



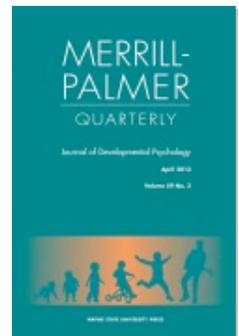
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Anthropomorphizing Science: How Does It Affect the Development of Evolutionary Concepts?

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Despite the ubiquitous use of anthropomorphic language to describe biological change in both educational settings and popular science, little is known about how anthropomorphic language influences children's understanding of evolutionary concepts. In an experimental study, we assessed whether the language used to convey evolutionary concepts influences children's (5- to 12-year-olds; $N = 88$) understanding of evolutionary change. Language was manipulated by using three types of narrative, each describing animals' biological change: (a) need-based narratives, which referenced animals' basic survival needs; (b) desire-based or anthropomorphic narratives, which referenced animals' mental states; and (c) scientifically accurate natural selection narratives. Results indicate that the language used to describe evolutionary change influenced children's endorsement of and use of evolutionary concepts when interpreting that change. Narratives using anthropomorphic language were least likely to facilitate a scientifically accurate interpretation. In contrast, need-based and natural selection language had similar and positive effects, which suggests that need-based reasoning might provide a conceptual scaffold to an evolutionary explanation of biological origins. In sum, the language used to teach evolutionary change impacts conceptual understanding in children and has important pedagogical implications for science education.

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We can see the uneasiness, for instance, in the microbiologists' frank use on the one hand of intentional terms to describe and explain the activity of macromolecules, while feeling the puritanical urge to renounce all talk of function and purpose on the other.

—Daniel Dennett, "Précis of the Intentional Stance" (1988, p. 503)

As Dennett implies, anthropomorphic language is difficult to avoid when explaining natural phenomena. Darwin himself struggled with anthropomorphic language, which reflected a culture in which the language barrier between scientists and nonscientists was porous, with terms such as *design* and *creation* denoting God's hand in the natural world (Beer, 2000; O'Hara, 1992; Shapin, 1996). Biologists today continue to use concepts such as *design*, albeit in a highly specialized, nonpurposeful manner. The use of compelling but biologically imprecise language to describe evolutionary change has been criticized, with some arguing that such language contributes to the widespread misunderstanding of evolutionary theory and may reinforce misconceptions based on intuitive teleological and essentialist biases (e.g., Jungwirth, 1975; Sprinkle, 2006).

Challenges associated with teaching Darwin's theory of evolution in U.S. schools are not rooted exclusively in substantial popular resistance to scientific ideas on religious or other ideological grounds (Bloom & Skolnick Weisberg, 2007; Brem, Ranney, & Schindel, 2003; Evans, 2000; Lombrozo, Shtulman, & Weisberg, 2006; Scott, 2004). Growing evidence from cognitive developmental science indicates that a variety of conceptual biases (Evans, 2000; Evans & Lane, 2011; Shtulman, 2006; Sinatra, Brem, & Evans, 2008) pose substantial obstacles to an accurate understanding of biological change. Among these are the essentialist tendency to view species as unchanging (Evans, 2000; Gelman, 2003; Herrmann, French, DeHart, & Rosengren, 2013; Mayr, 1982), the teleological tendency to explain all kinds of natural phenomena by reference to purpose (Evans, 2001; Keil, 1989; Kelemen, 1999), and the anthropomorphic tendency to attribute characteristics, such as humanlike mental states, to nonhuman agents or events (Evans, 2008; Waytz, Epley, & Cacioppo, 2010).

The use of anthropomorphic language to describe biological change is pervasive in educational settings (Evans, Spiegel, Gram, & Diamond, 2009) and in popular science media (Judson, 2009). For example, in a *Scientific American* article on the evolution of cancer, science writer Carl Zimmer (2007) described cancer cells that "trick the body into supplying them with energy to grow even larger" (p. 69). This description elicits the idea that cancer cells, like humans, are capable of consciously carrying out a duplicitous act. Such metaphorical language engages an audience, but what effect

does it have on their scientific understanding? Does the novice reader grasp the metaphor? When the language used to describe evolution both mirrors our everyday understanding of intentional action (Kelemen & Rosset, 2009; Malle & Knobe, 1997; Mull & Evans, 2010; Rosset, 2008) and reflects the cross-domain mappings we use to conceptualize one domain in terms of another (Lakoff, 1993), does it reinforce the use of intentional reasoning or scaffold (Carey, 2000) a deeper understanding of evolution? Answering this question has widespread implications for formal and informal learning experiences in which language, either spoken or written, provides an important interpretive bridge between the science to be learned and the learner.

One possibility is that language referring to biological organisms' desire for change may help learners understand core scientific concepts by providing a readily grasped metaphor that reflects intuitive anthropomorphic semantics that are familiar to both children and adults. Alternatively, such language may reinforce misconceptions and leave learners with an inaccurate understanding that biological change is indeed intentional. This is a particular problem for evolutionary change, which is not under an organism's conscious control, because it is often conceptualized in anthropomorphic terms (Evans, 2000, 2001, 2008).

In the current study, we investigated whether language that draws on intuitive conceptual biases, in particular anthropomorphic language implying that an animal's intentions and desires are the impetus for change, contributes to the maintenance of these biases in children's explanations for evolutionary change. Our objective was to examine the effects of such language on a novice population—namely, elementary school children. Children in this age range are fine-tuning their early-developing understanding of human intentionality (Moses, Baldwin, & Malle, 2001; Mull & Evans, 2010) at the same time as they are being introduced to basic scientific concepts in formal and informal learning contexts. For this reason, they may be especially susceptible to the influence of anthropomorphic explanations.

To address this issue, it is necessary to parse the conceptual framework that underlies the interpretation of intentional action. In a folk theory of intentionality, a purposeful act invokes a complex network of beliefs, desires, and skills that is focused on a goal that might or might not be achieved (Malle & Knobe, 1997; Wellman, 2011). Goal-directed reasoning is a broader category that includes a family of teleological concepts that imply a progression toward an end point (see Mayr, 1982, pp. 47–51). Many actions—from the beating heart to flowing neurotransmitters—appear to be goal-directed in the limited sense that they are functional yet

occur independently of the organism's conscious intent. These actions reflect an internal state, or "intrinsic purpose" (Keil, 1994) that must be satisfied if the organism is to survive. Such purposes can be described by using anthropomorphic, desire-based language that refers to animals' mental states such as their desires or wants, or with need-based language that refers to animals' nonmentalistic, biological needs. Importantly, need-based explanations that exclude mentalistic language are closer to a scientifically accurate notion of biological change.

