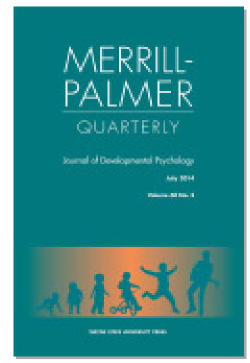
Introduction to the Special Issue

David H. Uttal



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Introduction to the Special Issue

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The development of conceptions of evolution is a problem of both great practical concern and important theoretical interest. Many Americans do not understand basic principles of evolution, such as natural selection, and part of the reason may be that these concepts are notoriously difficult to learn and to teach. The four contributions in this special issue all investigate the development of conceptions in evolution. Several of the articles focus on the interaction between children's prior beliefs and their interpretation and cognitive construction of evolutionary concepts. For example, *essentialist* beliefs (e.g., Gelman, 2003) may affect how children understand and interpret natural selection and the evolution of species. The four articles all demonstrate that prior beliefs constrain and influence how children and adults interpret what they observe and are taught about evolution. Taken together, the articles demonstrate the importance of taking a developmental approach to understanding the development of conceptions of evolution.

The best basic research often focuses on problems of practical or societal concern (e.g., Medin, 2012; Stokes, 1997). For example, major advances in understanding the psychology of attention grew out of the very practical needs that arose in World War II from the introduction of radar as an early warning system. The topic of this special issue—the development of conceptions of evolution—is another good example of the reciprocal benefits for basic and applied work that can derive from working on real, practical problems.

The practical problem in this case is obvious and extreme: Many Americans, perhaps the majority, either reject evolution outright as an explanation for the origin of species or are unsure whether evolution is correct. For example, a Gallup Poll (Newport, 2009) conducted on the

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200th anniversary of Darwin's birthday found that only 39% of Americans say they "believe in the theory of evolution." There are many reasons that Americans doubt the validity of evolution, including religious beliefs that are assumed to be incompatible with evolution. Here, we focus on another possible reason for American's rejection and misunderstanding of evolution: Evolutionary concepts, such as natural selection and phenotypic variation, are notoriously difficult to learn and teach (see Evans, 2001; Scott, 2005). Evolutionary change can rarely be observed directly, and people often have great difficulty reconciling their initial ideas about how species change with formal teaching about evolution.

A central premise that guides most of the articles in this special issue is that the perspectives and methods of developmental psychology can shed light on why these topics are so difficult to learn and to teach. For example, evolutionary change will often involve conceptual change, and developmental psychology has made great strides in understanding the nature of conceptual change and how it can be influenced. We know from decades of research that concepts are cognitive constructions; they emerge through an interaction between the concepts that the child already has and what he or she observes or is taught. Concepts cannot be directly put into children's heads; they are integrated with an influence (e.g., diSessa and Sherin, 1998; Vosniadou & Brewer, 1992).

At the same time, the field of developmental psychology benefits greatly from studies of the nature and development of concepts of evolution. All of the articles in this special issue shed light on fundamental issues of interest to psychologists and education researchers, such as the following: What does it mean to say that someone *has* a concept, and what do we make of variability in understanding and application of that concept. How does visual-spatial thinking influence conceptual development? How, when, and why should students' concepts be challenged? How do children integrate new information with what they already know?

More specifically, most of the articles deal with the relation between children's *essentialist* beliefs and their reasoning about concepts related to evolution (e.g., Gelman, 2003, 2004). The essentialist bias manifests as a tendency to view living things in terms of inherent, unchangeable characteristics that are present at birth and passed on from parents to child. This bias is termed *essentialism* because the child focus is on the essential, enduring properties of the organism. For example, in the classic "switched at birth" paradigm (e.g., Springer, 1996), children are asked to reason about a pet or other animal that is born to parents of one kind but raised by parents of another. Young children's answers almost always favor the influence of the biological parents. Young children may incorrectly attribute the causes of changes to the organism even when the environment would offer a better explanation.

