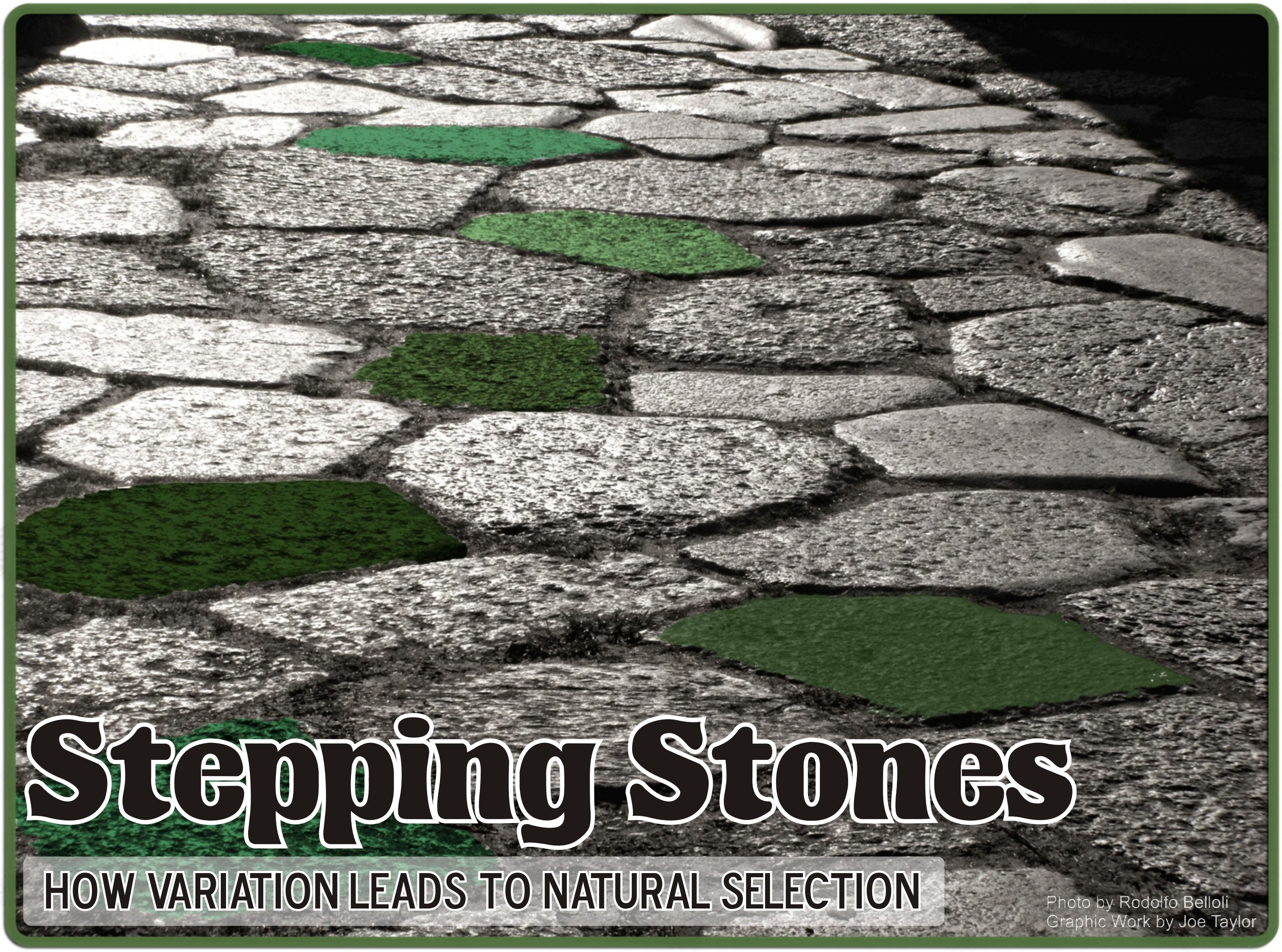

Stepping Stones

HOW VARIATION LEADS TO NATURAL SELECTION

Anne H. Weaver, Ph.D. & Brian "Fox" Ellis

ABSTRACT: *This is the second of a series of articles in celebration of Charles Darwin's 200th birthday and the 150th anniversary of the publication of his seminal work* On the Origin of Species*. In the article below we discuss ways to introduce students to variation and develop their understanding of Natural Selection.*

The theory of natural selection has left every other explanation of life's unity and diversity in the dust. Natural selection can explain the amazing instinct of the honeybee to build hexagonal cells, the tendency of the cuckoo to lay eggs in other birds' nests, the gorgeous enticements of flowers, the presence of giant fossil sloths in the Americas but not in Europe, and the apparent brutality of wasps that lay their eggs in the soft bodies of other insects.