Adults use both forms of reasoning. In a study of natural history museum visitors' concepts of evolution, for example, some adult visitors used desire-based reasoning to describe changes in the size and shape of the Galapagos' finches' beaks: "They had to try and work harder, probably, to develop their beaks" (Evans et al., 2010). However, the majority of visitors used need-based reasoning with no reference to conscious intent or desires on the part of the organism: "Well, in order to survive, their body parts had to adjust to certain things, similar to the way giraffes' necks probably grew long as they reached for the plants at the top of the trees, so the beak grew longer in order to deal with the tougher seeds." Moreover, the ability to distinguish between need- and desire-based language seemed to be pivotal in visitors' emerging grasp of evolutionary concepts (Diamond & Evans, 2007; Evans et al., 2009, 2010; Spiegel et al., 2012).

There is evidence that the ability to make this distinction between need and desire is linked to an improved understanding of evolutionary change. Adult and youth visitors to an evolution exhibition increased their use of both need-based reasoning and evolutionary reasoning (i.e., referring to basic evolutionary concepts of variation, inheritance, selection, time, and adaptation) but decreased their desire-based reasoning (Spiegel et al., 2012). Furthermore, visitors' need-based reasoning (e.g., "The first fruit flies needed to change into different kinds in order to live on the different Hawaiian islands"), but not their desire-based reasoning, was positively correlated with their endorsement of evolutionary themes. This effect was, however, less pronounced for the youngest visitors (11- to 13-year-olds), who were also the group most likely to endorse desire-based explanations (Spiegel et al., 2012). On the other hand, need-based reasoning was negatively correlated with intentional design reasoning in which an anonymous creator designs organisms for a particular purpose (e.g., "Special fruit flies were created to live on Hawaii"), whereas desire-based reasoning (e.g., "The first fruit flies wanted to change ..."), was positively correlated with intentional design. Overall, the youngest visitors and those visitors who rejected the idea of evolutionary origins for religious reasons were the groups most likely to endorse intentional-design

arguments, albeit at relatively low levels—results that are consistent with previous studies (Evans, 2000, 2001).

This pattern of results suggests that these two intuitive conceptual biases—desire-based and need-based reasoning—may be distinct and embedded in different knowledge structures at a certain point in development: the former a component of an intuitive psychology, with a focus on mental states, and the latter a component of an intuitive biology, with a focus on internal, nonmentalistic states, those necessary for survival. Both, however, are directed toward *goals*. As explanations for evolutionary change, both reasoning patterns are pervasive, found in students spanning the educational spectrum from elementary school to college (Alters & Nelson, 2002; Evans, 2008), as well as among natural history museum visitors (Evans et al., 2010; Macfadden et al., 2007). Although young elementary school children can make the distinction between need and desire, reasoning that animals breathe because they *need to* not because they *want to* (Poling & Evans, 2002), they are more likely than older elementary school children to default to mental-state language to describe evolutionary change (Evans, 2000, 2008). To investigate this phenomenon in more detail, we use the term *anthropomorphic* in a narrow sense to refer to mentalistic or desire-based concepts, and the term *need-based* to reference internal, nonmentalistic states.

The use of multiple explanatory frameworks to interpret evolutionary change is pervasive (Evans, 2001; Evans, Legare, & Rosengren, 2011; Legare, Evans, Rosengren, & Harris, 2012). Evans et al. (2010) demonstrated that 72% of highly educated U.S. visitors to natural history museums used a mixture of intuitive reasoning (e.g., need- or desired-based reasoning) and less-intuitive evolutionary reasoning. A further 28% used creationist reasoning, as well (Evans et al., 2010), which was less than the 45% of the U.S. general public who endorsed creationist views (Gallup, 2007). These findings demonstrate that some conceptual biases apparent in early childhood (e.g., a tendency to conceive of biological change as intentional) persist in adult populations, even highly educated populations interested in natural history (Evans et al., 2010).

Given persistent misconceptions about evolutionary concepts, what might be the best way to convey an understanding of evolutionary change? There is abundant evidence that narrative can be used as an effective pedagogical tool (e.g., Bruner, 1996). In the case of evolution, narrative in an easily accessible causal framework can unite disparate biological and environmental events occurring over the eons. Moreover, previous research in museum settings indicates that narrative can be used successfully to convey information about natural selection to elementary school children, though

it may be more successful with older children (Legare, Hazel, French, Witt, & Evans, 2007; see also Abbott, 2003; Kelemen, Seston, & Ganea, 2009; Metz, Sisk-Hilton, Berson, & Ly, 2010).

In the current study, narrative was used as a pedagogical device to assess whether the language used to convey ideas about evolution influences the extent to which children both endorse and express different kinds of explanations for evolutionary change. We experimentally manipulated the language to describe evolutionary change with three types of narrative by using (a) *need-based* explanations, referencing basic survival needs; (b) *desire-based* or *anthropomorphic* explanations, referencing mental states; and (c) scientifically accurate *natural selection* explanations. In a within-subjects design, children were asked about their understanding of evolutionary change in three populations of birds by using the three different narratives. Apart from the verb forms, the narratives for each story were identical; for example, the basic concepts of natural selection—differential survival and reproduction—were embedded in each narrative even though the verbs used to convey this information differed by condition.

Dependent measures included the language children used when asked to retell the stories and children's responses to closed-ended questions about the narratives. Our focus was on children's expression of and endorsement of need-based, desire-based, and natural selection explanations. Additionally, we were interested in whether children differed in their endorsement of intentional-design and evolution explanations. Endorsement of the term *evolution* would indicate that children had been exposed to information about evolution, although children in these age groups have not yet taken formal courses on the topic. The intentional-design explanation focused on the action (i.e., to make), not the designer. This wording had been successfully used in earlier studies (Evans, 2008; Spiegel et al., 2012), and it ensured that children were not just responding to the term *God* reflexively while ignoring the significance of the underlying action (Evans, 2001).

Our central hypothesis was that the language of the narrative would influence children's expression of evolutionary concepts, with anthropomorphic language being the most likely to reinforce intuitive anthropomorphic misconceptions and detract from an accurate conceptual understanding of evolution, particularly of natural selection. Based on prior research with adults and children, more specific predictions were that (a) the desire-based narrative would have the strongest influence on children's use of anthropomorphic language in their retelling of the story and in their endorsement of desire-based explanations for the closed-ended questions; (b) the effect of condition would also hold for the language used in children's retelling of the need-based and natural selection narratives;

(c) younger children (5–7 years) would be more likely both to express and to endorse anthropomorphic language and intentional-design concepts across conditions; conversely, older children (8–12 years) would be more likely to express and endorse natural selection explanations and evolutionary language across conditions; and (d) children in both age groups would endorse more than one of these kinds of explanations simultaneously.

