Revisiting preschoolers’ *living things* concept: A microgenetic analysis of conceptual change in basic biology

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Abstract

Many preschoolers know that plants and animals share basic biological properties, but this knowledge does not usually lead them to conclude that plants, like animals, are living things. To resolve this seeming paradox, we hypothesized that preschoolers largely base their judgments of life status on a biological property, capacity for teleological action, but that few preschoolers realize that plants possess this capacity. To test the hypothesis, we taught 5-year-olds one of four biological facts and examined the children’s subsequent categorization of life status for numerous animals, plants, and artifacts. As predicted, a large majority of 5-year-olds who learned that both plants and animals, but not artifacts, move in goal-directed ways inferred that both plants and animals, but not artifacts, are alive. These children were considerably more likely to draw this inference than peers who learned that the same plants and animals grow or need water and almost as likely to do so as children who were explicitly told that animals and plants are living things and that artifacts are not. Results also indicated that not all

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biological properties are extended from familiar animals to plants; some biological properties are first attributed to plants and then extended to animals.

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1. Introduction

Most 5-year-olds know that plants and animals share numerous important characteristics that they do not share with nonliving things: the capacity to grow (Hatano et al., 1993; Inagaki & Hatano, 1996), to reproduce (Springer & Keil, 1989, 1991), to heal (Backscheider, Shatz, & Gelman, 1993; Hatano et al., 1993), and to die (Hatano et al., 1993; Inagaki & Hatano, 1996), among them. Not until around age 7 or 8, however, do most children conclude that plants, like animals, are living things (Carey, 1985; Hatano et al., 1993; Richards & Siegler, 1984). The goals of this paper are to present an analysis of why children show this puzzling mixture of biological understanding and misunderstanding and to describe a microgenetic study that tests predictions from the analysis.

Several explanations for children’s difficulty in forming an adult-like living things concept have been proposed. One of the most prominent is that preschoolers’ and adults’ concepts of life are incommensurate (Carey, 1985, 2000). In this view, the features that imply life for an adult do not do so for young children, whereas the features that young children see as essential, such as psychological capacities, seem superfluous to adults. Expressing this perspective, Slaughter, Jaakkola, and Carey (1999) wrote, “children lack the biological concept of life, and thus cannot unite animals and plants under a single category, ‘living thing’” (p. 76).

A second explanation for why young children rarely view plants as living things emphasizes analogical mapping (Inagaki & Hatano, 1996, 2002). Within this perspective, preschoolers initially organize their understanding of life status around people’s characteristics; the more closely that an entity resembles people, the more likely that the entity will be judged to have biological properties (see also Carey’s (1985) “comparison-to-people” model). Five-year-olds are said to use this understanding to discover and reason about the common biological characteristics of animals and plants, such as growth and need for water. Eventually, children draw the analogy that if people and animals share these characteristics and are living things, and plants possess these characteristics as well, then plants too may be living things.

Although both of these accounts are attractive, they share an important weakness: they say little or nothing about the source of change. If 5-year-olds’ and adults’ concepts of life are incommensurate, how and why do they ever stop being so? If 5-year-olds organize their concept of living things around characteristics shared by plants and animals, such as growth and need for water, why is there an extensive time period in which they know about the shared characteristics but do not infer that plants
are living things? Moreover, what type of experience or realization eventually leads children to conclude that plants indeed are alive?

In this article, we propose and test a third hypothesis regarding sources of change in children’s concept of living things. The hypothesis is that understanding of animals’ and plants’ capacity for goal-directed, autonomous movement plays a central role in children’s construction of a biological concept of life. Such a developmental process may proceed as follows. Young preschoolers (3- and 4-year-olds) may initially map the living/nonliving distinction onto many features that are characteristic of prototypic classes of living things, people, and other animals. Among the features that young preschoolers view as characteristic of living things are presence of eyes and moving legs, capacity for motion and locomotion, and being a natural kind rather than an artifact (Gelman & Opfer, 2002; Richards & Siegler, 1986). As preschoolers learn that diverse animals are alive, despite not possessing eyes and legs, and as they learn that numerous nonliving things possess some of the characteristic features, such as ability to move and natural kind status, goal-directed movement emerges as first among equals within the coordinated cluster of properties viewed as characteristic of life. Never observing goal-directed movement in plants, preschoolers infer that plants are not living things, despite recognizing that plants and animals share certain properties, such as growth, that nonliving things lack. However, once children learn that plants, like animals, can move in goal-directed ways, they infer that plants, like animals, are living things.

This account of the acquisition of the living thing concept envisions development in this domain as a data limited process rather than a conceptually limited one. The crucial source of change within the account is encountering data that indicate that plants as well as animals are capable of goal-directed movement. The analysis also suggests that although the extension of children’s concept of living things changes to include plants as well as animals, a central part of the intension of their concept—capacity for goal-directed movement—may be in place well before the extension changes to include plants.

Several types of evidence support a central part of this hypothesized account of development—that from the end of the preschool period onward, the capacity for goal-directed movement occupies a central position within people’s concept of living things (Keil, 1992; Opfer & Gelman, 2001). First, from 5 years to adulthood, life judgments parallel predictions of goal-directed movement. Most 5-year-olds claim that all things or only animals are alive, and most predict that all things or only animals move toward goals that promote their functioning. Conversely, most 10-year-olds and adults claim that both plants and animals, but not artifacts, are living things, and they predict that both plants and animals, but not artifacts, will move toward goals that promote their functioning (Opfer & Gelman, 2001). Second, when preschoolers encounter novel entities, they base life judgments on whether the entities engage in goal-directed movement. In particular, 5-year-olds, older children, and adults usually attribute life to videotaped microorganisms that move toward an initially stationary goal and then, when the goal moves, track its motion until they reach it (Opfer, 2002). In contrast, at no age do participants usually attribute life to the same videotaped organisms moving identically in the absence of any apparent
goal. Third, adults and older children also attribute other biological features, such as the capacity to grow and die and the need for food and water, to goal-directed blobs but not to blobs that move without an obvious goal (Opfer, 2002). Fourth, 5-year-olds, older children, and adults often explain their judgments by saying that they view the goal-directed blobs as simple animals, such as worms or jellyfish, which they know are alive. All of these findings are consistent with the view that from 5 years through adulthood, goal-directed action is viewed as implying life.

The subclass of goal-directed movements that promote functioning—teleological movements—may be viewed as especially characteristic of animals, and therefore of living things. Five-year-olds are more likely to predict that an animal will turn toward food than toward balls, dead leaves, or empty boxes; children of this age make no such distinction in predicting the paths of moving artifacts (Opfer & Gelman, 2001). Presumably, the children thought that food was a more likely goal than an empty box for an animal because they know that animals need food to function (a fact that children of this age have been shown to know about humans; Inagaki & Hatano, 2002). The children and adults are not misguided in viewing such capacity for teleological action as a central biological property. The capacity is present in all living things (e.g., animals will pursue food, plants will turn toward sunlight), but it is not found in any nonliving thing (e.g., a glass rolling off a table will not stop to avoid being shattered) (Binswanger, 1992; Mayr, 1982).

The findings reported in this article provide the most direct evidence to date that learning that plants as well as animals engage in goal-directed movement can play a central role in children’s acquisition of a biological concept of life. In particular, the findings indicate that: (1) most 5-year-olds do not believe that plants can act teleologically; (2) providing data that plants do act in ways that promote their functioning, and that artifacts do not, leads 5-year-olds to infer that plants as well as animals are living things and that artifacts are not; and (3) providing data that plants and animals share other biological properties with each other but not with artifacts (growth and need for water) does not lead to comparable change in the children’s categorizations of objects as living or non-living. We next describe the microgenetic method and how it was used in the present study.

2. The microgenetic method

Microgenetic designs are defined by three characteristics: (1) observations span the period during which rapid change in the particular competence occurs, (2) the density of observations within this period is high, relative to the rate of change of the phenomenon, and (3) observations are subjected to intensive trial-by-trial analysis, with the goal of inferring the processes that give rise to the change.

