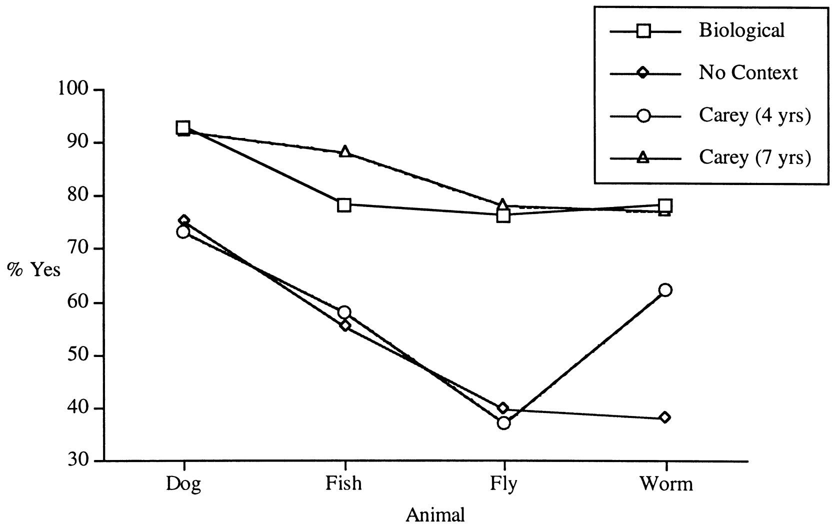

Fig. 2. Comparison of preliminary study responses with Carey (1985).

2. Study 1

2.1. Method

2.1.1. Participants

Thirty-eight children (range: 3–2 to 4–6, *m*: =4–0) were randomly assigned to one of two conditions. There were roughly equal numbers of boys and girls in each condition. The sample represented a predominantly white, middle class population.

2.1.2. Procedure

Children were randomly assigned to either the biological or the no-context condition, and tested individually in a single session lasting roughly 15 min. Each participant was first shown line drawings of a person, dog, fish, fly, worm, flower, tree, sun, cloud, car, hammer, table and toy monkey. These were the same objects used by Carey (1985) and were identified by the experimenter if necessary. The experimenter then explained that children were going to be told something about the person and then asked if the same thing was true of the other items. Children were asked about six properties for each item: eating, sleeping, having bones, having a heart, having babies and thinking. The properties were always presented in this order within participants. For each property in the biological condition, children were told the context story listed in Table 2. In the no-context condition children were simply told the person had the property and then asked about the other items. Items were presented in random order for each participant.

2.2. Results

The response that an item possessed the target property was coded as ‘1’; the response it did not was coded as ‘0’. Table 3 shows the percent of participants generalizing a given property in each property/item pair. Children were consistently

Table 2
Context given with each property in the biological condition of Study 1

Eats	This person eats because he needs food to live and grow. If he doesn’t eat he will get skinnier and skinner and he will die.
Sleeps	This person sleeps because his body needs to rest and become strong again for the next day. If he didn’t sleep he would get very tired and his body wouldn’t work very well.
Has bones	This person has bones to hold his body up and make space for all the inside parts. If he didn’t have bones he would be a bag of skin.
Has a heart	This person has a heart that pumps blood around his body. The blood carries food and air to all the parts of the body, and the person would die without the heart pumping.
Has babies	This person has babies when he grows up because people grow old and die and without babies there would be no more people.
Thinks	This person thinks so he can know where his home is and how to find food. He also thinks so he can know who his family and friends are.

Table 3
Percent of children providing positive responses to each item and property combination in study 1[1]

Items	Properties						
	Eats[b]	Sleeps	Bones	Heart	Babies	Thinks	SD
Dog	100/75[c]	94/87	87/69	87/50	87/62	87/37	5/18
Fish	100/81	62/37	62/25	62/25	94/56	56/25	19/23
Fly	94/56	50/31	50/0	50/25	69/19	50/25	18/18
Worm	69/50	75/31	44/19	62/25	81/44	56/25	13/12
Flower	19/6	25/6	0/0	6/0	37/12	6/0	14/5
Tree	12/6	25/12	19/12	0/0	25/25	0/6	11/8
Sun	0/6	12/12	0/6	0/0	6/0	6/12	5/5
Cloud	0/6	0/0	0/0	0/0	6/0	6/6	3/3
Car	0/0	0/0	6/6	0/0	12/0	6/6	5/3
Hammer	0/0	0/0	6/12	0/0	6/0	0/6	3/5
Table	0/6	0/0	6/6	0/0	6/0	0/6	3/3