The premise of natural selection is straightforward. A simple acronym, VISTA, sums it up. Variation. Inheritance. Selection. Time. Adaptation (Ellis, 2008). That is, in any population of organisms, individuals will be different from one another. They will vary in ways both visible and unseen and many of these variations will be passed on to their offspring. Depending on the environment, some variants will be better able to compete in the great struggle for life: to obtain food and water; to withstand the elements; to attract mates. Nature culls the unsuccessful variants and rewards the survivors with progeny who inherit their parents' advantageous traits. As time passes, the composition of the population will reflect the traits that confer success.

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Introducing students to evolution

The importance of variation

The idea of variation is central to understanding evolution. Yet variation may be the most problematic of the elements of natural selection theory for children (or anyone) to grasp. The activities presented here are designed to help students negotiate a barrier for understanding evolution that baffled even Darwin for many years: the manifestation of individual variation within and among species.

Like many children, the young Darwin was a collector, driven by an obsession to amass and name all kinds of objects. He found them interesting in themselves, but made no effort to fit them into an overarching theoretical framework. Of beetles he said, "It was the mere passion for collecting, for I did not dissect them, and rarely compared their external characters with published descriptions, but got them named anyhow (Darwin, 1993)."

Darwin did not break away from thinking (as many children do) that members of a species represent more or less true versions of an ideal type until cornered by an inability to make sense of a mountain of evidence. Years of collecting, naming and classifying compelled him to write, at the age of 35:

> I was so struck with distribution of Galapagos organisms ....& with the character of the American fossil mammifers, ...that I determined to collect blindly every sort of fact, which bear any way on what are species. I have read heaps of agricultural & horticultural books, & have never ceased collecting facts. At last gleams of light have come, & *I am almost convinced (quite contrary to opinion I started with) that species are not (it is like confessing a murder) immutable* (Darwin, 2009). [Emphasis added.]

If Darwin himself had such a hard time accepting that the boundaries between species are not fixed; that there can never be an individual within the species that perfectly embodies its essence; that species are merely a convenient way for us to classify and conceptualize the natural world, but they can actually morph into something else, how much more difficult it is for our students, who often cannot name the birds in their own back yards or the ants on the school playground!

If our students are to understand natural selection, then this is the place to start, with an introduction to variation. The following activities are adaptable for many age-levels, but the earlier students have an opportunity to open their eyes to the wealth of variation that surrounds them, the better.

Observing Variation

The purpose of this introductory activity is to observe biological variation within and between species and to speculate what might cause this variation.

Start by showing students a group of organisms (i.e.: a flock of pigeons, group of guppies, or a bouquet of the same flowers). Ask students to list the characteristics of the organisms. Put the list on the board/overhead. Once students have identified common characteristics ask them how they might be able to tell the difference from one organism to the next. For example,

- "How could we tell one flower apart from the group?"
- "If we each picked out our own guppy, how would you know which is yours?"
- "What specific things could you use to identify *your* organism?"

During this discussion, work to help students identify differences in these similar organisms.

Once students have identified several traits that can be useful in distinguishing individual organisms move onto examining the traits in more detail. I often use the example of flowers to help students understand variation. I begin by asking the class,

- "The color of the flowers all seems to be similar, but you have noted the color can be used to tell one flower from the next. What do you think is the "normal" color of this flower?"

To continue the discussion, ask students questions such as:

- "How can the color of the flowers be used to distinguish between the individual flowers?"
- "How do you think these variations in the flowers occur?"
- "How can you explain that we don't look exactly like our parents?"
- "How might this help you explain how flower variations occur?"
- "How could we set up a test to see if the variations are inherited or caused by the flower's surroundings?"
- "You have observed visible variation. In what other ways might individuals vary?"
- "How do you think the differences in color of the flowers might affect their ability to survive or reproduce?"

To continue developing student ideas about variation, additional organisms could be examined or different traits of the original organism could be discussed. As another option, students could work in groups on various organisms and present variations of interest to the class. The key to this activity is to help students identify *that* variation occurs, to begin speculating *how* variation occurs, and to wonder how variation might affect the ability of the organism to survive and/or reproduce.

When engaging students in discussion, we work to react to student ideas as best as we can. Instead of expecting students to have specific responses, we work to use student ideas. Many of the questions above could be modified for any organism or characteristic students point out. In addition to using student ideas, we are sure to maintain positive facial expressions and move around the room to encourage multiple ideas from students. We want students

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to be discussing ideas with each other rather than waiting for directions from the teacher. By waiting a few seconds after questions or responses, students are more likely to jump in with their own thoughts. Over time the classroom culture becomes discussion oriented and we can interject our questions and thoughts at critical times to keep the discussion moving forward or to draw students' attention to important ideas.