The method has proven applicable for studying development in diverse content areas: memory (Coyle & Bjorklund, 1997), attention (Miller & Aloise-Young, 1996), locomotion (Thelen & Ulrich, 1991), arithmetic (Siegler & Jenkins, 1989), and scientific reasoning (Kuhn & Phelps, 1982) among them. However, almost all of the applications have been to studying development of procedures, rules and
strategies; the microgenetic approach has rarely been applied to studying acquisition of declarative knowledge, such as that involved in conceptual development. Thus, one purpose of the present study was to demonstrate the usefulness of the method for informing our understanding of conceptual growth.

Microgenetic studies have suggested a framework for thinking about strategic development, one that also may be useful for thinking about conceptual development. This framework (Siegler, 1996) distinguishes among five dimensions of cognitive growth: its source, breadth, path, rate, and variability. The source of change concerns the causes that set a change in motion. The breadth of change involves how widely a new approach is generalized to other problems and contexts. The path of change concerns the sequence of strategies or knowledge states through which children progress while gaining competence. The rate of change involves the amount of time or experience required to discover a new approach or to move from occasional to consistent use of one. The variability of change involves differences among children, tasks, and measures in the other dimensions of change. These five dimensions are useful not only for analyzing the effects of microgenetic manipulations, but also for organizing existing knowledge about particular aspects of development, such as knowledge about development of the concept of living things.

3. The present study

The central goal of this study was to identify the types of information that lead young children to categorize plants and animals as members of a single living things category. Table 1 lays out the design of the study. The study comprised the three

<table>
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<td>Water feedback</td>
<td>Life task—Set A items (two trial blocks)</td>
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<td>Life task—Set B items (two trial blocks)</td>
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phases described in the rightmost three columns of the table: pretest, feedback, and posttest. As shown in the second column from the left, all children were presented a pretest. On it, they were asked to categorize animals, plants, and artifacts according to life status. For reasons that will be explained later, children in the life feedback group were also presented a task intended to assess their understanding of teleological movement.

Next, in the feedback phase, children were asked one of four types of questions and given feedback on their answers. The questions concerned whether individual animals, plants, and artifacts either: (a) are alive, (b) move toward goals, (c) grow, or (d) need water. The particular property about which each child was asked during the feedback phase was determined by the child’s experimental group (life feedback, teleology feedback, growth feedback, or water feedback). Thus, children in the teleology feedback group were asked about goal-directed movement during the feedback phase, whereas those in the growth feedback group were asked and given feedback about capacity for growth.

Finally, after the feedback phase, children in all four groups were presented the posttest. The procedure was identical to that on the pretest except for the particular animals, plants, and artifacts that were included.

4. Issues addressed by the study

4.1. The source of change

As noted earlier, the hypothesized source of development examined in this article is the discovery that plants, like animals but unlike other objects, are capable of goal-directed movement. To be specific, children initially fail to categorize plants as living things because the various teleological actions that plants display (e.g., heliotropism, hydrotropism, gravitropism, etc.) elapse too slowly to be observed in natural contexts (Opfer, 2002). This inability to observe plants’ goal-directed movements leads young children to conclude that plants are not alive. By this logic, if children learn that plants do act teleologically, they should re-categorize them as living things.

4.2. The breadth of change

How broadly do children’s biological concepts change in response to informative experiences? Presenting children feedback that indicates that some exemplars possess biological characteristics, and then examining their categorization of other exemplars on those characteristics, provided a means of addressing this question. Presumably, if children’s biological concepts are piecemeal and local, then children should have more difficulty in generalizing to new instances than if all entities within a class are conceptualized as equivalent with regard to the characteristic in question.

Previous empirical studies indicate that the breadth of children’s generalization of biological characteristics varies with the type of entity being judged. In categorizing the life status of animals, for example, children generalize broadly: worms and
aardvarks are as likely as dogs and fish to be categorized as living things (Carey, 1985; see Massey & Gelman, 1988, for evidence of wide generalization of other biological properties to animates). In categorizing the life status of plants, in contrast, children generalize more narrowly. Some children categorize flowers, but not trees, as living things; others do the opposite (Hatano et al., 1993). Similar inconsistencies have been reported in categorization of artifacts (Carey, 1985). The present microgenetic design provided a means for examining breadth of generalization immediately after a new categorical distinction is made and for several trial blocks thereafter, which should be informative regarding changes with experience in the breadth of generalization.

4.3. The path of change

Researchers have proposed a variety of developmental sequences leading to correct use of the concept living things (Carey, 1985; Hatano et al., 1993; Laurendeau & Pinard, 1962; Piaget, 1929). Although these proposals differ in a variety of ways (e.g., in their interpretation of childhood animism), they agree on the basics. All of the theories posit that children use multiple approaches, including: (1) an early approach in which either everything is considered to be living (our E-Rule) or in which animals, plants, and some but not all nonliving things are considered to be living (our E/L-Rule); (2) an approach typical of slightly older children in which only animals are considered to be living (our A-Rule) or all animals and some plants are considered to be living (our A/L-Rule); and (3) an approach typical of still older children, in which only living things are considered to be living (our L-Rule). Consistent with these proposals, Hatano et al.’s (1993) study of categorization of life status by Japanese, Israeli, and US children indicated that across the three societies, 98% of children could be classified as using one of these approaches. Also consistent with the proposals, in Hatano et al. (1993), use of the E- and A-Rules became less frequent with age, and use of the L-Rule became more frequent. The present microgenetic approach of providing relevant biological information to children whose initial rules vary should provide direct evidence regarding the path of change leading to consistent use of the L-Rule to attribute life (and to attribute teleological movement, growth, and need for water as well).

4.4. The rate of change

Theories of cognitive development differ considerably in their predictions regarding the rate of change. Stage theories predict relatively abrupt change, whereas learning theories predict much more gradual change (Flavell, 1971). Theories of categorization also differ along this dimension, with most symbolic models swiftly generalizing new information over all the representations referenced by a symbol and most connectionist models slowly updating distributed representations over thousands of learning trials (Marcus, 2001).

One way of reconciling the two types of models and the data consistent with each of them is Keil’s (1983) hypothesis that the rate of change varies as a function of the novelty of the material being learned. Keil proposed,
When a totally new distinction is discovered between two major categories [e.g., objects versus events], that distinction seems to be discovered as a single conceptual insight that quickly sweeps through all the natural language predicates [e.g., “is heavy,” “is an hour long”] that honor that distinction. If, however, the distinction has already been made there may be less predicate unity as certain superordinate properties of the class common to those two are uncovered. Thus, the abstract concept of living things is one that emerges gradually as an in-principle distinction. (p. 376)

The microgenetic data obtained in the present study provided a means of testing Keil’s hypothesis that the living things concept emerges gradually.

4.5. The variability of change

Speaking of the path, the rate, and the breadth of change is often misleading, because substantial differences among children and tasks are usually present along each of these dimensions. For example, children’s initial approaches often vary considerably, and the particular approach they use tends to influence the subsequent rate of learning (e.g., Kuhn, Garcia-Mila, Zohar, & Anderson, 1995; Schauble, 1996; Siegler, 1995; Siegler & Chen, 1998). The present microgenetic design allowed us to examine whether rate of learning about the life concept was related to children’s initial categorizations of life status. Similarly, children’s rate and breadth of learning about different properties may vary with the particular property. In the present context, goal-directed movement may be strongly associated with animals but not at all with plants; the property therefore may be extended to plants more slowly than other biological properties, such as growth, which may already be somewhat associated with plants. Thus, the microgenetic design of the present study promised to yield data on the variability of change as well as the regularities.

5. Method

To understand the methods used in this study, it is essential to distinguish clearly among three variables: tasks, experimental groups, and rules. This is especially important, because the descriptors attached to the variables are often, by necessity, quite similar and somewhat confusable. Probably most confusing are the three terms involving “life” or “living things.” The life task involved questions about whether a given entity is a living thing. As shown in Table 1, this task was presented to children in all four experimental groups on the pretest and posttest. The life feedback group was the experimental condition in which children were presented questions about life status during the feedback phase, as well as during the pretest and posttest phases. As noted, children in all four groups were presented the life task on the pretest and posttest, but only children in the life feedback group were presented such questions during the feedback phase (Table 1). Finally, the L-(living things) Rule was a response pattern in which children categorized living things as having the property in question and non-living things as lacking it. The L-Rule was the correct approach on all four tasks; all living things, and only living things, grow, act teleologically,
need water, and possess life. Thus, the L-Rule was correct regardless of whether it was used on the life task or on one of the other three tasks and regardless of whether it was used by children in the life feedback group or by children in one of the other three groups. Distinguishing between the teleology task and the teleology feedback group, the growth task and the growth feedback group, and the water task and the water feedback group is similarly essential.