As Shtulman and Calabi point out in this issue, essentialist assumptions may make it very difficult for children to understand some of the most important concepts of evolutions (see also Gelman & Rhodes, 2012). Natural selection happens at the level of individual members of the species, and hence variation within individuals is the most important factor in natural selection. Believing that inheritance is the passing of an *essence* seems diametrically opposed to understanding that natural selection operates at the level of individuals. Several of the articles in this special issue deal with the complex and fascinating interaction between children's essentialist beliefs and their understanding of evolutionary information.

Synopsis of the Four Papers

Shtulman and Calabi assessed the effect of taking a college-level biology course on students' understanding of evolution and its mechanisms. The pretest and posttest assessments included not only measures of what students knew but also how the information was organized cognitively. Their specific focus was on whether students were transformationists or variationists. *Transformationists* believe that one species changes in another in response to environmental demand. *Variationists,* in contrast, understand that natural selection operates on variability across individuals within a species. Variability is thus essential to natural selection.

Shtulman and Calabi assessed six different aspects of students' understanding of evolution: variation, inheritance, adaptation, domestication, speciation, and extinction. Patterns of responses across these six sets of questions revealed both which set of beliefs students held and whether the beliefs were strongly consistent across the different kinds of questions. For example, a strong variationist would tend to give coherent answers across all six sets of questions, all of which appealed to ideas of variability and natural selection of phenotypic traits.

The results were intriguing. A surprisingly high number of the students held (incorrect) transformationist beliefs, even after the class. Overall, biology class instruction was only modestly successful in addressing misconceptions. However, the class did lead to changes among a particular subset of students: Those who were both inaccurate and consistent in this inaccuracy across the different questions. This is a counterintuitive finding; the students who were most consistently wrong and hence held the strongest transformationist beliefs were the *most* likely to change their conceptual models of evolution. This finding is very important for both basic research and its application to teaching; it strongly suggests that personal theories of evolution are most amenable to change when they are coherent, perhaps because the new information contradicts so strongly with existing beliefs.

The article by *Legare, Lane, and Evans* demonstrates the importance of language in the development of children's conceptions of evolutionary conception. Evolutionary change is not easy to describe, particularly to young children. To help, adults often cast evolution in anthropomorphic terms, such as suggesting that biological entities have a conscious desire to change. For example, they may talk about finches wanting to change their beaks to be more effective in foraging for different kinds of seeds or about dinosaurs evolving into birds because the dinosaurs wanted to fly. As the authors point out, these anthropomorphic references could conceivably facilitate understanding because they provide a tractable metaphor to understand an unobservable change. However, anthropomorphic language also might reinforce misconceptions of the nature of evolutionary change.

To test the effects of anthropomorphic language on children's understanding of evolutionary change, Legare et al. told children three stories about three different birds. One of the stories used anthropomorphic language, describing evolution in terms of the birds' desire to change. The children also heard two other stories that emphasized different (possible) mechanisms of change. One was the *correct* explanation, in that it explained change in terms of natural selection. The third explanation focused on needs. For example, the story emphasized that a bird's beak evolved from small to large because of a change in a food source; the bird *needed* to change its beak to obtain the new food. The stories were randomly assigned to be about the three different birds, so the effects are not due to the characteristics of one particular bird.

The researchers included a variety of measures. One of the most interesting was simply having children recall and retell the stories. Of course, none of the children remembered the stories exactly, so coding what words they used and what information they emphasized provided insights into how they thought about evolutionary change and the influences of the different stories on children's comprehension.

The results indicate that the language we use matters: Anthropomorphic language—casting evolutionary change in terms of a desire to change—led to significantly more explanations and memories that focused on specific desires for change. Both the natural selection and need-based stories led to improved understanding of the nature of evolutionary change. Legare et al. suggest that need-based language could be a scaffold that helps children *not* to think in anthropomorphic terms and to focus instead on the relation between environmental change and evolutionary change. Once again, we see that basic research leads to important implications for education, and that studying an educationally relevant question leads to better research.

The article by *Herrmann et al.* also investigated the effects of an intervention on people's thinking about evolution, but in this case, the participants were young children and the intervention was less formal than Shtulman and Calabi's intervention. Herrmann et al. investigated how children integrate transformative biological events with their prior conceptions of biological changes and with essentialist beliefs. Children must learn about a variety of different biological changes, and reasoning about these changes may be critical to understanding evolution. Some changes involve only growing larger but maintaining a similar form; a puppy growing into a dog is a good example. But other changes are much more dramatic; the metamorphosis of a caterpillar into a butterfly, for example.