Method

Participants

Ninety-eight 5- to 12-year-olds were interviewed at a Midwest university-affiliated natural history museum in two individual interview sessions. Children were recruited through a science summer camp administered by the museum—a half-day program consisting of mixed-age 2-week-long sessions. These programs expanded students' knowledge of science through experimental and instructional activities. Topics included astronomy, aerospace, wildlife, ecology, geology, and paleontology. Ten children did not complete the interview. The final sample included 88 children (45 boys), from 5.83 to 12.47 years of age ($M = 8.51$ years, $SD = 1.64$). To examine age-related differences, the sample was divided into two age groups: *young* (5.5–7.9 years, $n = 34$) and *old* (8.0–12.4 years, $n = 54$). Participants were 75% European American, 16% Asian American, 3% African American, 3% Latin American, 2% unspecified.

Design and Procedure

Children's understanding of evolutionary change was assessed with a structured interview that included open-ended (i.e., story recall) and closed-ended questions. They were interviewed individually in a quiet area of the museum. Experimenters read children three narratives (with accompanying pictures) on evolutionary change, each on a different bird population (brownbirds, Haast eagles, and kiwis); the birds were presented in a fixed order. For each bird population, there were three narrative types, each of which used different language to describe population change: natural selection, need-based, and desire-based (anthropomorphic) narratives. Children were presented with the three narrative types in a random order with the constraint that for each age group there were an equal number of the three narrative types (natural selection, need-based, desire-based) in the first, second, or third positions. In both closed- and open-ended responses, we assessed whether children differentiated between natural selection

language, desire-based (anthropomorphic) language, and need-based language. Following each story, children were asked to retell the story and were then asked how much they endorsed different explanations for change in bird population. See Appendices A–C for the narratives about the brownbird, the Haast eagles, and the kiwis, respectively. Each of the narratives was accompanied by photographs or drawings of the birds and their environments, and the language of the stories was equated for reading level. All of these narratives were based on changes that have actually occurred in these bird populations, but the name brownbird was used instead of the finch in case children were familiar with the latter bird.

Measures

Narrative recall. Following each of these narratives, children were told, “Tell the story back to me just the way that I told it to you. Try to remember as many details as possible.” Following children’s initial response, children were asked, “Can you tell me a bit more about the story?” Their responses were then coded for different kinds of language use, described next.

Coding and Scoring

Interviews were audiotaped and transcribed verbatim. A coding rubric was developed based on extensive review of the transcripts. Coding captured information about story details, evolutionary concepts, the kind of argument used to describe biological change, and desire-based, need-based, and evolution language. All coding was completed by a research assistant unaware of the study hypotheses. To establish interrater reliability, 20% of the interviews were also coded by the second author (percent agreement \geq 80% for all coding categories).

Children’s recall was coded for *story details*, which included mentioning the specific bird (e.g., brownbird, Haast eagle, kiwi), location (e.g., Galapagos Islands, New Zealand), characteristics of descendants (e.g., cannot fly, small wings, big feet), and characteristics of ancestors (e.g., could fly, had larger wings, had smaller feet). For each of the three narratives, children who referred to the *bird species* earned a score of 1. For *location*, children received a score of 1 for each narrative if they mentioned the location of the birds. For *ancestor* and *descendant* facts, a score ranging from 0 (no details) to 3 (many details) was earned for each narrative.

Story recall was also coded for information about five basic *evolutionary concepts*: variation, inheritance, selection, time, and adaptation (VISTA) (see

Evans et al., 2010). *Variation* was coded for information about within-species variation (members of a species vary; e.g., “some have smaller beaks and some have bigger beaks”) and between-species variation (comparing and contrasting differences between modern birds and their ancestors; e.g., “the brownbirds had thicker beaks than their ancestors”). *Inheritance* was coded for information that traits (genes) are inherited and passed from one generation to the next (e.g., “they had chicks and some of them had heavier beaks also”). *Adaptation* was coded for information about the link between the beak size and food, the link between climate change and the food source, or the link between body size and food source, which differed depending on the bird (e.g., “the climate changed so their beaks got wider over evolutionary time”). Additionally, we coded for the *type of adaptation argument* that the children made: *desire-based change* (e.g., “some birds wanted to change so they could eat those seeds”); *need-based change* (e.g., “some birds needed to change so they could eat different seeds”); and the two components of a natural selection argument: *differential survival* (e.g., “there was a drought and for many years it got dry and the birds with bigger beaks survived better because there were only bigger seeds that were harder to crack open”) and *differential reproduction* (e.g., “these birds breed more than the ones with small beaks and so some of their children had big beaks so they grew”). Information about *time* was also coded (i.e., many years ago, millions of years, billions, over evolutionary time, a long time ago, after a while, as time went by, old times). For each of these concepts, children received a 1 if the concept was recalled from a story, and a 0 if that concept was not recalled from a story, for a total of 0–3 across the three stories.

The specific *language* children used to recall the narratives was also coded. Language was coded as *anthropomorphic* if it included any of the following phrases indicating that the animal was making a conscious effort or choice: tried to, like to, want to, decided to, or thought (e.g., “they tried to have bigger beaks,” “they liked eating small seeds,” “some birds wanted to change so they could eat those seeds”). *Need-based* language included the following: need to, had to, so that, so they could, in order that, or adapted to (e.g., “some of them needed to be bigger,” “some of the birds changed after a while so they could eat”). *Evolution* language included the following terms: variation, adaptation, selection, and evolution (e.g., “over time the birds evolved,” “the change in the climate determined a change in the food source which in turn made the birds adapt”). Children’s language was coded for up to five different forms of need-based language (for a score of 0–5 for each of the three narratives), up to five different forms of desire-based (anthropomorphic) language (for a score of 0–5 for each narrative), and up to four different evolution terms (for a score of 0–4 for each narrative).

Endorsement of explanations for change. Following children's recall of each randomly ordered story, children were also asked how much they agreed or disagreed that the population change was a result of (a) intentional design, (b) desire for change, (c) need for change, (d) natural selection (which included both components, differential survival and differential reproduction), and (e) evolution, randomly ordered. Children rated their agreement with each of these five explanations for each of the three birds by using the following scale: 1 = "Disagree a lot," 2 = "Disagree a little," 3 = "Don't know," 4 = "Agree a little," and 5 = "Agree a lot." At the beginning of the procedure, children were trained to use the agree-disagree scale, with expressive faces reflecting the degree of agreement. Below are the explanations given for the brownbird narratives. (See Appendix D for questions for the other two narratives.)

"I am going to tell you about some ideas that other kids have had about how birds changed. You can agree with all of their ideas, or some of their ideas, or you can disagree with all of their ideas. It depends on what you think. We asked kids: How did the brownbirds get to have beaks with different sizes? Some kids said ..."

1. Special brownbirds were made that way to eat different kinds of food.
2. The brownbird ancestors' wanted to have different beaks because they liked different kinds of food.
3. The brownbird ancestors' beaks changed because they needed to eat different kinds of food.
4. Only the brownbird ancestors with heavy beaks could eat the tough seeds, so they lived and had more babies.
5. The different sizes of brownbird beaks are the result of evolution.