5.1. Participants

The 106 kindergartners who participated in the initial screening were recruited from local schools (university-based, public, and private) serving middle class populations. The 80 children who did not correctly categorize the life status of all 12 items (randomly selected from Set A in Appendix A) were selected for further participation in the study. These children (44 girls, 36 boys) ranged in age from 5.0 to 6.8 years, with a mean age of 5.7 years.

5.2. Tasks and materials

Children’s task in all four experimental conditions and in all three phases of the experiment was to sort realistic, color pictures (4 in. × 2.5 in.) of animals, plants, and artifacts into one of two categories. Depending on the group and phase, the sorting was along the dimension alive/not alive, can grow/can’t grow, needs water/doesn’t need water, or acts teleologically/doesn’t act teleologically. When presenting each picture, the experimenter pointed to the target item and identified it at both the superordinate and basic level (e.g., “This animal is a dog,” “This plant is a clover,” and “This thing is a crayon”). The objects used to assess and to train understanding of all four properties were identical; for example, children were asked whether dogs, clover, and crayons were living, could act teleologically, could grow, and needed water (depending on condition). Also identical were the type of responses children needed to make (has property/doesn’t have property) and the correct answer for each item (plants and animals possess all four properties; artifacts lack them). Thus, the conditions used to assess understanding of the four properties were tightly matched.

5.2.1. Life task

On this task, children were told, “First, I’m going to show you some pictures of different things, and I’ll tell you what the thing is. Your job is to figure out if it’s alive or not. If it is a living thing—if it’s the kind of thing that can live—you’ll put it in here [target box indicated], but if it’s not a living thing—if it’s the kind of thing that cannot live—you’ll put it in here.” Children were then presented trial blocks of six pictures each, one picture at a time, with each trial block including two animals, two plants, and two artifacts. Order of presentation within each trial block was randomized, first with respect to category (animal, plant, and artifact) and then within each category. In this way, we could characterize categorization patterns for each trial block without item biases.
The items in the life categorization task were drawn from two sets, with one (Set A) presented only during the pretest and posttest phases and the other (Set B) presented in all three phases (see Appendix A for a description of the items). The order of trial blocks was counterbalanced across subjects, using a balanced Latin Square design for Set A blocks and an unbalanced Latin Square design for Set B blocks. It is worth noting that for an individual child, the items presented on the pretest were not the same as those presented on the posttest but that at the group level, each item was presented equally often in the two phases.

5.2.2. Teleology task

The teleology task was like the life task except for the particular scenarios and questions. The scenarios were adapted from those used in Opfer and Gelman (2001). As illustrated in the leftmost column of Fig. 1, the experimenter presented a picture of a target object, identified what the object was and where it was moving initially, what goal it needed, and where the goal was moving with respect to the object. Then the experimenter asked whether the object would modify its path so that it would reach the needed goal (as depicted in the middle column) or if it would continue moving in its original path (away from the goal, as depicted in the rightmost column). For example, in one scenario, children were told, “This plant is a clover. The clover is growing this way. It needs the sunlight over here. If the sunlight moves over to here, will the plant—by itself—just keep growing this way, or will the plant—by itself—grow over to where the sunlight is?” (See Appendix B for a description of the scenarios.) In half of the scenarios for each type of object, the teleological action was presented as the first alternative; in the other half of the scenarios, it was presented as the second alternative.

In all scenarios, the goal was simply whatever object, state, or location the entity needed in order to continue to function. The specific way in which goal-attainment influenced functioning was not explicitly mentioned but could easily be inferred. For example, in one of the artifact scenarios (see Fig. 1), a glass was rolling off the edge of a table and either: (a) landed on a pillow and thus remained intact, or (b) did not land on the pillow and therefore shattered.

The particular teleological actions presented were not shared by all categories (or all members of a category). For example, no plants were presented chasing mice, and no animals were presented growing toward sunlight. Thus, the teleological actions that we presented differed for plants, animals, and artifacts. Additionally, because most of the teleological actions that plants engage in involve growth, children in this condition also received information that plants grow. We did not expect this to present a confound because 5-year-olds in this and other studies (Inagaki & Hatano, 2002; Hickling & Gelman, 1995) almost invariably know this fact.

5.2.3. Growth task

The growth task paralleled the others except that children were told, “Your job is to figure out if it can grow or not. If it is a growing thing—if it’s the kind of thing that can grow—you’ll put it in here [target box indicated], but if it’s not a growing thing—if it’s the kind of thing that can not grow—you’ll put it in here.”
Fig. 1. Examples of items from teleological action task for animals (top row), plants (middle row), and nonlivings (bottom row). In each case, the child was first presented the scenario on the left and then asked to predict whether the outcome depicted in the center or the outcome depicted on the right would occur. Order of presentation of the teleological and non-teleological actions was counterbalanced, so that the center and rightmost actions were presented as the first possibility on half of trials for each type of object.
5.2.4. Water task

The water task followed the same format, except children were told, “Your job is to figure out if it needs water or not. If it is the kind of thing that needs water, you’ll put it in here [target box indicated], but if it’s not the kind of thing that needs water, you’ll put it in here.”

5.3. Procedure and design

The experiment comprised three phases: pretest, feedback, and posttest. Table 1 summarizes the tasks presented in each phase to children in each condition.

5.3.1. Pretest phase

The main purpose of the pretest was to examine children’s initial performance on the life and teleology tasks, and thus to provide a base of comparison for the subsequent phases. The pretest results also allowed us to limit participation to children who did not already consistently categorize life status correctly. No feedback was provided in this phase.

5.3.2. Feedback phase

The feedback phase began immediately after the pretest. On the first trial block, children were asked to categorize all six items and then were given feedback about them. The second, third and fourth blocks were identical, except that children were given feedback and asked to explain the corrected answers immediately after each item, rather than after they had answered all six items in the trial block. The fifth trial block was presented without feedback, to determine what children had learned by the end of the feedback phase.

The feedback affirmed children’s correct answers and denied their incorrect answers. For example, when asked about a cat and a mouse on the teleology task, children were told after correct answers “That’s right; This animal, it will go over to where the mouse is, so it goes in here,” and after incorrect answers, “Actually, this animal will go over to where the mouse is, so it goes in here.” After receiving this feedback, children were asked to explain the answers to questions they initially answered incorrectly (e.g., “Why is this a living thing?”). For children who did not generate explanations when asked to do so, we first repeated the question. If this did not elicit an explanation, we then rephrased the question, for example by saying, “If it couldn’t go over to the mouse, what would happen?” If the child still did not explain the answer, the experimenter proceeded to the next problem.

5.3.3. Posttest phase

As shown in Table 1, all children received a posttest identical to the pretest except for the order in which items were presented. As on the pretest, children in three of the four groups received four trial blocks of the life task. Those in the life feedback group were presented two trial blocks of life questions and two of teleology questions. The goals of this selection of tasks were to compare the effects of the four experimental conditions on the frequency of children’s use of the L-Rule on the life
task and to examine linkages between each child’s learning of whatever property was the subject of questioning during the feedback phase and the child’s life categorizations on the posttest. Presenting children in the life feedback group with both teleology and life tasks on the posttest also allowed exploration of whether learning about life status changed children’s understanding of teleological movement.

Individual children never encountered the same question about the same item twice, though they often were asked about one property for an entity in the feedback phase and a different property for the entity on the posttest. This made it possible to examine the breadth of transfer on the posttest—for example, whether children who had learned that a clover’s roots would move toward water would infer that a tree was a living thing as often as they inferred that a clover was. The design also avoided any need to ask children to directly contradict their initial answers (e.g., if they initially said that a pine tree was not a living thing, they later could say that a bean plant was a living thing without contradicting themselves).