[1] n = 16 per condition.
[b] Percents rounded down from 0.5.
[c] The first percent in each pair is the biological condition. The second is the no-context condition. SD, standard deviation.

more likely to generalize the properties across all four animals in the biological condition than in the no-context condition. They were also consistently unlikely to generalize these properties beyond the animals in either condition.

Data were analyzed in terms of the effects of each condition on each item, and the effects of condition on each property. The number of positive responses was averaged for each subject over each property for four categories of items: animals, living things (animals and plants), plants and inanimate objects. Both sets of analyses were broken down into comparisons of these four categories of items between the two conditions.

Fig. 3 shows the overall patterns of induction for the two conditions collapsing over properties. A 2(condition) ×4 (animal) mixed ANOVA with animal as the repeated measure revealed main effects for condition, $F\ (1,30) = 12.66$, $P < 0.01$, and animal, $F\ (3,90) = 27.88$, $P < 0.0001$, but no interaction of these factors. Follow-up analyses indicated a significantly greater number of inferences in the biological condition (70%) than in the no-context condition (43%) for all animals[4]. Children’s willingness to generalize properties was greatest for the dog item and dropped off to some degree for the remaining animals in both conditions. However, as in the preliminary study this drop was less severe in the biological condition (27%) than the no-context condition (47%) (see Fig. 3).

With properties collapsed over animals, a 2 (condition) ×6 (property) mixed ANOVA with property as the repeated measure showed a significant main effect for condition, $F\ (1,30) = 12.66$, $P < 0.01$, and property, $F\ (5,150) = 6.83$, $P < 0.0001$), but no interaction of these factors. Follow-up analyses revealed that across both conditions children were most likely to generalize ‘eat’ followed by ‘has babies’ and ‘sleeps’ (see Table 3; Fig. 4).

[4] All P-values are 0.05 or less unless otherwise noted.

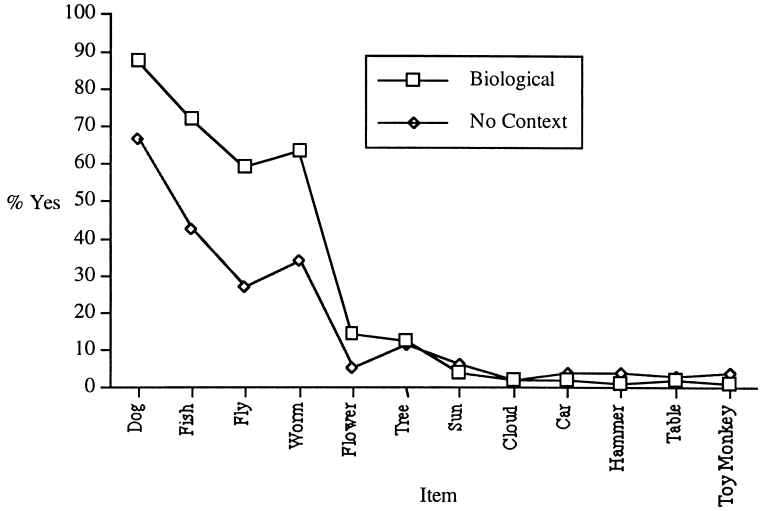

Fig. 3. Percent of positive responses for each item in Study 1.