Field Observation

Now that students have identified variations, they are ready to expand their understanding and knowledge of individual variation within and among organisms. Students will conduct fieldwork to increase their observations and deepen their thinking about variation. Students will make observations outside during this class period so we start by discussing expectations and goals regarding what is to be achieved while outside.

To set up our expectations for individual work we ask students,

- "You know that I have high expectations for you. Why will maintaining these expectations be more difficult when we are outside?"
- "How can you help yourself live up to these expectations?"

We may even expand on this discussion by asking students what behaviors we expect to see and what behaviors we expect to not see.

Next we discuss the activities for the day. We tell students they are going to be observing a square of grass approximately 3 ½ feet x 3 ½ feet. We often have the squares pre-measured for students, but having students find and measure their own area works as well. We lead students in a discussion of what they might look for by asking questions such as:

- "What things do you think you'll observe in your "field"?"
- "How should you go about observing your field considering you do not want to disturb it?"
- "How could you document your observations?"
- "How will you organize all the different organisms you observe?"

Notice we do not simply tell students how to conduct their fieldwork. We want students to understand that science is a creative process that requires decision-making. Science is not the simple rote-memorization, step-by-step directions they have often experience in science classes. Not only are we helping students understand more accurately how science and scientists actually work, we are actively promoting creativity, critical thinking, problem-solving and effective communication.

When these discussions do not go as we hope, we should consider how our own responses might limit students' ideas and thinking, and in turn their responses and questions. If we consistently reject student ideas we limit their willingness to engage fully in discussion. Similarly, if we overly praise specific responses, the students pick up on the subtle clues that some responses are better than others. Moreover, when judgmental teacher responses are used in the classroom, some students are reluctant to participate unless they know their answer is correct. This makes understanding many students' ideas difficult. Instead of judging students' answers, we work to respond to student ideas symmetrically, asking for more ideas or further explanation rather than confirming/rejecting ideas.

While students are observing and taking notes of their "field," we roam around to different fields (sometimes we have multiple students at each site) and ask questions to push student thinking and observation to more depth and detail. These questions can also serve as class discussion questions after the students have collected their data. Questions we have asked include:

- "How do you think the different kinds of organisms are related? How might the organisms interact with one another?"
- "What adaptations did you notice on the organisms you have observed"
- "What variations did you notice between the same types of organisms?"
- "How might the variations between similar types of organisms affect that organism?"
- "What do you think causes the variations from one individual to the next?"

Observing and Investigating Natural Selection

Once students have been introduced to the idea of variation, they can begin to wrestle with the ramifications of such variation. Starting students off with an experience such as the activity described below will be useful in later discussions regarding natural selection. This activity can serve as common experience for students to reflect on during future class discussions.

Materials:

- Two pieces of different colored felt (24"x 24"). To represent a natural environment, one might be gray; the other light brown.
- 100 pompom "mice" of each color to match the felt.
- tweezers (representing hawk's talons)

In this inquiry, two pieces of different colored felt will represent two different environments. Small creatures (pompoms) exposed on the surface of the felt will represent "mice" living in that environment.

We usually hand out a sheet to students as outlined on the next page. We have also explained to students the "rules of

Hawks and Mice: An Investigation

Purpose
In this inquiry you will investigate how adaptations affect two populations of mice living in different environments.

Method
Lay out the two pieces of felt. On each piece of felt, scatter 12 gray pompons and 12 brown pompons. You will go through two or three cycles of predator activity followed by reproduction, as described below.

Predict
If hawks flying overhead catch the most visible mice, which mice will they capture more often on the gray felt? On the brown felt? Why?

After a hawk attack, the surviving mice will reproduce. Predict which color mouse will be the most common in the gray environment after several cycles of predation and reproduction? Predict which color mouse will be the most common in the brown environment after several cycles of predation and reproduction?

Procedure
Mice in Gray Environment

1. First generation: Scatter 12 gray mice and 12 brown mice on the gray felt background.
2. Let one student act as a hawk, using the tweezers to capture as many mice as you can in ten seconds (the time may need to be adjusted depending on student speed).
3. Put the captured mice in the storage bag.
4. Now the surviving mice will reproduce to make Generation 2. The offspring (children) will inherit their fur color from their parents. For every surviving gray mouse, add two gray pompon offspring. For every surviving brown mouse, add two brown pompon offspring.
5. Count your mouse population and record your observations in a drawing or table (see the example below).
6. Second Generation: Repeat
   Let a hawk capture the most visible mice on each background. Let your surviving mice produce two offspring each. Count the new population and record your data.
7. Third Generation: Repeat
   Let a hawk capture the *most visible* mice on each background. Count the remaining mice of each color and record your data. Let your surviving mice produce two offspring each. Count the new population and record your data.