6. Results

Children’s categorizations of which of the six objects in each trial block possessed the property in question fit one of eight patterns: L (living things), A (animals), P (plants), E (everything), A/L (animals/living things), P/L (plants/living things), E/L (everything/living things), or O (other). As shown in Table 2, to be classified as using the L-Rule on a trial block, a child needed to categorize both of the plants and both of the artifacts as things that do not possess the property and both of the animals as things that possess the property. As shown in Table 2, the “/L” rules were ones that fit the L-Rule and the rule whose abbreviation is before the backslash equally well. Thus, children were classified as using the A/L Rule if they classified both animals, one plant, and neither artifact in a trial block as things that possess the relevant property, because the A-Rule and the L-Rule fit this pattern equally well. The chance probability of generating responses in accord with the A-, L-, E-, and P-Rules was 1/64; the chance probability of generating the A/L, E/L, and P/L patterns was 1/32. As can be seen in

<table>
<thead>
<tr>
<th>Rule</th>
<th>% Use</th>
<th>% Yes</th>
<th>Animals</th>
<th>Plants</th>
<th>Artifacts</th>
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the second column of Table 2, all eight of the response patterns were common, though the pure forms of the rules were more common than the backslash forms. Changes in frequency of these response patterns provided information about the source, breadth, rate, path, and variability of change. Information about the source and breadth of change came from pretest–posttest differences; information about the path, rate, and variability of change came from analyses of changes over trial blocks during the feedback phase. Unless otherwise indicated, all post-hoc tests were performed using Fisher’s PLSD.

6.1. Source of change

The first question examined was whether children’s categorizations of life status were affected by the particular experience they received during the feedback phase. To find out, we performed a feedback group (life, teleology, growth, need for water) × test phase (pretest and posttest) ANOVA on percent L-Rule use on the life task. The analysis indicated that use of the L-Rule to classify life status increased from pretest to posttest, $F(1, 76) = 88.58, p < .0001$. Paired $t$ tests revealed pretest–posttest increases for every group except water (life feedback, $t[19] = 8.39, p < .0001$; teleology feedback, $t[19] = 5.10, p < .0001$; growth feedback, $t[19] = 3.46, p < .01$; water feedback, $t[19] = 1.79$, ns). Because the magnitude of the pretest–posttest increases differed by condition, a phase × condition interaction also was present, $F(3, 76) = 8.55, p < .0001$. Percent use of the L-Rule to categorize life status increased from pretest to posttest more among children provided feedback about life status (12–82%) than among peers provided feedback about growth (14–40%) or need for water (10–25%). In addition, feedback regarding teleological capacities increased use of the L-Rule to categorize life status more (11–54%) than did feedback regarding need for water (10–25%) ($p$’s < .05).

This analysis indicated the effects of exposure to information about each property. To determine how learning each property impacted L-Rule use on the life task, we separately analyzed pretest–posttest changes of “learners,” defined as children who on the last trial block during the feedback phase used the L-Rule to classify the relevant property in their condition. Learners included 90% of children in the life feedback group, 65% in the teleology feedback group, 75% in the growth feedback group, and 60% in the need for water feedback group.

A condition × test phase ANOVA indicated a main effect of test phase, $F(1, 56) = 95.12, p < .0001$. As illustrated in Fig. 2, among children who learned the property they were questioned about during the feedback phase L-Rule use increased reliably from pretest to posttest for the life feedback group, $t[17] = 10.91, p < .0001$, the teleology feedback group, $t[13] = 6.90, p < .0001$, and the growth feedback group, $t[14] = 2.74, p < .05$. For learners within each feedback group, as for the overall sample, the magnitude of the increases in performance on the life task varied with the property about which children received feedback, leading to a feedback group by test phase interaction, $F(3, 56) = 10.75, p < .0001$. Increases from pretest to posttest in learners’ percent use of the L-Rule to judge life status were greater among those who learned about life status (13–91%) or teleological capacities.
(16–75%) than among peers who learned about growth (12–37%) or need for water (10–27%) ($p's < .05$). Thus, learning about capacity for teleological action produced gains in judgments of life status considerably larger than the gains produced by learning about growth or need for water and almost as large as learning about life status.

Adding support to the hypothesis that acquisition of understanding of teleological action plays an important role in acquisition of understanding of life status was performance of non-learners. As shown in Fig. 2, non-learners in the teleology feedback group used the L-Rule to classify life status on only 4% of posttest trial blocks (versus 75% among learners in the same group). This large difference was not attributable to the children who learned from the teleology feedback task simply being smarter than those who did not. Similar percentages of children learned about growth and need for water during the feedback phase as learned about teleological capabilities (60–75% in the three conditions), but percent use of the L-Rule to judge life status on the posttest was similar for learners and non-learners in the growth and water feedback groups (Fig. 2).

The relation between understanding of teleology and understanding of life status was not bi-directional. The relevant data came from children who received feedback regarding life status. A paired $t$ test comparing these children’s pretest and posttest performance on the teleology task revealed no change, $t = .70$, ns. Thus, learning about teleological behavior improved understanding of life status, but learning about life status did not improve understanding of teleological action.

To summarize, three types of evidence supported the hypothesis that learning about teleological capacities promotes understanding of life status. Children who learned that plants and animals act teleologically, and that other objects do not, were
subsequently much more likely to attribute life status correctly than they had been before learning. These children also were considerably more likely to attribute life status correctly than peers who learned that plants and animals share other biological properties, in particular growth and need for water, or children in the teleology feedback group who were not learners. Finally, children who learned about teleological action were almost as likely to attribute life correctly as children who were directly taught that plants and animals are alive and that other things are not.

6.2. Breadth of change

To examine the breadth of change in attributions of life, we compared posttest categorizations of life status of Set B items, on which children had earlier received feedback, to categorizations of Set A items, on which they had not. A 4 (feedback condition) × 2 (problem set, A or B) ANOVA on the number of posttest trial blocks on which children used the L-Rule indicated no difference between the two problem sets and no interaction between problem set and feedback condition. Thus, children extended the L-Rule as often to objects they had not specifically learned about previously as to ones they had. This was true regardless of whether children learned directly about life status during the feedback phase (as in the life feedback condition) or whether they learned about other properties and then extended their learning to categorization of life (as in the teleology feedback group).

6.3. Path of change

Previous findings from cross-sectional studies were consistent with several possible paths of change. One possibility was that children’s understanding of life progresses from the overly inclusive E-Rule (everything is alive) to the overly restrictive A-Rule (only animals are alive) to the “just right” L-Rule (animals and plants are alive). Although this hypothesis seemed plausible, the current microgenetic findings offered no support for it. On the life task, all five of the children who used the E-Rule on the first trial block of the feedback phase (before receiving feedback) moved directly to the correct L-Rule on the next trial block. Four of the five continued to use the L-Rule on all subsequent trial blocks as well. Moreover, neither of the children who first used the E-Rule on a later trial block of the life task used the A-Rule before progressing to the L-Rule. These results indicate, at minimum, that children can progress directly from the E-Rule to the L-Rule, rather than needing to progress through the A-Rule on the way.

Another possibility was that children would progress from one of the pure rules (the A-Rule or E-Rule) to the A/L or E/L Rule, in which they correctly categorized some but not all of the entities that they previously had categorized incorrectly, before categorizing all entities correctly. This also proved not to be the case. Of the 12 children who used the A-Rule or E-Rule on the life feedback problems before using the L-Rule, only 2 used the A/L or E/L approach before the L-Rule.

What path of change, then, did children follow? To find out, we examined changes over the five trial blocks of the feedback phase using a backward trials graphing
Feedback Phase Performance

Fig. 3. Backward trials graph of percentage of children using particular rules during the feedback phase in each of the four experimental conditions. The 0 trial block is the block on which each child first used the L-Rule for the property about which feedback was being provided, the −1 trial block is the block before that, and so on. The particular backward trials graph shown in Fig. 3 includes only one procedure (Fig. 3). Within such a graph, the 0 trial block is the first trial block on which each child used the approach of interest (in this case, the L-Rule). Similarly, the −1 trial block is the block just before the child’s first use of the approach of interest, the +1 trial block is the block just after the child’s first use of that approach, and so on. The particular backward trials graph shown in Fig. 3 includes only one
trial block before the first use of the L-Rule and three trial blocks after, because for three of the four properties, most children first used the L-Rule by the second block.