Results

Focal to the current investigation were the effects of age and of narrative type on children's explanations. Two-way analyses of variance (ANOVAs) were used to assess the effects of age as a between-subjects factor (2: young, old) and narrative type as a within-subjects factor (3: desire-based, need-based, natural selection) on children's *recall* of particular language and concepts from the narratives (see Table 1). Another set of five two-way ANOVAs was used to assess the effects of age as a between-subjects factor (2: young, old) and narrative type as a within-subjects factor (3: desire-based, need-based, natural selection) on children's *endorsement* of each

Table 1. Descriptive statistics and effects of narrative-type and age on the language and explanations children used to recall narratives

Recall	Narrative type						Age group					
	Desire-based		Need-based		Natural selection		5-7 Years		8-12 Years		F	
	M	SE	M	SE	M	SE	M	SE	M	SE		
Explanations for adaptation												
Desire-based change	.66	.05	.07	.03	.09	.03	53.60***	0.71	.11	0.93	.08	2.65
Need-based change	.24	.05	.48	.05	.17	.04	13.35***	0.68	.14	1.11	.13	4.79*
Differential survival	.25	.05	.26	.05	.42	.05	3.01*	0.74	.12	1.12	.13	4.18*
Differential reproduction	.17	.04	.28	.05	.37	.05	5.01**	0.47	.11	1.17	.12	15.53***
Evolution concepts												
Variation between species	.49	.05	.46	.05	.38	.05	1.00	1.29	.14	1.39	.11	0.28
Variation within species	.34	.05	.40	.05	.48	.05	1.97	0.79	.12	1.65	.13	19.28***
Inheritance	.14	.04	.22	.05	.23	.05	2.40	0.26	.11	.91	.13	12.12***
Deep time	.22	.05	.16	.04	.17	.04	0.70	0.44	.14	.67	.11	1.56
VISA composite	1.39	.14	1.63	.14	1.88	.14	3.68*	1.19	.15	2.08	.12	20.48***
Language used												
Desire-based terms	.84	.07	.08	.03	.08	.03	47.09***	0.91	.16	1.09	.11	0.93
Need-based terms	.33	.06	.75	.10	.27	.06	10.19***	0.88	.17	1.81	.21	9.42***
Evolutionary terms	.10	.04	.14	.04	.14	.04	0.35	0.12	.07	0.63	.13	8.38**

Note. Descriptive statistics for age group are collapsed across the three narratives. *F* values for narrative type and age group were computed by using three (Narrative type) \times 2 (Age group) ANOVAs, with narrative type as a within-subjects factor. Degrees of freedom for the effect of narrative type = 85. Degrees of freedom for the effect of age group = 86. Means for age group are collapsed across all three narrative types. VISA = variation, inheritance, selection, and adaptation.

* $p \leq .05$.

** $p < .01$.

*** $p < .001$.

of the five explanations for biological change in birds. (Figure 1 presents corresponding graphs.) As there were main effects for narrative type and for age group, but no interactions between the two independent variables, the results are presented first for narrative type, followed by age group.

Effects of Narrative Type

Story recall. The type of reasoning that children used for adaptive change in their recall of the narratives, as well as the language they used, are particularly revealing. (See Table 1 for F and p values for each two-way ANOVA.) Post hoc analyses (adjusting for multiple comparisons by using Bonferroni corrections) demonstrated the following: Children more often referred to desire-based change when recalling the desire-based narrative, $ps < .001$; more often referred to need-based change when recalling the need-based narrative, $ps < .01$; and more often mentioned differential reproductive success, $p < .01$, and (to a lesser extent) differential survival, $p = .07$, when retelling the natural selection narrative (in contrast to the desire-based narrative). Further, when presented the desire-based narrative, children

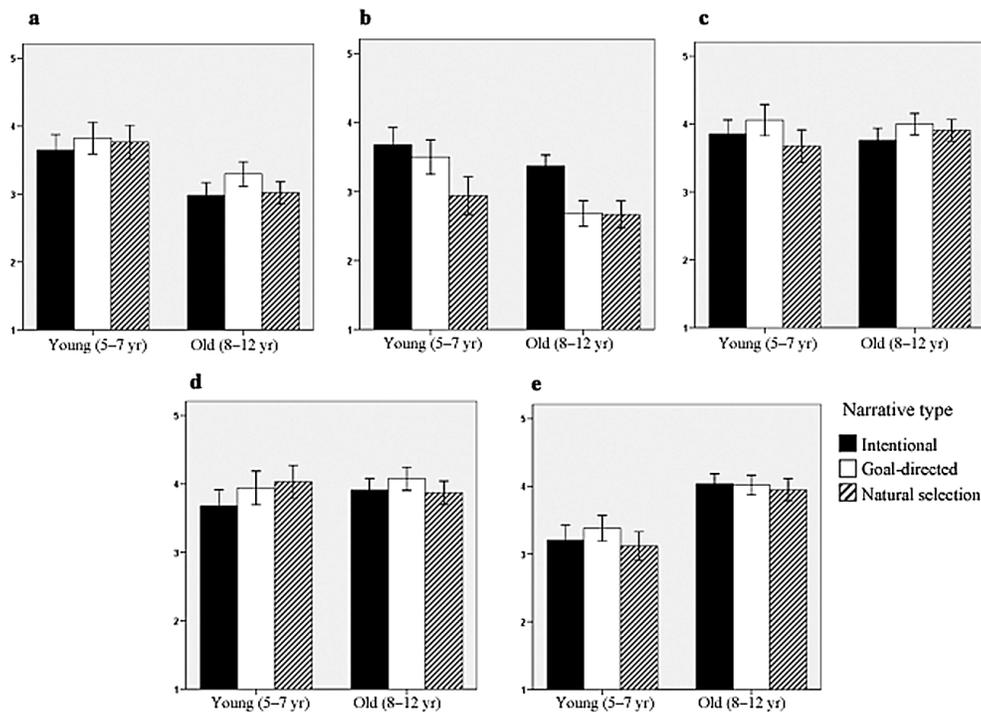


Figure 1. Mean endorsement of each of the five explanations for biological change in birds, by age group and narrative type: (a) design explanation, (b) desire (anthropomorphic) explanation, (c) need explanation, (d) natural selection explanation, and (e) evolution explanation. Error bars represent ± 1 standard error.

more often used desire-based (anthropomorphic) language, $ps < .001$; and when presented the need-based narrative, children more often used need-based language, $ps < .001$.

Given that the dependent variable for each explanation and evolutionary concept was coded dichotomously (as present or absent) for each narrative type, we constructed a continuous dependent variable that reflected children's broader use of evolutionary concepts by combining the codes for those concepts that adults may reference when asked about evolutionary change (Evans et al., 2010), into a VISA composite (ranging from 0 to 5): (a) variation between species, (b) variation within species, (c) inheritance, (d) differential survival explanations, and (e) differential reproduction explanations. (Time was rarely invoked, so it was not included in the composite.) Children were found to use VISA concepts more frequently when presented with the natural selection narrative (as opposed to the desire-based narrative), $p < .05$; there was no difference between need-based and natural selection narratives.