Additional analyses were then conducted on plants, living things and inanimates. Results for living things were consistent with those for animals alone, showing a significantly greater number of inferences in the biological (53%) versus the no-context condition (33%). However, when plants were examined independently of animals, there were no significant differences between the two conditions (13% vs. 17%). There was, however, a significant effect of property, F (5,150) = 4.80, $P < 0.001$. Both for flower and tree, 'sleeps' and 'has babies' received more affirmative responses than 'has bones' and 'has a heart', 'eats' and 'thinks' were in between (see Table 3). This pattern was the same in both conditions. Finally, there

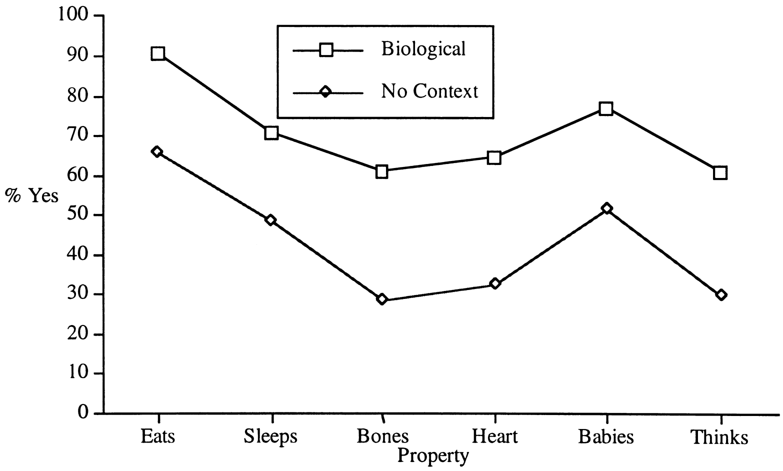

Fig. 4. Percent of positive responses for each property in Study 1.

were no significant condition or property effects involving inanimates. Children uniformly refused to generalize any of the properties to inanimates (see Fig. 3).

2.3. Discussion

As with the preliminary investigation, these results suggest the presence of multiple explanatory systems in preschoolers' understanding of biological kinds and the use of the psychological framework as the default (no-context) explanatory option. The sharp drop in induction after animals indicates that the effect of the biological contexts is neither random nor due to an overall biasing effect of the functional nature of the descriptions. Furthermore, removing behavioral cues from the biological contexts had no effect on the pattern of results. The increase in children's attributions is specific to animals as opposed to natural kinds, and results from the biological nature of the property explanations. The lack of a context effect on children's generalizations to flowers and trees indicates that at least for these properties, children do not see animals and plants as biologically equal.

One possible limitation to the studies presented to this point is that children are taught a biological context specific to each target property. For example, children are told that 'this person eats because he needs food to live and grow. If he doesn't eat food he will get skinnier and skinnier, and he will die.' They are then immediately questioned about the presence of this property in the remaining items. Although we believe this type of task provides a clear test of children's biological understanding, it does so within a very specific and structured framework. A more stringent test of the presence of a biological explanatory system would be to ask children to generalize the properties across different items without providing a biological context specific to those properties. Rather than providing children with separate stories for each property, they could be told a more general biological context story at the beginning of the task that does not provide information specific to the target properties. If preschoolers are able to consider the properties in biological terms given this limited and general context, this would support the hypothesis that they possess the basics of an autonomous theory of biology.

3. Study 2

3.1. Method

3.1.1. Participants

Seventeen children (m = 4–8, range 3–11 to 5–4) participated in this study. There were seven girls and ten boys in the sample. Children were recruited from local day-care centers and represented a predominantly white, middle-class population.

3.1.2. Procedure

Children were first shown a series of line drawings. These were similar to those used in Study 1 with the exception that the toy monkey was omitted. Children were then shown the human picture again and told the following story.

Lets talk about people, okay? You know how machines have inside parts that let them do things, like motors that make trucks move or batteries that make flashlights light up? Well, people have inside parts that let them do things in all sorts of interesting ways as well. We all can breathe by ourselves and we can all move around by ourselves and we all have the same kinds of stuff inside that lets us do this. People aren't the only things in the world that can do things like move around and breathe, right? We're going to look at the pictures of people and other things and talk about them. While we look at the pictures, try to think about all the different kinds of things in the world that can do things like move around by themselves, and breathe by themselves, and have the same kinds of stuff inside. Okay, here we go.