As shown in Fig. 3, most children’s categorization of life status progressed directly from the A-Rule or E-Rule to the L-Rule. After their first use of the L-Rule, the large majority of children continued to use it consistently to categorize life status on subsequent trial blocks.

The paths of change of the other three properties differed in a variety of ways. Categorization of teleological capacity followed a similar path to that for life status up to the first use of the L-Rule. After that initial use, however, children more often regressed to a less advanced approach before consistently predicting that plants and animals would act in goal-directed ways and that artifacts would not. When categorizing capacity for growth or need for water, the P- and P/L-Rules were the most common forms immediately before the first use of the L-Rule and also were the most common alternatives to the L-Rule after that rule’s first use. Thus, children often judged that plants would grow and use water even though they judged that animals would not.

These results indicated that growth of understanding of different biological properties did not follow a single path. In keeping with past conclusions regarding development of biological understanding, the most common flaw in initial approaches on the life and teleological action tasks was failure to realize that plants possess these properties. On the first trial block in the feedback phase of the life feedback group, children correctly classified animals as being alive on 100% of responses, versus 55% for plants. Similarly, on the first trial block in the feedback phase in the teleology group, children classified animals as acting teleologically on 83% of trials versus 57% for plants ($p < .05$). Contrary to past conclusions, however, the most common flaw in initial understanding of capacity for growth and need for water was lack of knowledge about animals’ biological functioning. Percent correct on the first trial block was higher for plants than for animals on categorizations of growth (93% versus 60%, $p < .01$) and the difference was in the same direction on need for water (78% versus 65%, ns). Thus, rather than biological understanding being acquired in a single unified progression, in which children first understand animals’ biological functioning and then extend that understanding to plants, understanding of some biological capacities was more advanced for plants than for animals.

6.4. Rate of change

The rate of change for each property was first examined by identifying the number of trial blocks during the feedback phase before children’s first use of the L-Rule for that property. For this analysis, we excluded children who used the L-Rule on the first trial block of the feedback phase, before they received feedback, because they presumably already knew which objects possessed that property; we also excluded children who never used the L-Rule. The fastest learners, children who first used the L-Rule on the second trial block of the feedback phase, were assigned a score of 2, and the slowest learners, children who first used the L-Rule on the final trial block of the feedback phase, were assigned a score of 5. An ANOVA indicated
differences among the four properties in how quickly children adopted the L-Rule, $F(3, 68) = 2.82, p < .05$. The first use of the L-Rule occurred on earlier trial blocks when the task was to classify life or growth than when it was to classify capacity for teleological action ($M$'s = 2.27 and 2.36 versus 3.07 trial blocks, $p$'s < .05). Thus, although learning the L-Rule for teleological action produced considerable transfer, learning which entities were capable of such action was relatively slow.

We next looked at another aspect of the rate of change—the last trial block during the feedback phase on which children failed to use the L-Rule. Here, we eliminated children who already used the L-Rule on the first trial block and did not deviate from it thereafter. Thus, scores could range from 1 (if the child did not use the L-Rule on the first trial block of the feedback phase but always used it after that) to 5 (if the child did not use the L-Rule on the last trial block of the feedback phase). An ANOVA revealed that the trial of last error, like the trial of first use of the L-Rule, varied with the property being judged, $F(3, 76) = 11.92, p < .001$. The last deviation from the L-Rule occurred earlier in the feedback phase for categorization of life status than for categorization of growth or teleological agency, and earlier for them than for need for water ($M$'s = 2.0, 3.5, 3.5, and 4.53 trial blocks respectively).

The data also allowed examination of the more specific issue of the rate at which children, given different types of feedback, come to understand that plants are alive. We first examined rate of change in this understanding among children who were given feedback on life status. A backward trials graphing procedure was used, with the 0 trial block being the first trial block during the feedback phase on which the child said that both plants were alive. As can be seen in Fig. 4, the rate of change for

![Fig. 4](https://example.com/fig4.png)  
**Fig. 4.** Backward trials graph of percentage of plants judged to be alive by children in the life feedback group. The 0 trial block is the first block during the feedback phase on which both plants were judged to be alive, the −1 block is the block before that, and so on.
categorizing plants as living things was extremely rapid; on the trial block immediately before each child first attributed life to both plants, percent correct categorization of plants was only 30%, but after that trial block, it was 99%. The finding was even more striking because of the extreme diversity in the appearances of the specific plants that children needed to classify as being alive. For example, a child who first classified flowers and bean plants as being alive would subsequently need to classify trees, ivy, and grass as also being alive.

Children did not need to receive feedback about life status for their understanding of the life status of plants to change abruptly. Children who learned the L-Rule for classifying teleological capacities during the feedback phase classified both plants as being alive on 75% of posttest trial blocks; in contrast, they classified one but not both plants as alive on only 2% of trial blocks. Here, too, when learning occurred, it involved a sudden change from not understanding to understanding that plants are living things, rather than a gradual transition in which the proportion of plants that are viewed as living things slowly increases.

6.5. Variability of change

The microgenetic design allowed examination of two types of variability in the feedback phase: variability of categorization within a trial block and variability of categorization across trial blocks. To examine within-block variability, we compared the four biological properties with regard to the percentage of trial blocks during the feedback phase on which children advanced consistent answers about the two objects of the same type (e.g., the child said either that both animals could grow or that neither could grow). Classification was in general quite consistent; aggregating across biological properties and types of objects, children indicated that either both or neither object of a given type possessed a given biological property on 87% of feedback phase trial blocks.

In addition to the consistency of categorization during the feedback phase generally being quite high, the degree of consistency varied somewhat among objects and properties. A biological property (life, teleology, growth, and need for water) × object category (animals, plants, and artifacts) ANOVA on number of consistent categorizations yielded a main effect of biological property, $F(3, 76) = 6.45$, $p < .001$. Categorizations of teleological action were more variable than those for either life or growth. Categorizations of need for water also were more variable than those for either life or growth. Categorizations of need for water also were more variable than categorizations of life status.

Of greater interest was a substantial property by object category interaction, $F(6, 152) = 4.70$, $p < .001$. As shown in Fig. 5, when the question concerned life or teleology, categorization of plants was more variable than categorization of animals. In contrast, when the question concerned growth or need for water, categorization of animals was more variable than that of plants. This pattern seems attributable to categorization consistently being more variable on the object–property combinations for which the most learning was needed—that plants are living things and engage in teleological actions and that animals grow and need water.
The four biological properties also differed greatly with regard to the second kind of variability—variability of categorization following initial use of the L-Rule. The percentage of children who used the L-Rule on at least one trial block during the feedback phase and then regressed to a less advanced approach later in the feedback phase was 16% for life, 47% for teleological action, 56% for growth, and 78% for the need for water.

\[ \chi^2(3) = 14.69, p < .005 \]

Thus, once children acquired the L-Rule on the life task, they generally used it consistently, whereas on the need for water and growth tasks, most children regressed on at least one trial block after having used the L-Rule. The pattern could not be explained by children having more opportunities to regress for properties on which the L-Rule was acquired quickly. The life task had the fastest rate of acquisition (and therefore the greatest number of chances to regress afterward), but it also had the fewest regressions. Rather, it appeared that newly acquired knowledge of different biological properties varies in stability.

7. Discussion

How do children learn to categorize plants as well as animals as living things, and why does it take them so long to do so? To address these questions, we examined 5-year-olds’ changing categorizations as they received feedback regarding whether animals, plants, and artifacts possess four biological properties: life, growth, teleological agency, and need for water. The microgenetic design, in which children needed to learn to categorize identical objects in identical ways in all four conditions, allowed observation and comparison of changes in understanding of the four properties as the changes were occurring. The design also allowed examination of how
learning about each property influenced judgments of life. The implications of the results for understanding the source, breadth, path, rate, and variability of change in basic biological understanding are discussed in this section.