Closed-ended explanations. With regard to children's ratings of different explanations for biological change (see Figure 1), in separate two-way ANOVAs (one for each of the five explanations for change) we found a main effect of narrative type on endorsement of the idea that birds changed because of their desire for change, $F(2, 85) = 6.80, p < .01$. Parallel to the finding on children's story recall, Tukey post-hoc comparisons indicated that children more strongly endorsed the desire-based explanation when they were presented the desire-based narrative ($M = 3.52, SE = .14$), in contrast to the natural selection narrative ($M = 2.80, SE = .16$), $p < .01$, and need-based narrative ($M = 3.09, SE = .15$), $p = .06$.

To investigate whether there was an effect of narrative on mixed reasoning, for each of the five closed-ended explanations, children's responses were coded as 0 for 1–3 (strongly disagree, disagree, or don't know) or 1 for a 4 (agree) or 5 (strongly agree). A *mixed reasoning* composite was computed by summing the 0s and 1s across the five explanations (possible range: 0–5). There was no effect of narrative type; for each of the three narratives children endorsed the same number of explanations, roughly three (desire-based: $M = 2.96, SE = .11$; need-based: $M = 3.04, SE = .13$; natural selection: $M = 2.74, SE = .12$), $F(2, 85) = 5.59, ns$.

Effects of Age Group

Story recall. Next we turn to the effects of age on children's narrative recall. (See Table 1 for F and p values for two-way ANOVAs.) In their recall of the narratives, older children (8- to 12-year-olds) remembered more

details about the stories, including the location of the birds, $F(1, 86) = 7.13$, $p < .01$, and details about the bird ancestors, $F(1, 86) = 6.17$, $p < .05$. Older children more often used need-based reasoning to explain adaptive change, and more often mentioned differential survival and differential reproductive success in their recall. Older children were also more likely to mention the evolutionary concepts of within-species variation and the inheritance of traits and were more likely to use need-based and evolutionary terms. Overall, older children used VISA concepts more often than did younger children.

Closed-ended explanations. There were significant main effects for age in children's agreement with the intentional-design explanation, the desire-based (anthropomorphic) explanation, and the evolution explanation (see Figure 1). The youngest children more strongly endorsed the idea of intentional design, that birds were "made that way," $F(1, 86) = 9.95$, $p < .01$, and the idea that birds change because of desire, that birds "wanted to" change, $F(1, 86) = 5.21$, $p < .05$. In contrast, the oldest children more strongly endorsed the idea that birds changed because of evolution, $F(1, 86) = 14.03$, $p < .001$. Younger and older children equally endorsed the idea that the birds changed because they "needed to" and because of natural selection. Using the *mixed reasoning* composite, we found that younger children ($M = 2.89$, $SE = .14$) endorsed as many of the five explanations as did older children did ($M = 2.94$, $SE = .11$), $F(1, 86) = .06$, *ns*.

Patterns of Reasoning: Multiple Explanations

To determine whether there were discernible patterns in children's endorsement of multiple explanations, zero-order correlations were carried out on children's endorsement of the five closed-ended explanations for biological change, collapsed across the three stories and the two age groups. Endorsement of desire-based explanations for change was correlated with endorsement of intentional-design explanations, $r(88) = .46$, $p < .001$; desire-based explanations were also correlated with need-based explanations, $r(88) = .31$, $p < .01$. Endorsement of evolution explanations was correlated with endorsement of natural selection explanations, $r(88) = .26$, $p < .05$. This pattern is consistent with the hypothesis that need- and desire-based explanations are embedded in different explanatory frameworks.

Examining the explanations that children offered to describe animals' adaptation (desire-based, goal-directed, differential survival, and differential reproduction reasoning), desire-based reasoning was not correlated with any other form of reasoning. Need-based reasoning was correlated with reasoning involving differential survival, $r(88) = .34$, $p = .001$, and

with reasoning involving differential reproduction, $r(88) = .25, p < .05$. Children who mentioned differential survival often also mentioned differential reproduction, $r(88) = .53, p < .001$.

Discussion

This study demonstrates that the language used to describe evolutionary change influences children's retelling of and endorsement of evolutionary concepts, particularly of natural selection. Anthropomorphic language is most likely to have a negative effect. Need-based and natural selection language, in contrast, have similar and more positive effects. Regardless of the language of instruction, however, children in this age range are able to grasp some core ideas about natural selection. Before considering the implications of this research, we describe the effects of both narrative type and age on children's reasoning about evolutionary change, focusing on the major explanations used in each of the three types of narrative: desire-based (anthropomorphic), need-based, and natural selection.

Our data support our first prediction that the desire-based narrative would have the strongest influence on elementary school children's explanations of evolutionary change. In contrast to explanations given for the other two narratives, desire-based explanations of adaptive change and the use of desire-based language were much more frequent in children's retelling of the desire-based narrative, regardless of age. For the endorsement task, in contrast, there were effects of age as well as narrative type, with younger children (5–7 years) and children who had heard the desire-based narrative more likely to agree with desire-based explanations.

Consistent with the second prediction, need-based explanations of adaptive change and need-based language were more likely to be elicited by the need-based narrative in children's retelling of the story. In this case, there were age differences in children's recall; older children (8–12 years) more often expressed need-based explanations and language, regardless of narrative type. In contrast, for the endorsement task, children's agreement with need-based explanations did not vary by age group or by narrative type; most children agreed with need-based explanations. For the natural selection narrative, the results were somewhat similar. Children were much more likely to express natural selection explanations of evolutionary change when they retold the story following the natural selection narrative and were also more likely to express evolutionary concepts, as reflected in the overall composite score. However, there was no effect of narrative type on their use of evolutionary terminology; children rarely spontaneously expressed evolution terms. For the endorsement task, in contrast, children

from both age groups were very likely to agree with the natural selection explanations for the closed-ended questions, and there was no effect of narrative type. Overall, children expressed significantly fewer evolutionary concepts when they were exposed to the desire-based narrative, in comparison with both the need-based and natural selection narratives.

The third prediction, based on the results of prior research (Evans, 2000; Spiegel et al., 2012), was that younger elementary school children would be more likely to agree with intentional design explanations, and that, conversely, older elementary school children would be more likely to agree with evolutionary terminology, as assessed in the endorsement task. Our data indicate that younger children were especially likely to endorse both types of anthropomorphic explanations: desire-based and design-based. Younger children were more likely than older children to agree that birds were specially “made that way.” Even though these children were a self-selected group (i.e., they had chosen to attend a natural history summer camp), these findings are consistent with those of other research studies, conducted in fundamentalist and nonfundamentalist Christian communities, indicating that, regardless of background, early elementary school-aged children are more likely to endorse creationist explanations (Evans, 2000, 2001). One interpretation of these findings is that because of the centrality of developing an understanding of human intentionality in this age group, these children are more susceptible to the artifact analogy: Just as people make artifacts, someone must have made animals. Thus this analogy is easily elicited as an explanation for the creation of different kinds of animals.