For each property children were directed to the human picture and asked 'do you see this person? This person Xs (i.e. 'eats', 'sleeps' etc.).' The experimenter then went through the remaining pictures one at a time, and asked the child if each possessed the specific property taught for the person. For example, 'do you think this dog eats food?' The properties were the same as those in Study 1, with the exception that 'has a heart' was dropped, in order to shorten the procedure. Properties were presented in the same order as in Study 1. The pictures were shuffled and presented in a random order for each property.

Results were coded in the same manner as in Study 1, and assessed in comparison with both the biological and the no-context conditions in that study. Children's responses in Study 2 were expected to be both highly similar to those in the biological-context condition of Study 1, as well as significantly different from the no-context condition in Study 1.

3.2. Results

Given only the general biological context story at the start of the task, children's responses were both highly similar to those of the more extensive biological-context condition of Study 1, as well as significantly different from the no-context condition of that study. For purposes of discussing the analyses, the results of Study 2 are presented as the third of three between participants conditions (i.e. specific (Study 1), no-context (Study 1), and general (Study 2)[5]). As in Study 1 we first investigated children's responses to questions concerning the four animals. A 3 (condition) by 4 (animal) mixed ANOVA with animal as the repeated measure revealed a main effect for condition, F (2,46) = 8.73, P = 0.0006, a main effect for animal, F (3,138) = 39.47, $P < 0.0001$, and no interaction, F (6,138) = 0.711, P = 0.64, (see Fig. 5).

Follow-up analyses indicated that, for all animals, children made fewer inferences in the no-context condition (45%) than in either biological-context condition, with no significant differences between the biological-context conditions (72% specific condition; 70% general) (see Fig. 5). Even when given a general biological context story that mentioned none of the target properties, children were just as likely to generalize the specific properties as in the more specific biological-context condition

[5]Given that Study 2 did not contain 'has a heart' this item was not included in these analyses.

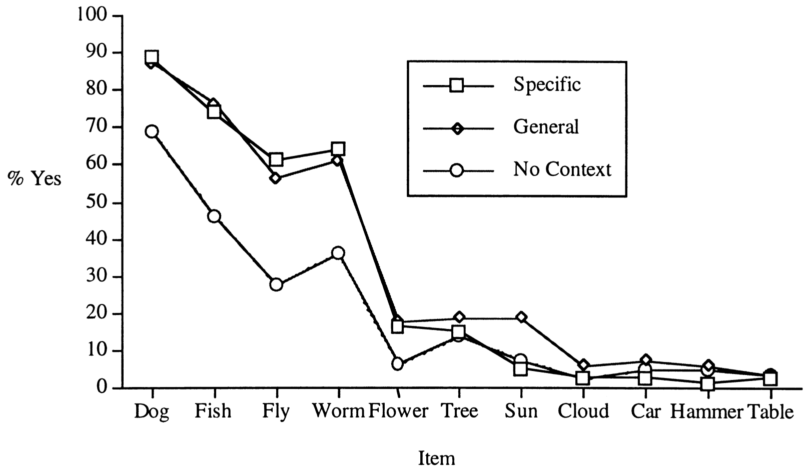

Fig. 5. Percent of positive responses across three conditions of Studies 1 and 2.

of Study 1. Further analyses indicated significant differences in responses between all animals across conditions except the fly and worm ($P < 0.01$) (see Fig. 5). These results are consistent with Study 1. Although the drop in property generalization from dogs to the other animals is significant across conditions, it is almost twice as large (47%) in the no-context condition than in either specific biological (27%) or general biological (26%) conditions.

To explore the effect of context on responses for each property, a 3 (condition) by 5 (property) mixed ANOVA with property as the repeated measure revealed significant main effects for both condition, F (2,46) = 8.73, $P = 0.0006$, and property, F (4,184) = 13.27, $P < 0.0001$, and no significant interaction. Follow-up analyses indicated that across conditions, participants were most likely to generalize 'eat' followed by 'sleep' and 'has babies', and least likely to generalize 'has bones' and 'thinks' (see Table 4).