7.1. Source of change

The most dramatic changes in categorization of life status were observed among children who were given feedback either on life status itself or on capacity for teleological movement. The latter finding was of particular relevance to the central hypothesis of the study. The changes in categorization by children in the teleology feedback group suggest that although 5-year-olds initially categorized only animals as living things, the preschoolers’ concept of living things included capacity for goal-directed movement as an important property of life. After the preschoolers learned that plants, like animals, were capable of goal-directed movement, they quickly inferred that plants, like animals, are alive. Conversely, children who failed to revise their judgments about teleological agency also failed to revise their life judgments. These findings with familiar plants, animals, and artifacts complement Opfer’s (2002) finding that 5-year-olds concluded that unfamiliar objects (blobs) are alive after observing them engaging in goal-directed movement but not after seeing them move independent of a goal.

The present findings regarding the source of change call into question Inagaki and Hatano’s (1996, 2002) hypothesis that realizing that both plants and animals grow and need water is central to acquiring the distinction between living and nonliving things. Judgments of life status changed considerably less among children who learned that both plants and animals grow and need water than it did among children who learned that both plants and animals engage in teleological action. The Inagaki and Hatano claim seemed entirely reasonable, given that children often know that plants and animals have in common growth and need for water before they know that plants and animals are both living things (though see Carey, 2000). In addition, our data lent a degree of support to Inagaki and Hatano’s hypothesis by showing that exposure to information that both plants and animals grow led to some increase in correct categorization of life status. However, learning about growth had less effect on categorization of life status than learning about teleology, and learning about need for water had no effect on life status categorization.

Development of a biological concept of life may well be aided by children’s uniting of animals and plants in a single category, as Inagaki and Hatano (2002) argue. However, the particular commonality that they learn about appears to influence the likelihood that such unification will occur. The reason may be that the extension of some properties (e.g., teleological agency) invites biological explanations for plants, whereas the extensions of other properties do not. This can be seen in the present study, where errors in the growth and need for water feedback groups usually involved children not attributing these properties to animals. As a result, the children’s learning focused on animals, a type of entity for which children’s life categorizations were already correct. Presumably, explaining why animals grow or need water only solidified children’s prior belief that animals are living things. In contrast, when the
questions concerned capacity for teleological action, children’s errors typically entailed not attributing teleological agency to plants. Consequently, explanations generated by children in the teleology feedback group tended to elaborate on the beneficial effects of goal-attainment for plants, which include support of life and health.

How common was it for children to appeal to cognates of the life concept when explaining why plants would act teleologically? Because we only asked children to explain the correct answer on the limited subsets of trials on which they initially answered incorrectly, the present data did not allow strong conclusions. However, in a recent follow-up study (Opfer & Siegler, in preparation), we presented kindergartners with the same scenarios used in the present study but asked them on all trials to explain why plants would act teleologically. Of the 24 children tested, 96% mentioned a biological reason for a plant’s movement on at least 2 of these 8 trials. These explanations included “so it can grow,” “to live,” and “so it wouldn’t die”. In contrast, only 29% of children advanced psychological explanations on at least 2 of the 8 trials involving plants (e.g., “it wanted to get sunlight”). These psychological explanations were not only less common than biological ones, they also in most cases were merely adjuncts to biological explanations (e.g., “it wanted the sunlight to live”). Especially striking, 54% of children offered two or more biological explanations for plants’ goal-directed movement without ever referring to plants’ psychological states, whereas 0% of children advanced two or more psychological explanations without ever referring to their biological characteristics.

Prominent among the biological rationales that children cited was maintenance of life. Fully 50% of the 24 children cited maintenance of life as the reason on at least two trials. These children explained that a plant would turn itself toward a goal “to live,” “so it wouldn’t die,” “to get healthy,” “to survive” or for some other survival-based purpose. These references to the maintenance of life were spontaneous, generated without any prompting or clues from the experimenter. Additionally, 25% of children in Opfer and Siegler (in preparation) explained that an artifact would not turn toward a self-beneficial goal “because it’s not alive.” Thus, 5-year-olds’ explanations of teleological actions (and non-actions) seem to be based more on biological than on psychological considerations.

Data from other recent studies also attest to the centrality of the connection between life and goal-directed movement in biological understanding. Adults and 10-year-olds often cite maintenance of health and avoidance of death to explain the teleological actions of plants and animals (Opfer & Gelman, 2001). Some 5-year-olds understand that certain body parts move in ways that are essential for supporting life (Jaakkola & Slaughter, 2002) and, when instructed about this relation, randomly selected 5-year-olds can apply the knowledge to improving their understanding of death (Slaughter & Lyons, 2003). These findings and the present ones are consistent with the hypothesis that the linkage between life and goal-directed movement is a prominent part of the biological concepts of children 5 years and older. Whether children younger than 5 years possess similar understanding is an interesting question for future investigation.
7.2. Breadth of change

Children’s learning about life status proved to be quite broad, in the sense that learning occurred primarily at the superordinate level (animal, plant, and artifact) rather than at the basic level (cat, clover, and crayon). Animals, plants, and artifacts are exceptionally encompassing and diverse categories, and children do not always use them to make inferences (Carey, 1985; Gelman & O’Reilly, 1988). However, in the present study, posttest performance within each of the categories was impressively consistent. Posttest categorizations of life were as accurate for animals, plants, and artifacts that children had never previously encountered as for ones about which they had received specific feedback earlier in the experiment. This broad (and rapid) generalization implies that children view life as a property possessed by all members of these broad superordinate categories or by none of them, rather than as being specific to some of the entities within each category. Consistent with this analysis, rules that preserved the structure of superordinate categories (the A-, E-, and L-Rules) were used to attribute life on 82% of pretest trial blocks, despite being less likely to be produced by chance than the A/L, E/L, and P/L Rules (which used on 12% of pretest trial blocks collectively). The 43% of children who used the A-Rule or the E-Rule without a single deviation over the course of the four pretest trial blocks (24 items) provided particularly strong evidence for categorization of the life status being at the superordinate level of plant, animal, or nonliving thing.

7.3. Path of change

Categorizations of life status followed an unexpected path of change. Previous cross-sectional data (Laurendeau & Pinard, 1962; Piaget, 1929) suggested that children initially attribute life to living things and some or all nonliving things, then attribute it only to animals, and finally attribute it (correctly) to plants and animals but not to nonliving things. However, the present observations of the paths of change of individual children revealed no evidence of this progression in any individual child. Children did use both of the previously observed incorrect approaches to categorize life status, but not one child progressed from one incorrect approach to the other before using the living things rule. Thus, our observations of children’s approaches to categorization of life replicated previous ones, but suggested that the previous observations reflect individual differences in categorization rather than an ordered developmental sequence through which all children progress on the way to correct performance. Initial use of the E-Rule, for example, may reflect a response bias, which is broken by feedback.

For teleological action, growth, and need for water, the path of change was almost unexplored territory prior to this study. The study yielded several clear findings. Children’s initial approaches to categorizing capacity for teleological action were much like their initial approaches to categorizing life status (predominant use of the A- and A/L-Rules, some use of the E- and E/L-Rules). However, beyond this initial point, children’s approaches became highly variable, with many regressions after initial use of the L-Rule. The most common approaches to categorizing which
objects could grow or needed water prior to the first use of the L-Rule were the P- and P/L-Rules, approaches that had not previously been described in the literature. These approaches also were the most common type of regression after children first used the L-Rule. Previous classification systems have not included the P- and P/L-Rules, but children in previous studies may well have used them. Consistent with this conjecture, almost half of the children in Inagaki and Hatano (1996) were classified as using “other” approaches on the task that measured understanding of growth. The prior widespread assumption that biological understanding is consistently extended from animals to plants may be responsible for this omission.