Older children, on the other hand, more often agreed that evolution explained adaptive change, suggesting that they had heard this term. However, older children were no more likely than younger children to use evolutionary terminology in their story recall and were just as likely as younger children to default to desire-based language following the desire-based story. In sum, for the story-recall task, older children were just as susceptible as the younger children to the effects of a narrative in which anthropomorphic language was used to explain evolutionary change. Thus, even though they recognized that evolution was a good explanation for biological change, a reflective understanding of evolution might not yet be part of their everyday account of biological change.

Consistent with the results from adults and older youth in earlier museum studies (Evans et al., 2010; Spiegel et al., 2012), we found an increase in children’s recall of key evolutionary concepts across development. Although both age groups were sensitive to between-population differences, the older children were significantly more likely to recall the

key concept of within-species variation. This finding, we argue, indicates that the older children are less wedded to an essentialist constraint that each kind of bird is essentially the same (Evans, 2000, 2001, 2008; Gelman, 2003; Shtulman & Schulz, 2008). Furthermore, older children were more likely to mention differential selection, the inheritance of traits, and differential reproduction, with the age effects being greatest for the latter two concepts. These age effects are not simply a function of older children's better memory, because the main differences were for the type of explanation, not the quantity of information. Both age groups (5- to 7-year-olds and 8- to 12-year-olds) recalled similar amounts of information about the bird descendents. This pattern of results suggests a developmental trajectory in an understanding of natural selection, from within-species variation to differential survival to inheritance to differential reproduction. A full grasp of natural selection requires all of these concepts. Whether they build on one another, as this trajectory suggests, should be assessed in future studies.

Like adults (Evans et al., 2010; Legare et al., 2012), children endorsed more than one of these explanations simultaneously. On average, children agreed with three of the explanations articulated in the closed-ended questions. Further, there was a significant, though modest, correlation between endorsement of the evolution and natural selection explanations, suggesting that some of the children had prior exposure to these ideas. Endorsement of the desire-based explanation was correlated with endorsing need-based and the intentional-design-based explanations. However, endorsement of need-based explanations was not correlated with endorsement of design-based explanations. Taken together, these findings suggest that children who endorse desire-based explanations may be more receptive to endorsing multiple explanations, including explanations consistent with creationism, than are children endorsing need-based explanations.

The explanations that children produced to explain biological change were particularly revealing. Need-based reasoning (but not desire-based reasoning) was correlated with children's spontaneous reference to two important components of evolution: differential survival and differential reproduction. This pattern is consistent with the possibility that need-based and desire-based explanations function differently in children's intuitive explanatory frameworks than they appear to do for adults (Evans et al., 2010; Spiegel et al., 2012). Need-based narratives (e.g., "Change is necessary to survive") are central to naïve biological reasoning and may scaffold evolutionary reasoning. In contrast, desire-based narratives, which incorporate anthropomorphic language (e.g., "The animal wanted to change to get the food") and are thus central to a naïve psychology, do not. Further evidence for this claim comes from our finding that the need-based narrative was

as likely as the natural selection narrative to elicit evolutionary concepts on the VISA (evolutionary) composite variable, whereas the desire-based narrative elicited significantly fewer VISA concepts than either of the other narratives.

There were clear developmental differences in need-based explanations, with older children much more likely to express need-based and natural selection explanations for adaptation in their story retelling. Yet, on the closed-ended task, both the need-based and natural selection explanations were highly endorsed by children in both age groups, regardless of narrative type. The desire-based explanation, in contrast, was more likely to be endorsed by the younger children. Thus, even the youngest children recognized that need-based and natural selection explanations were plausible accounts of change; even if they had difficulty expressing these concepts in the story-recall tasks (perhaps indicating that such explanations had not yet been integrated into their everyday understanding of biological change). The distinction between need- and desire-based explanatory frameworks was especially clear among the older children. As one 8½-year-old explained, “You don’t evolve because you want to; you evolve because you have to.” Thus, among older children, the ostensible goal of evolutionary change is much clearer: Change satisfies the intrinsic needs (not desires) of the organism (Evans, 2000, 2008; Keil, 1994).

We propose that need-based reasoning may function as a transitional explanation, a placeholder, in which an intrinsic, nonmentalistic goal, the need for survival, may be tied to differential survival in a population (Evans et al., 2010; Spiegel et al., 2012). The child (or adult) who has achieved this level of reasoning is approaching an understanding of the mechanism of evolutionary change: natural selection. However, there is a cautionary tale, particularly for younger school-age children who are in the process of acquiring a folk theory of intentionality (Mull & Evans, 2010). Anthropomorphic narratives elicit intentional explanations in the listener. Such metaphorical language is engaging, yet it can also mislead, reinforcing intuitive anthropomorphic misconceptions and hindering children’s expression of evolutionary concepts.

Implications: Both Practical and Theoretical

This study lends further support to a growing body of research (Kelemen et al., 2009; Legare et al., 2007; Metz et al., 2010) demonstrating that elementary school children can successfully learn about the basic mechanism of evolutionary change: natural selection. The willingness of older elementary school children to express and endorse evolutionary explanations

supports the idea that narratives based on natural selection language can be used for pedagogical purposes. This is encouraging in light of evidence that many U.S. adults currently reject or misunderstand evolutionary explanations (e.g., Evans et al., 2010; Gallup, 2007). It should be noted, however, that the sample of children participating in this study consisted of summer campers at a natural history museum and thus were not representative of the general population of age-matched peers in terms of their interest in science. The sample was chosen in order to examine the extent to which narrative style influences evolutionary reasoning in a population sympathetic to evolutionary concepts and interested in natural history. To our knowledge, this is the first study to manipulate the language of instruction explicitly and to demonstrate that the language of instruction is key to successfully conveying these ideas.

Despite the fact that the children in the current study were self-selected and more likely to have been exposed to evolutionary concepts at home or in the museum, similar results have been found with children from more diverse backgrounds, both in schools (Metz, et al., 2010) and in museums (Evans & Lane, 2010; Evans, Rosengren, Lane, & Price, 2012). Collectively these studies suggest that if evolution education was a feature of the elementary school curriculum, this might translate into a greater acceptance of evolution in the population at large. Future research with more heterogeneous samples would strengthen claims about the generalizability of our findings.