As in Study 1, we next investigated the effect of biological context on property generalizations to living things. A 3 (condition) by 6 (living thing) mixed ANOVA with living thing as the repeated measure revealed a main effect of condition, F (2,46) = 7.33, $P < 0.002$, a main effect of living thing, F (5,230) = 119.34, $P < 0.0001$, and an interaction of these two factors, F (10,230) = 2.33, $P = 0.012$. Follow-up analyses indicated that although both biological inference conditions (m specific = 53%, m general = 53%) were significantly different from the no-context condition (m = 33%), and not significantly different from each other, this was true only for the animals. There was no significant effect of condition for either the flower, F (2,46) = 2.02, $P = 0.14$, or the tree, F (2,46) = 0.27, $P = 0.76$. This is again consistent with Study 1, and further indicates that children differentiate between animals and plants when making generalizations of these properties.

An investigation of inferences to inanimates indicated a significant interaction of condition and item, F (8,184) = 2.10, $P = 0.038$. Children in the general condition were more likely to generalize properties to the sun than to the other inanimates, and

Table 4
Percent of children providing positive responses to each item and property combination in study 2 (n = 17)

Items	Properties					
	Eats[a]	Sleeps	Bones	Babies	Thinks	SD
Dog	100	88	82	88	76	9
Fish	88	82	65	94	53	17
Fly	82	53	29	59	59	19
Worm	82	82	18	59	65	26
Flower	29	23	23	12	0	11
Tree	41	29	12	6	6	16
Sun	12	59	6	18	0	23
Cloud	12	6	0	6	6	4
Car	12	12	0	6	6	5
Hammer	0	12	12	6	0	6
Table	0	0	6	6	6	3

[a] Percents rounded down from 0.5.

this was particularly true for the ‘sleeps’ property (see Table 4). This pattern of attribution seems to be due to a specific connection in the children’s minds between sleeping and the sun rising and setting, rather than any general misconstrual of the relationship between the target properties and inanimates overall.

3.3. Discussion

The results of Study 2 support and expand Study 1. Four-year-olds seem able to shift from a default psychological framework to a biological framework given only a minimal general context. Children do not simply learn and apply property-specific information. Rather, they seem to be tapping into an autonomous biology that they already possess.

In Studies 1 and 2, however, children treat animals and plants quite differently. Children in both biological-context conditions are significantly more willing to generalize the target properties to all the animals but to neither of the plants. This could be due to a response strategy in which children ignore the property entirely and simply respond positively to all the animals and negatively to all other items. This seems unlikely given both children’s positive response to the sun sleeping in Study 2, as well as the noticeable drop in generalization for ‘has bones’ on the fly and worm items (see Table 4). However, this response strategy could clearly account for the majority of the data to this point, without the need to posit an autonomous biology.

One way to test for the presence of this strategy would be to teach children a property that should not generalize equally to all animals, and that would be more likely to generalize to an animal phylogenetically distant from human beings. In addition, they could be taught a property that is specific to human beings and should not generalize to even phylogenetically similar animals. If children are responding positively to all animal + property combinations, they should generalize these properties across all animals. If, however, children attend to each property + item combination, they should continue to generalize biologically appropriate properties across all animals, while not generalizing either of the more specific properties beyond their appropriate human/animal categories.

4. Study 3

4.1. Method

4.1.1. Participants

Seventeen children (m = 4–6, range 3–11 to 5–3) participated in this study. There were 11 girls and six boys in the sample. Children were recruited from local day-care centers and represented a predominantly white, middle-class population.

4.1.2. Materials and procedure

These were identical to Study 2 with two exceptions: (a) a picture of a song-bird was added to the items, for a total of 12 and (b) the properties ‘eats candy bars’ and ‘can sing’ replaced ‘eats’ and ‘has babies’. The order of presentation was then: ‘sleeps’, ‘eats candy bars’, ‘has bones’, ‘sings’ and ‘thinks’.

Results were coded in the same manner as in Studies 1 and 2. In contrast to these studies, the generalization patterns in Study 3 were predicted to be highly property-dependent with respect to the animals, and consistent with the previous studies for the remaining items. Specifically, participants were predicted to be consistent with Studies 1 and 2 for the ‘sleeps’, ‘has bones’ and ‘thinks’ properties. They should, however, respond that birds sing significantly more than any other animal including dogs, and be generally unwilling to believe that anyone but humans eat candy bars.