Mice in brown Environment
Repeat steps 1-7, but this time the background will be brown and the hawk will capture more gray mice.

Observe and Record
Make sure to record your observations. Every time you change the number of mice through predation or reproduction, write down the number of mice present in the population and make note of interesting trends or patterns you note.

the game," but have found the sheet to be more useful as students can refer back to the sheet with questions. In this activity we are not worried that the directions are step-by-step because we want the students to make specific observations on which we will have them later reflect. However, we do point out to students that the step-by-step nature of this activity does not accurately reflect how real scientists work by asking,

- "Why are the step-by-step directions of this activity not like real science?"
- "Why do you think I am having you complete this task as directions?"

Discussions like this can deepen students understanding of both the nature of science and the nature of learning.

While working through the activity, students should record their observations in an age appropriate way. Younger students might count and draw the number of mice on each background to develop an elementary bar graph (Figure 1); older students should record their data in table form and display it in a more formal graph (Figure 2). Most students will be able to create a way to organize their data. Instead of giving students the charts/graphs below, use the examples as a guide to help you lead rather than direct students. Depending on your time constraints, you might even have students discuss pros and cons of various ways to organize their data.

We are sure to circulate around the room while students are working to probe student thinking and monitor their progress. Our presence helps us to proactively manage the class. As necessary, we pose questions and help struggling groups so that the students continue to be engaged with the activity.

Discussing student investigations

Students may be surprised to learn that one consequence of natural selection is that individuals will vary for any given characteristic, though do not change during their lifetime. What changes is the proportion of individuals with a given characteristic from generation to generation. To draw their attention to this we ask,

- "Notice that the mice did not change colors, but over time the population becomes more uniform. How does that happen?"

For older students we might ask,

- "How is the gray/brown mice situation different than nature?"

To continue the discussion toward natural selection we ask questions such as:

- "The mice in this situation are varied in color, how does nature then "select" for certain varieties?"
- "What other characteristics of mice are adaptations resulting from natural selection?"

Linking Variation and Natural Selection

To help students put the whole puzzle together, we start a discussion by asking,

- "You have observed variation in organisms and we have discussed possible ways that variation occurs. Considering the mice activity and natural selection, how can these variations lead to changes in the overall population of a type of organism?"

Students may struggle with this question and may need scaffolding questions such as:

- "How do you think a light brown mouse could be born in a population of all dark brown mice?"
- "In what sort of environment would this new mouse be better adapted than the rest of the population?"
- "If that light brown mouse was better adapted for the environment, how will the mouse benefit?"

FIGURE 1
Sample bar graph that an elementary student might create.

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- "Over time, what is likely to happen within this population of mice?"
- "What control do the mice have over this process?"
- "What does control this process?"

Application of Natural Selection

We use a real world example to encourage students to think more deeply about and apply their new understanding of natural selection. We explain to students that in New Mexico lava flows have colored some ground surfaces deep gray or black; in other places, limestone results in a pale brown background. Mice living in each environment tend to have fur that matches their environment. We then ask the students to either reflect in writing or discuss as a class how they can use what they just learned to explain the color of the mice living in New Mexico. This discussion or writing provides us with great insight concerning student understanding.

Parting Suggestions

The activities above require extensive expertise of the teacher. We must not only understand our content, but also how to manage our class and create a culture of curiosity and openness. The questions we have provided indicate possible directions discussions may go, but none of us knows what ideas each new group of students may put forth. Reacting to students' ideas rather than following a script better meets student needs and helps them navigate through their misconceptions. Yet, this navigation takes expert guidance. Furthermore, if students do not feel safe sharing their ideas, we limit our own ability to help them through conceptual hurdles. Effective teaching requires flexibility, understanding our content, and perhaps most importantly, understanding the learners our students.

Through careful use of these activities, students will gain valuable experience and understanding of the ideas behind natural selection. Rooting students' learning in experience helps them understand the important role of evidence and observation in science and provides rich concrete experience on which later learning can be built. By encouraging students to make observations and voice their ideas, their minds are more actively engaged with the content. From this fertile ground of curiosity, we can help them grow in understanding.

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***Dr. Anne Weaver** and **Brian "Fox" Ellis** previously published an article about Charles Darwin in the Winter 2009 issue of ISTJ. Dr. Weaver has published two books: The Voyage of the Beetle and Children of Time. She also mentors middle school science teachers and works with local organizations devoted to improving science education. Visit her web site at www.voyageofthebeetle.com. **Brian "Fox" Ellis** is a noted storyteller, author and school consultant. He was the keynote speaker at the 2008 ISTS Fall Conferences . For more information about performances and workshops please visit www.foxtalesint.com.*

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