When developing curricular or exhibition materials, it is tempting to engage learners by using anthropomorphic language. Thus, it is important to demonstrate how such language influences children's understanding of evolution. Parents often translate the evolutionary language found in exhibition text into intuitive terms, such as anthropomorphic explanations, in order to convey these ideas to their children (Tare, French, Frazier, Diamond, & Evans, 2011). Whereas it is essential that we expose young children to the theoretical framework that unites the field of biology (Mayr, 1982), it is equally critical that we do not do so by providing an explanatory framework, a naïve psychology, that has the potential of providing a conduit to a compelling alternative to the theory of evolution: creationism (Evans, 2000, 2001, 2008). This is especially the case with younger children, who are particularly susceptible to the effects of anthropomorphic language. We suggest that need-based reasoning supplies an equally compelling narrative that is less likely to mislead and might well provide a conceptual scaffold to an evolutionary explanation of origins (see also Zohar & Ginossar, 1998).

Despite other advantages that anthropomorphism may have (Waytz et al., 2010), we argue that a conceptual cost is associated with the tendency

to anthropomorphize biological change. By applying human characteristics to animals and plants, the biological world is assigned a sense of human purpose and free will that impedes an accurate understanding of biological processes. The natural world requires neither purpose nor free will to undergo profound change that might well ensure its survival. The tendency of religious groups to see free will and purpose where, for the evolutionary biologist, there is none, is at the core of the difference between evolutionary theory and creationism (Evans, 2008).

We propose that a central explanatory framework for a naïve biology (Carey, 1985; Erickson, Keil, & Lockhart, 2010; Inagaki & Hatano, 2002; Medin & Atran, 2004) is the need for survival. Living things, both plants and animals, have features that serve an organism's intrinsic needs, its ability to survive. These features were not bestowed upon the organism by a sentient being, nor did the organism develop them through a conscious act of free will. The idea of the need for survival is intuitive and provides a sense of purpose lacking in a purely mechanical or contingent account of evolutionary change. Need-based reasoning may give humans an understanding of purpose without impeding their understanding of natural law.

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Appendix A. Intentional Reasoning Narratives

Brownbird

This is a medium brownbird. These brownbirds live on these islands. Different kinds of brownbirds *like* to have different beaks because they *want* to eat different sorts of food. The medium brownbirds *wanted* to have big heavy beaks so that they can eat the tough seeds of Tribulus plants that grow on these islands. But, do you know what!? Many years ago, the ancestors of these brownbirds had beaks that looked quite different. Scientists think that they *wanted* to have small light beaks. How could that happen? The brownbird ancestors were probably blown to the islands by storms. When they arrived, the islands were covered with plants with small soft seeds. Because the brownbird ancestors had small beaks, they *liked* to eat the soft seeds. But, there was a change in the weather. For many years, there was no rain, and the plants with the soft seeds died. Only the tough Tribulus plants lived. Most brownbirds could not live because they could not eat the tough Tribulus seeds. But some brownbirds *wanted* to change to have slightly heavier beaks so that they were able to eat the tough Tribulus seeds. The brownbirds with heavier beaks could eat better and live longer than the small-beaked brownbirds. They also *wanted* to have more chicks, some of which had heavier beaks, too. The chicks with the heavier beaks lived longer, and they had more chicks, as well. So, over many years, *trying* to change their beak size made a big difference. Over time, brownbirds

wanted to change to adapt to their surroundings. Now, many years later, the medium brownbirds have very different beak shapes than their ancestors.

Haast Eagle

This is a Haast eagle. They were the biggest eagles ever. They *tried* to have very strong legs, long wings, and a sharp beak. Haast eagles once lived in New Zealand. But, do you know what!? Millions of years ago, the ancestors of the Haast eagle looked very different. Scientists think they looked like regular eagles. How could that happen? About 2 million years ago, there were huge birds in New Zealand called moas. They were almost 10 feet tall. They couldn't fly, but they were safe and didn't *want* to fly, because there were no animals big enough that *liked* to catch them. Then, about a million years ago, a small flock of eagles arrived on New Zealand. Maybe they were blown there by storms. At first, these eagles were much smaller than the moas. But some eagles *wanted* to change, and they became a little bit bigger than most of the other eagles. Because they *tried* to be bigger, they began to catch bigger food, like the moas. So the eagles that had bigger wings and bodies were able to catch and eat the moas. They were better fed and lived longer than the smaller eagles. They also *wanted* to have more chicks, some of which *wanted* to be bigger, too. The chicks that were bigger were able to live longer, and they had more chicks, as well. So, over many millions of years, these little changes in body size made a big difference. Over time, eagles *wanted* to change to adapt to their surroundings. After a million years, the Haast eagles were larger than any other kind of eagle that ever lived on Earth.

Kiwi

This is a kiwi. Kiwis don't *like* to fly. They have tiny wings, kind of furry feathers, and big feet. They also have a great sense of smell, which most birds don't. Kiwis live in New Zealand. To get food, kiwis *like* to burrow in the ground to find bugs and worms. But, do you know what!? Millions of years ago, the ancestors of kiwis looked very different. Scientists think they looked like regular birds. They could even fly. How could that happen? In New Zealand, where the ancestors of the kiwis lived, the ground was safe because there were no animals who *wanted* to hunt them. There were lots of bugs and worms in the ground for them to eat. So they didn't *like* to fly. Some kiwi ancestors *wanted* to change so that they could have bigger feet for digging and a better sense of smell. The kiwi ancestors with bigger feet

were better at finding food under the ground. So these kiwi ancestors ate better and lived longer than the other kiwi ancestors. They also *wanted* to have more chicks, some of which had bigger feet, too. The chicks with the bigger feet lived longer, and they had more chicks, as well. So, over many millions of years, these little changes in foot size made a big difference. Over time, kiwis *wanted* to change to adapt to their surroundings. Now, there are kiwis with big feet they *like* to use for digging, a good sense of smell they *like* to use to hunt for worms, and almost no wings. They look really different from their ancestors, who had wings.

Appendix B. Need-Based Narratives

Brownbird

This is a medium brownbird. These brownbirds live on these islands. Different kinds of brownbirds *need* different beaks in order to eat different kinds of food. The medium brownbirds *needed* big heavy beaks so that they can eat the tough seeds of Tribulus plants that grow on these islands. But, do you know what!? Many years ago, the ancestors of these brownbirds had beaks that looked quite different. Scientists think that they *needed* small light beaks. How could that happen? The brownbird ancestors were probably blown to the islands by storms. When they arrived, the islands were covered with plants with small soft seeds. Because the brownbird ancestors had small beaks, they were able to eat the soft seeds. But, there was a change in the weather. For many years, there was no rain, and the plants with the soft seeds died. Only the tough Tribulus plants lived. Most brownbirds could not live because they could not eat the tough Tribulus seeds. But some brownbirds changed in order to have slightly heavier beaks so that they were able to eat the tough Tribulus seeds. The brownbirds with heavier beaks could eat better and live longer than the small-beaked brownbirds. They also had more chicks, some of which *needed* heavier beaks, too. The chicks with the heavier beaks lived longer, and they had more chicks, as well. So, over many years, these little changes in beak size made a big difference. Over time, brownbirds *needed* to change to adapt to their surroundings. Now, many years later, the medium brownbirds have very different beak shapes than their ancestors.