4.2. Results

Children clearly differentiated the generalizability of the different properties. Responses to the general biological properties were consistent with Studies 1 and 2, and inferences to the two more specific properties were confined to the appropriate category members (see Table 5). We first examined responses across properties for the five animals. A 5 (property) by 5 (animal) repeated measures ANOVA revealed a significant main effect for property, $F\ (4,64) = 28.31$, $P < 0.001$, a significant main effect of animal, $F\ (4,64) = 11.17$, $P < 0.001$, and a significant interaction of these two factors, $F\ (16,256) = 7.79$, $P < 0.001$. Follow-up analyses indicated that, as predicted, children thought birds almost always sang (88%) and that the other animals almost never did (12%). Also as predicted, children’s responses to ‘thinks’ and ‘eats candy’ did not differ significantly across animals. Children agreed that all the animals were equally likely to think (48%), and virtually never ate candy (13%). Children also responded that dogs and fish are significantly

Table 5
Percent of children providing positive responses to each item and property combination in study 3 (n = 17)

Items	Properties				
	Sleeps[a]	Candy bars	Bones	Sings	Thinks
Dog	100	18	100	18	53
Bird	94	12	76	88	47
Fish	100	0	88	18	41
Fly	76	23	65	6	47
Worm	88	12	47	6	53
Flower	41	0	0	0	0
Tree	23	0	0	0	0
Sun	23	0	0	0	6
Cloud	18	0	0	0	0
Car	0	0	0	0	0
Hammer	0	0	0	0	0
Table	0	0	0	0	0

[a] Percents rounded down from 0.5.

more likely to sleep than are flies. In addition, dogs and fish were significantly more likely to have bones, followed by birds and flies, and finally by worms (see Table 5).

Results for living kinds and inanimate objects are consistent with previous studies. As in Studies 1 and 2, children generalized all properties significantly less often to the flower and tree items than to the animals (see Table 5). As in Study 2, there was a significant effect of item for ‘sleep’, $F\ (4{,}64) = 3.66$, $P = 0.01$. Children were significantly more likely to respond that the sun sleeps (23%) versus the car, hammer or table (0%).

4.3. *Discussion*

Children’s responses both here and in the prior studies are unlikely to be due to a simple response bias in which any property generalizes to all animals. Children clearly differentiated those properties that should generalize across animals (e.g. ‘sleeps’ and ‘thinks’) from those that should not (‘eats candy’). In addition, children attributed a specific property (‘can sing’) only to birds, not to other animals. Both of these response patterns are independent of the level of phylogenetic similarity of the animals to humans.

5. Discussion

Children’s responses across the studies are consistent with the use of multiple explanatory frameworks for living kinds. The contexts did not tell children how to project the property to other entities; they simply clarified the property and the suitable explanatory framework to use in generalizing to other items. This is especially true in Studies 2 and 3 in which a global context is provided at the start of the procedure, and is never directly connected to the specific properties tested. Children's success goes beyond the use of the biological context as a simple template (e.g. people need food or they will die, therefore worms needs food or they will die.) They correctly generalized those properties such as 'sleeps' and 'thinks' to all animals, while refusing to generalize those that were specific to individual categories ('eats candy' and 'sings').

We have suggested that, like adults, preschoolers possess multiple explanatory frameworks concerning biological kinds, and can use these frameworks to guide their inductive judgments. Unlike adults, the behavioral/psychological framework seems to be the default option. However, given simple contexts, children are capable of applying an apparently biological framework to the task. Research on induction must therefore consider how children initially interpret properties before drawing conclusions about their explanatory frameworks. Patterns of induction are intimately related to conceptual structure, but in a far more intricate way than can be uncovered by simply asking for intuitions about the applicability of a few terms, especially when it is unclear in which domain those terms are embedded (e.g. Roth and Shoben, 1983).