7.4. Rate of change

The rate of change varied considerably with the source that produced the change. Direct feedback about life status led to rapid adoption of the L-Rule, usually on the second trial block. However, learning through direct feedback that plants are living things did not allow children to infer that plants also possess teleological capacities. In contrast, feedback about teleological action produced learning considerably more slowly, but once children learned, they were very likely to transfer their learning about teleological capacities to understanding of life status. The slower learning of teleological agency, coupled with the asymmetry of transfer, suggests that learning that plants as well as animals possess teleological capacities required greater conceptual change (in the sense of restructuring and belief-revision) than did simply learning to label plants and animals as alive. Some children in the teleology feedback group were so entrenched in their initial conceptualization that they even argued with the experimenter, as illustrated by one child’s reaction to being told that the flowers in the picture would turn toward the sun:

*Child:* But they can’t turn theirselves! ... Remember, they can’t turn theirselves?

*Experimenter:* But they can.

*C:* [shrugs]

*E:* Why would the yellow flowers turn...?

*C:* They couldn’t! They can’t turn theirselves.

*E:* Sure they can.

*C:* [quietly] They can? [more loudly] Not if the wind blows it.

*E:* Well, there is no wind.

*C:* Then how can it turn over? Only a person can turn over, like this [moves arm as flowers were depicted as doing]—or, the wind can blow it over [moves arm to illustrate wind blowing flowers to face the sun].

We think this episode, together with the relatively slow rate of acquisition in the teleology feedback group, reveals a deep-seated belief that plants lack the capacity to turn toward goals of their own accord. Moreover, the episode suggests that children really do have to change their conception of plants at a fundamental level to learn that they possess teleological capabilities. This conceptual change may result in the learning about life status that occurs via this route being more enduring than the learning about life status that occurs through direct feedback about which entities are living things. The hypothesis remains to be tested.
7.5. Variability of change

Substantial variation was evident in all four of the other dimensions of change examined in the present study. As noted earlier, different sources of change led different children to conclude that plants and animals were living things, and children within each feedback group followed different paths to this conclusion. In addition, children attained understanding at different rates, and the breadth of generalization of initial learning to other properties differed among the feedback groups, as well as among different children in the same group.

Another, somewhat surprising aspect of the variability involved the rate of change of different properties. Understanding of life status, which has been depicted as a particularly difficult concept to grasp (Slaughter et al., 1999), was acquired extremely quickly in response to feedback about it. In contrast, understanding organisms’ need for water, which has been depicted as more easily acquired (Inagaki & Hatano, 2002), was acquired more slowly in response to exactly the same feedback (animals and plants possess the property; nonliving things do not). These findings underline the importance of distinguishing between differences in existing knowledge and differences in learning: Initial knowledge of the types of objects that need water was somewhat more advanced than initial knowledge of life status, but learning about life status proved to be easier.

Properties also vary in the path of change. Some properties, such as life and teleological agency, are extended from animals to plants; other properties, such as capacity for growth and (to a lesser extent) need for water, are extended from plants to animals. Moreover, the consistency with which children maintain initial correct classifications also varies with the particular property. At one extreme, once children first used the L-Rule to attribute life, 84% continued to use it on all subsequent trial blocks. At the other extreme, once children first used the L-Rule to attribute need for water, only 22% continued to use it on all subsequent blocks. Thus, development of basic biological understanding does not appear to involve a single broad and stable paradigm shift; instead, the acquisition of understanding of different biological properties varies in rate, path, and stability (see Keil, 1983; Carey, 2000, for related perspectives).

This study represents the first application of microgenetic methods to the study of conceptual development. The results indicate both that the approach is applicable to this area and that such applications can yield unique information. Like conventional training studies, microgenetic methods can indicate sources that are sufficient to produce change and the breadth of the changes that are produced. Unlike training studies, microgenetic studies also yield information on the path, rate, and variability of change. For example, the finding that children who initially use the E-Rule advance directly to the L-Rule, rather than using the A-Rule or E/L-Rule before doing so, could not have been obtained through traditional cross-sectional or longitudinal designs or through a typical training study that focused solely on pretest–posttest differences. Similarly, only a microgenetic study could indicate that for some biological properties, such as life status, regressions are rare, but for others, such as growth and need for water, regressions are common. The general lesson is that observing
learning while it is occurring can enhance understanding of conceptual development in this and other domains.

8. Conclusion

Development of the living things concept typically takes a number of years. During this time, children come to generalize novel properties of living things to plants and animals alone, to interpret basic biological activities (such as eating and drinking) as stemming from biological causes (such as maintenance of life), and to treat animals, plants, and nothing else as living things. These three transitions have been interpreted as central to a broad conceptual change in biological understanding during childhood (Carey, 1985, 2000).

The present study supports the hypothesis that an important source of this conceptual change is learning that plants and animals (but not nonliving things) act teleologically. When 5-year-olds in the teleology feedback group learned this information, they inferred that novel plants and animals would also act teleologically and that novel artifacts would not. The large majority of children who acquired this knowledge reclassified plants as living things, whereas children in the same feedback group who failed to acquire the information about goal-directed movement did not engage in such reclassification. In addition, children who learned that plants and animals possess other biological properties, in particular growth and need for water, did not change their living things concept as much.

The change shown by children in the teleology feedback group was accomplished within a single experimental session. This rate of change raises two questions: Did the experimental procedure induce a genuine conceptual change, and if so, what process led to the change?

The term ‘conceptual change’ denotes a type of development in which a new, fundamental, broadly applicable understanding of a domain is acquired. Such change is often contrasted to smaller changes, such as learning a single proposition of limited applicability. Some researchers reserve the term “conceptual change” for the sorts of conceptual revolutions that have been claimed to occur among communities of scientists (e.g., Kuhn, 1982). Other researchers, however, use the term to denote a broader range of changes. For example, Keil (1999, p. 181) wrote:

Children and adults often come to dramatic new insights not because of an underlying conceptual revolution . . . , but rather because they realize the relevance or preferred status of an already present explanatory system to a new set of phenomena. Because the realization can be sudden and the extension to new phenomena quite sweeping, it can have all the hallmarks of profound conceptual change. It is, however, markedly different from traditional restructuring notions. Children, for example, can often have several distinct theories available to them throughout an extensive developmental period but might differ dramatically from adults in where they think those theories are most relevant (e.g., Gutheil et al., 1998).

The present results are aptly described by this definition of conceptual change. The definition, together with previous and present data, also points toward an
explanation of how the conceptual change examined in this study occurred. The process can be described as follows:

1. When the 5-year-olds began the experiment, most believed that animals act in goal-directed ways and that plants and artifacts do not.
2. Most children also believed at the beginning of the experiment that animals’ goal-directed behavior serves the function of maintaining life.
3. When children received feedback that plants move towards goals, they searched for some aspect of their knowledge with which the new information could be integrated.
4. This search led them to reference their understanding of the reasons for animals’ goal-directed activities (e.g., eating to live).
5. When children referenced this pre-existing understanding of animals’ teleological activities, they changed their understanding of plants’ capabilities for teleological action and therefore changed their beliefs regarding plants’ life status.

Numerous findings from previous studies and the present one are consistent with this account. With respect to the first point, which concerns prior knowledge of goal-directed movement, 5-year-olds in this and other studies have been shown to believe that animals turn toward goals, but that plants and artifacts do not. Judgments fitting this pattern have been reported for familiar plants, animals, and artifacts in the pretest of the present study; for invented plants and animals, about which children could not have possessed specific prior knowledge, in Opfer and Gelman (2001); and for goal-directed blobs, that children sometimes characterized as animals, in Opfer (2002).

A variety of sources of evidence also supports the second point, that young children believe that animals’ goal-directed activities serve a life-sustaining function. Children do not believe that animals choose goals arbitrarily. For example, the 5-year-olds in Opfer and Gelman (2001) did not predict that animals would turn toward balls, dead leaves, or empty boxes, goals that would not contribute to the animals’ functioning. Rather, 5-year-olds seem to know that many goal-directed activities have survival value for humans and other animals. This understanding is especially well documented for reasoning about people. Five-year-olds reliably claim that people will die if they don’t eat, and could recover from illness by eating (Inagaki & Hatano, 2002). Similar understanding seems to be present regarding other animals. Reminding 5-year-olds that the reason that people need food is “to live” increases the likelihood that the children will infer that animals also need food, suggesting that 5-year-olds connect food with maintenance of life in animals other than people, as well as in people (Inagaki & Hatano, 1996).