Haast Eagle

This is a Haast eagle. They were the biggest eagles ever. They *needed* very strong legs, long wings, and a sharp beak. Haast eagles once lived in

New Zealand. But, do you know what!? Millions of years ago, the ancestors of the Haast eagle looked very different. Scientists think they looked like regular eagles. How could that happen? About 2 million years ago, there were huge birds in New Zealand called moas. They were almost 10 feet tall. They couldn't fly, but they were safe and didn't *need* to fly, because there were no animals big enough who had to catch them. Then, about a million years ago, a small flock of eagles arrived on New Zealand. Maybe they were blown there by storms. At first, these eagles were much smaller than the moas. But some eagles *needed* to change so that they were a little bit bigger than most of the other eagles. Because they were bigger, they began to catch bigger food, like the moas. So the eagles had bigger wings and bodies to be able to catch and eat the moas. They were better fed and lived longer than the smaller eagles. They also had more chicks, some of which *needed* to be bigger, too. The chicks that were bigger were able to live longer, and they had more chicks, as well. So, over many millions of years, these little changes in body size made a big difference. Over time, eagles *needed* to change to adapt to their surroundings. After a million years, the Haast eagles were larger than any other kind of eagle that ever lived on Earth.

Kiwi

This is a kiwi. Kiwis don't *need* to fly. They have tiny wings, kind of furry feathers, and big feet. They also *need* a great sense of smell, which most birds don't. Kiwis live in New Zealand. To get food, kiwis *have* to burrow in the ground to find bugs and worms. But, do you know what!? Millions of years ago, the ancestors of kiwis looked very different. Scientists think they looked like regular birds. They could even fly. How could that happen? In New Zealand, where the ancestors of the kiwis lived, the ground was safe because there were no animals that could hunt them. There were lots of bugs and worms in the ground for them to eat. So they didn't *need* to fly. Some kiwi ancestors changed in order to have bigger feet for digging and a better sense of smell. The kiwi ancestors with bigger feet were better at finding food under the ground. So these kiwi ancestors ate better and lived longer than the other kiwi ancestors. They also had more chicks, some of which *needed* bigger feet, too. The chicks with the bigger feet lived longer, and they had more chicks, as well. So, over many millions of years, these little changes in foot size made a big difference. Over time, kiwis *needed* to change to adapt to their surroundings. Now, there are kiwis with big feet, *needed* for digging, a good sense of smell, which they need to hunt for worms, and almost no wings. They look really different from their ancestors, who had wings.

Appendix C. Natural Selection Narratives

Brownbird

This is a medium brownbird. These brownbirds live on these islands. Different kinds of brownbirds have different beaks and eat different kinds of food. The medium brownbirds have big heavy beaks. They can eat the tough seeds of Tribulus plants that grow on these islands. But, do you know what!? Many years ago, the ancestors of these brownbirds had beaks that looked quite different. Scientists think that they had small light beaks. How could that happen? The brownbird ancestors were probably blown to the islands by storms. When they arrived, the islands were covered with plants with small soft seeds. Because the brownbird ancestors had small beaks, they could eat the soft seeds. But, there was a change in the weather. For many years, there was no rain, and the plants with the soft seeds died. Only the tough Tribulus plants lived. Most brownbirds did not live because they could not eat the tough Tribulus seeds. But some brownbirds had slightly heavier beaks and could eat the tough Tribulus seeds. The brownbirds with heavier beaks ate better and lived longer than the small-beaked brownbirds. They also had more chicks, some of which had heavier beaks, too. The chicks with the heavier beaks lived longer, and they had more chicks, as well. So, over many years, these little differences in beak size made a big difference. Over time, brownbirds evolved. Now, many years later, the medium brownbirds have very different beak shapes than their ancestors.

Haast Eagle

This is a Haast eagle. They were the biggest eagles ever. They had very strong legs, long wings, and a sharp beak. Haast eagles once lived in New Zealand. But, do you know what!? Millions of years ago, the ancestors of the Haast eagle looked very different. Scientists think they looked like regular eagles. How could that happen? About 2 million years ago, there were huge birds in New Zealand called moas. They were almost 10 feet tall. They couldn't fly but were safe because there were no animals big enough to catch them. Then, about a million years ago, a small flock of eagles arrived on New Zealand. Maybe they were blown there by storms. At first, these eagles were much smaller than the moas. But some eagles were a little bit bigger than most of the other eagles. Being bigger, they began to catch bigger food, like the moas. So the eagles that had bigger wings and bodies were able to catch and eat the moas. They were better fed and lived longer than the smaller eagles. They also had more chicks, some

of which were bigger, too. The chicks that were bigger lived longer, and they had more chicks, as well. So, over many millions of years, these little differences in body size made a big difference. Over time, eagles evolved. After a million years, the Haast eagles were larger than any other kind of eagle that ever lived on Earth.

Kiwi

This is a kiwi. Kiwis can't fly. They have tiny wings, kind of furry feathers, and big feet. They also have a great sense of smell, which most birds don't. Kiwis live in New Zealand. To get food, kiwis burrow in the ground to find bugs and worms. But, do you know what!?! Millions of years ago, the ancestors of kiwis looked very different. Scientists think they looked like regular birds. They could even fly. How could that happen? In New Zealand, where the ancestors of the kiwis lived, the ground was safe because there were no animals to hunt them. There were lots of bugs and worms in the ground for them to eat. So they didn't have to fly. Some kiwi ancestors had bigger feet for digging and a better sense of smell. The kiwi ancestors with bigger feet were better at finding food under the ground. So these kiwi ancestors ate better and lived longer than the other kiwi ancestors. They also had more chicks, some of which had bigger feet, too. The chicks with the bigger feet lived longer, and they had more chicks, as well. So, over many millions of years, these little differences in foot size made a big difference. Over time, kiwis evolved. Now, there are kiwis with big feet for digging, a good sense of smell to hunt for worms, and almost no wings. They look really different from their ancestors, who had wings.

Appendix D. Closed-Ended Items: Haast Eagle and Kiwi

Children were asked how much they agree with each of the following items:

Haast Eagle Questions

1. Special Haast eagles were made that way to eat the big moas.
2. The Haast eagles' ancestors wanted to have big bodies because they liked to eat the moas.
3. The Haast eagle ancestors' bodies changed because they needed to eat the big moas.

4. Only the Haast eagle ancestors with big bodies could catch the moas, so they ate well and had more babies.
5. The Haast eagles' big bodies are the result of evolution.

Kiwi Questions

1. Special kiwis were made that way to eat the bugs in the ground.
2. The kiwis wanted to have small wings and big feet because they liked to eat the bugs under the ground.
3. The kiwis' wings and feet changed because they needed to eat bugs under the ground.
4. Only the kiwi ancestors with small wings and big feet could eat bugs under the ground, so they lived and had more babies.
5. The kiwis' small wings and big feet are the result of evolution.