While vitalism is a useful and accurate characterization of young children's understanding of the specific components and processes of biology, it is difficult to fully characterize children's inductive responses in the present studies in vitalistic terms. Children's biological framework seems to extend beyond vitalism, to function at a broader conceptual level that encompasses general biological properties and the interrelationships of human beings and (at least) non-human animals. It is increasingly clear that vitalism itself is not a monolithic construct, and that historically, different cultures have believe in quite different versions (Hatano and Inagaki, 1994). As we learn more about these different forms of vitalism we may gain a clearer idea of whether those forms point towards more continuity in development, or towards more substantial changes within the domain of biology.

Children consistently differentiated animals and plants, raising the possibility that their biological theory does not yet extend beyond animals. The specific properties and contexts used in these studies, however, may have biased children away from considering plants and animals as biologically similar. Properties such as 'has bones' and 'thinks', for example, do not readily generalize to plants (see Tables 3, 4 and 5). In addition, the general context story used in Studies 2 and 3 is more applicable to animals than plants (e.g. emphasis on movement). These studies then, may not offer a fair assessment of children's understanding of plants as living kinds. In contrast, 5-year-olds clearly see animals and plants as an integrated category of living things with respect to properties such as growth and ingestion of food and water when given contexts specific to these properties (Hatano and Inagaki, 1996).

The present data do not argue against the occurrence of conceptual change across development. Older children's and adults' understanding of the world differs in clear and crucial ways from that of younger children. However, rather than radical shifts between incommensurable theories we argue that much of development (and certainly understanding of biological kinds) may be better characterized as shifts among default biases that are present quite early on in development and form the basis for more advanced theories.

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References

Atran, S., 1995. Causal constraints on categories and categorical constraints on biological reasoning across cultures. In: Sperber, E., Premack, D., Premack, J.A. (Eds.), Causal Cognition: A Multidisciplinary Debate. Clarendon Press, Oxford, pp. 205–233.

Atran, S., 1994. Core domains versus scientific theories: evidence from systematics and Itza-Maya folk biology. In: Hirschfeld, L.A. Gelman, S.A. (Eds.), Mapping the Mind: Domain Specificity in Cognition and Culture. Cambridge University Press, New York, pp. 316–340.

Au, T., Romo, L., 1998. Building a conception of HIV transmission: a new approach to AIDS education. In: Medin, D., Atran, S. (Eds.), The Psychology of Learning and Motivation, Folkbiology. MIT Press, Cambridge, MA.

Carey, S., 1985. Conceptual Change in Childhood. MIT Press, Cambridge, MA.

Carey, S., 1991. Knowledge acquisition: enrichment or conceptual change? In: Carey, S., Gelman, R. (Eds.), The Epigenesis of Mind: Essays on Biology and Cognition. Earlbaum, Hillsdale, NJ.

Coley, J.D., 1995. Emerging differentiation of folkbiology and folkpsychology: attributions of biological and psychological properties to living things. Child Development 66, 1856–1874.

Gelman, S.A., 1988. The development of induction within natural kind and artifact categories. Cognitive Psychology 20, 65–95.

Hatano, G., Inagaki, K., 1996. Young children's recognition of commonalties between animals and plants. Child Development 67, 2823–2840.

Hatano, G., Inagaki, K., 1994. Young children's naive theory of biology. Cognition 50, 171–188.

Inagaki, K., Hatano, G., 1993. Young children's understanding of the mind-body distinction. Child Development 64, 1534–1549.

Keil, F.C., 1992. The origins of an autonomous biology. In: Gunnar, M., Maratsos, M. (Eds.), Minnesota Symposium on Child Development. Earlbaum, Hillsdale, NJ, pp. 103–137.

Leslie, A., 1995. Causal understanding in naive psychology. In: Sperber, E., Premack, D., Premack, J.A. (Eds.), Causal Cognition: A Multidisciplinary Debate. Clarendon Press, Oxford, pp. 121–141.

Roth, E.M., Shoben, E.J., 1983. The effects of context on the structure of categories. Cognitive Psychology 15, 346–378.

Simons, D.J., Keil, F.C., 1995. An abstract to concrete shift in the development of biological thought: the 'insides' story. Cognition 56, 129–163.

Spelke, E.S., Breinlinger, K., Macomber, J., Jacobson, K.., 1992. Origins of knowledge. Psychological Review 95, 605–632.