With regard to the third point, several findings from the present study and from Opfer and Siegler (in preparation) indicate that the feedback that children received about plants’ goal-directed movement provoked a search for a way to integrate the information with prior knowledge. One sign that children engaged in such a search, rather than passively accepting the experimenter’s feedback, came from the observation that some children simply refused to accept that plants could act teleologically (recall the anecdote in which a boy rejected the experimenters’ feedback about the flowers’ movement by saying “But they can’t turn theirselves’”). In addition, almost all children in the
present study required a number of examples of plants acting teleologically before they predicted that other plants would act teleologically, more examples than they required to show the same pattern of extension for growth or life status.

Support for the fourth point, that this search led many 5-year-olds to reference their understanding of the reasons for animals’ teleological activities (e.g., eating to live) was apparent in the emphasis on life-sustenance in children’s explanations. As noted, many children explain plants’ goal-directed movement by saying that plants turn toward goals “to live,” “so it won’t die,” “to get healthy,” or “to survive.” Given that animals are the only type of entity other than plants to which these descriptions apply, the source of the explanations seems likely to have been the children’s understanding of animals’ goal-directed movement.

The fifth and final link in the chain was that once children conclude that plants can act in goal-directed, self-sustaining ways, they also conclude that plants are alive. The strongest evidence for this point comes from differences in the inferences of learners and non-learners in the teleology feedback group of the present study, a difference that was not paralleled by differences between learners and non-learners in other groups.

How similar is this process of learning to the processes through which changes in biological understanding occur in the everyday environment? Although any answer to this question must be speculative, there is reason to think that the processes are not totally dissimilar. In the early grades of elementary school, a period in which understanding of the biological characteristics that link plants and animals shows marked growth, children often encounter science lessons that emphasize plants’ teleological capabilities (National Academy of Sciences, 1996). Many of these lessons involve experiments that demonstrate the teleological capabilities we presented to kindergartners, including phototropism, hydrotropism, and gravitropism. Many lessons also highlight the life-supporting nature of these tropisms (e.g., one group of lessons is entitled, “Life Processes: How a Living Thing Stays Alive”). Our findings suggest that these lessons about plants’ teleological capacities may serve as an important source of change in children’s living things concept.

Appendix A. Items used across tasks

<table>
<thead>
<tr>
<th>Animals</th>
<th>Plants</th>
<th>Things</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Set A</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block A:</td>
<td>Dog</td>
<td>Fern</td>
</tr>
<tr>
<td>Block B:</td>
<td>Elephant</td>
<td>Butterfly</td>
</tr>
<tr>
<td>Block C:</td>
<td>Lizard</td>
<td>Snail</td>
</tr>
<tr>
<td>Block D:</td>
<td>Frog</td>
<td>Crab</td>
</tr>
<tr>
<td><strong>Set B</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block A:</td>
<td>Cat</td>
<td>Spider</td>
</tr>
<tr>
<td>Block B:</td>
<td>Shark</td>
<td>Caterpillar</td>
</tr>
<tr>
<td>Block C:</td>
<td>Snake</td>
<td>Worm</td>
</tr>
<tr>
<td>Block D:</td>
<td>Crocodile</td>
<td>Octopus</td>
</tr>
<tr>
<td>Block E:</td>
<td>Hawk</td>
<td>Bee</td>
</tr>
</tbody>
</table>
## Appendix B. Scenarios presented in teleology task

<table>
<thead>
<tr>
<th>Entity</th>
<th>Need</th>
<th>Teleological action</th>
<th>Non-teleological action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat</td>
<td>Mouse</td>
<td>Turn toward mouse</td>
<td>Move as before</td>
</tr>
<tr>
<td>Spider</td>
<td>Fly</td>
<td>Turn toward fly</td>
<td>Move as before</td>
</tr>
<tr>
<td>Clover</td>
<td>Sunlight</td>
<td>Turn toward sunlight</td>
<td>Grow as before</td>
</tr>
<tr>
<td>Houseplant</td>
<td>Sunlight</td>
<td>Turn toward sunlight</td>
<td>Grow as before</td>
</tr>
<tr>
<td>Glass</td>
<td>Landing on a pillow</td>
<td>Turn toward pillow</td>
<td>Roll as before</td>
</tr>
<tr>
<td>Pencil</td>
<td>Stay away from fire</td>
<td>Turn away from fire</td>
<td>Roll as before</td>
</tr>
<tr>
<td>Shark</td>
<td>Yellow fish</td>
<td>Turn toward yellow fish</td>
<td>Move as before</td>
</tr>
<tr>
<td>Caterpillar</td>
<td>Leaf</td>
<td>Turn toward leaf</td>
<td>Move as before</td>
</tr>
<tr>
<td>Tree</td>
<td>Water</td>
<td>Turn roots toward water</td>
<td>Grow roots as before</td>
</tr>
<tr>
<td>Flowers</td>
<td>Water</td>
<td>Turn roots toward water</td>
<td>Grow roots as before</td>
</tr>
<tr>
<td>Tennis ball</td>
<td>Land in bucket (away from lake)</td>
<td>Turn toward bucket</td>
<td>Roll as before</td>
</tr>
<tr>
<td>Basket ball</td>
<td>Air from air pump</td>
<td>Turn toward air pump</td>
<td>Bounce as before</td>
</tr>
<tr>
<td>Snake</td>
<td>Avoid hawk</td>
<td>Turn under rock</td>
<td>Move as before</td>
</tr>
<tr>
<td>Worm</td>
<td>Avoid flood</td>
<td>Turn away from flood</td>
<td>Move as before</td>
</tr>
<tr>
<td>Grass</td>
<td>Avoid salt</td>
<td>Turn away from salt</td>
<td>Grow as before</td>
</tr>
<tr>
<td>Mimosa</td>
<td>Avoid bug</td>
<td>Close leaves away from bug</td>
<td>Keep leaves open</td>
</tr>
<tr>
<td>Ice cream</td>
<td>Avoid heat</td>
<td>Move toward shade</td>
<td>Stay in heat</td>
</tr>
<tr>
<td>Carpet</td>
<td>Avoid paint</td>
<td>Turn away from paint</td>
<td>Unroll as before</td>
</tr>
<tr>
<td>Crocodile</td>
<td>Meat</td>
<td>Close mouth on meat</td>
<td>Keep mouth open</td>
</tr>
<tr>
<td>Octopus</td>
<td>Crab</td>
<td>Close legs around crab</td>
<td>Keep legs open</td>
</tr>
<tr>
<td>Venus plant</td>
<td>Fly juice</td>
<td>Close leaves around fly</td>
<td>Keep leaves open</td>
</tr>
<tr>
<td>Snow cabbage</td>
<td>Keep insides warm</td>
<td>Close leaves around insides</td>
<td>Keep leaves open</td>
</tr>
<tr>
<td>Oven</td>
<td>Keep fire inside</td>
<td>Close door</td>
<td>Keep door open</td>
</tr>
<tr>
<td>Scissors</td>
<td>Sharpener</td>
<td>Close onto sharpener</td>
<td>Keep open</td>
</tr>
<tr>
<td>Hawk</td>
<td>Get to branch</td>
<td>Turn against wind toward branch</td>
<td>Keep going with wind</td>
</tr>
<tr>
<td>Bee</td>
<td>Get to beehive</td>
<td>Turn against wind toward beehive</td>
<td>Keep going with wind</td>
</tr>
<tr>
<td>Bean plant</td>
<td>Sunlight</td>
<td>Turn against gravity toward sunlight</td>
<td>Grow as before</td>
</tr>
<tr>
<td>Poppies</td>
<td>Stay warm</td>
<td>Turn toward sun</td>
<td>Face same direction</td>
</tr>
<tr>
<td>Sweater</td>
<td>Stay dry</td>
<td>Turn out of washing machine</td>
<td>Stay in washing machine</td>
</tr>
<tr>
<td>Kite</td>
<td>Stay out of lake</td>
<td>Turn against wind away from lake</td>
<td>Keep going with wind</td>
</tr>
</tbody>
</table>

## References