In their first study, they asked 3-, 4-, and 7-year-olds to assess whether different kinds of change were possible, as well as about the causes of possible change (e.g., magic, biological transformation, growth). For example, children were shown a picture of a puppy and then a picture of an adult dog or adult cat. They were asked whether the puppy could turn into a dog, and whether it could turn into a cat. Likewise, they were shown a caterpillar and a butterfly and asked whether one could change into the other and to explain why (or why not). Children of all ages tended to reject changes that violated their essentialist beliefs, such as species change (e.g., puppy to cat). However, the younger children *also* were more likely to reject the possibility of transformative biological change, such as a caterpillar changing into a butterfly.

In their second study, Herrmann et al. allowed children to observe a transformative change. Terrariums containing caterpillars were placed in the children's classrooms, and the children watched as the caterpillars made cocoons and transformed into butterflies. Herrmann et al. then tested children's reasoning about these and other kinds of biological and nonbiological changes. The performance of the children who observed the metamorphosis was compared to that of a control group that was tested twice but did not experience an intervention between the two testings.

Observing the caterpillar-to-butterfly metamorphosis did lead to more acceptance not only of this change but of other dramatic biological changes, such as a tadpole changing into a frog. Nevertheless, the scope of the increase was limited. The children did not accept, for example, the suggestion that a puppy could change into a cat. The refusal to generalize across species shows that essentialist beliefs constrained the scope of the inference that they made from observing the metamorphosis. Witnessing this transformation may actually have reinforced essentialist beliefs because children could now think of the caterpillar and the butterfly as sharing a common essence. A puppy and a kitten do not have a common essence, and thus one could not change or evolve into the other. Thus, learning more about biological change does not replace essentialism but does alter what kinds of changes children think are possible. These findings may be helpful to teachers or museum directors because exposure to transformative changes is a very common intervention in early childhood education.

Finally, the article by *Ainsworth and Saffer* is a bit different from the others in that it does not emphasize preexisting beliefs or conceptual change. Instead, these researchers investigated elementary-school children's understanding and learning of evolutionary concepts from visual representations. In this case, the visual representation is the *cladogram,* which depicts the evolutionary or *cladistic* relations among species. The term is derived from *clade,* which refers to a group of organisms that are believed to have evolved from the same common ancestor. Cladograms facilitate reasoning about descendancy—they show how closely one species, or family, or class (depending on the depth of the representation) resembles another. Cladograms often resemble branching trees, as they may begin with a common ancestor (the trunk) and then branch out. These sorts of graphs, and what they represent, are so important in evolutionary biology that *tree thinking* has become a central focus on research on evolution education and related terms (Baum, Smith, & Donovan, 2005).

Ainsworth and Saffer's results clearly show that children can learn from cladograms. With practice and instruction, they could deduce relations of species, particularly common ancestry. These results are particularly interesting in light of recent research that has stressed the difficulties that *adults* can have in using these representations cladograms (Catley & Novick, 2008; Novick, Shade, & Catley, 2011). Ainsworth and Saffer's results indicate that it may be possible to begin instruction at an earlier age and hopefully avoid some of the difficulties that adult students experience when using cladograms. In addition, even though their article's focus was different than that of the others, their results are quite consistent with the general idea that new information about evolution both reflects and changes the conceptual understanding that children bring to these tasks.

Conclusion

The articles in this special issue demonstrate convincingly why evolution is so difficult to learn and to understand: It is not always easy to reconcile evolutionary change that contradicts some of the most fundamental and universal beliefs that people have about inheritance and what members of the same species share in common. After all, the fact that Darwin's theories were seen as so revolutionary is evidence that they were not easy to accept. Moreover, all of the articles point to important new ways to address the incongruence between evolutionary change and essentialist beliefs. For example, the articles indicate that we need to think carefully about the language that we use when talking to young children and about how they react to observing a metamorphosis. Finally, the articles clearly demonstrate the benefits that developmental psychology can gain from working on important, real-world problems. It may be time to abandon the false dichotomy between basic and applied research.

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