

---

# KICKING THE TIRES OF NATURAL SELECTION: THE CARRIAGE STILL RUNS AFTER 150 YEARS

By Anne H. Weaver, Ph.D. and Brian “Fox” Ellis

---

(Authors’ Note: This is the second of a series of articles in celebration of Charles Darwin’s 200<sup>th</sup> birthday and the 150<sup>th</sup> anniversary of the publication of his seminal work *On the Origin of Species*. In the article below we discuss how Darwin’s Natural Selection theory is still going strong. We include lesson plans designed to help students understand Variation, an important key concept underpinning Natural Selection theory.)

**“Evolutionary theory has been successful precisely because it is revisable in light of new observations and theorizing. Furthermore, it is the only theory of biological origins that has had this kind of success.”<sup>1</sup>**

Darwin’s classic theory of Natural Selection, the vehicle that transported our understanding of the living world into the modern age, first hit the road in 1859 with the publication of *On the Origin of Species by Means of Natural Selection*.

The theory of Natural Selection has left every other explanation of life’s paradoxical unity and diversity in the dust. Darwin’s new explanation could accommodate 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 amoral brutality of wasps that lay their eggs in the soft bodies of other insects.

After a century and a half, the carriage still runs. To be sure, Darwin’s capacious vehicle has been refurbished. Nowadays, evolutionary theory comes with standard equipment Darwin could not imagine.

Darwin could only speculate about critical turning points in the journey of life. To day, many gaps have been filled in by hard data: fossils document early feathers, wings, legs, jaws, ear bones, eye sockets, teeth, skulls, braincases, tail flukes, and fragments of ancient DNA document key transitions: from water to land and back again; from land to air; from reptile to bird; from slime to shell.

Modern evolutionary theory adds engine capacity to Natural Selection. The observations of field biologists now fit within a chassis powered by genetics, population biology and computer simulations. A transmission has been added to reflect the variable tempo and mode of evolutionary change. We have discovered that evolution may proceed gradually, as Darwin envisioned, but that it is sometimes characterized by long periods of stasis punctuated by bursts of evolutionary innovation.<sup>2</sup> But Natural Selection still rumbles along.

The premise of Natural Selection is straightforward. A simple acronym, **VISTA**, sums it up. Variation. Inheritance. Selection. Time. Adaptation<sup>3</sup>. That is, in any population of organisms individuals will be different from one another. They will vary in ways both visible and invisible 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

*continued on page 12*

---

1 Richards, R.A. “Philosophical Challenges in Teaching Evolution.” *Evo Edu Outreach* (2008) 1:158–164.

2 Eldredge, Niles and Gould, Stephen Jay. (1972). “Punctuated equilibria: an alternative to phyletic gradualism” In T.J.M. Schopf, ed., *Models in Paleobiology*. San Francisco: Freeman Cooper. pp. 82-115. Reprinted in N. Eldredge *Time frames*. Princeton: Princeton Univ. Press. 1985

3 Ellis, B. (2008). *Charles Darwin’s Revolutionary Idea*. BookSurge Publishing.

---

traits. As time passes, the composition of the population will reflect the traits that confer success.

Once Natural Selection theory had been publicly unveiled, scientists at last had a framework for formulating hypotheses to do some tire-kicking of their own. And kick they did, shod in everything from sturdy hiking boots to laboratory booties. And lo and behold: souped-up and subject to ongoing tinkering, the carriage still runs.

Darwin jotted down his first tentative notes about natural selection theory in a notebook started in 1838, three years after his return from his round-the-world voyage on the *H.M.S. Beagle*. By 1842 he had sketched out his idea, and in 1844 he outlined his ideas in a 235-page manuscript. Darwin spent the next fifteen years gathering observations, testing hypotheses, “kicking the tires,” looking for weaknesses, facing them head on, struggling to integrate inconsistencies; in other words, employing every skill and tool he could muster as a scientist before he road-tested his idea on a public highway.

*On the Origin of Species* has an entire chapter devoted to a conscientious recitation of the problems Darwin could not resolve. Three categories of problems were especially hard to account for: In 1859 the fossil record for crucial transitions was abysmal. And in 1859 no one understood the mechanisms of inheritance: how did valuable traits get passed on from generation to generation? And neither he nor anyone else had documented natural selection in action.

Thanks to the work of geneticists from Gregor Mendel to Theodosius Dobzhansky<sup>4</sup> and Nobel winner Barbara McClintock<sup>5</sup>; thanks to the work of scientists like Rosalind Franklin, James Watson, Francis Crick, Ernst Mayr, and Lynn Margulis<sup>6</sup>; we have answered the questions about traits are passed on from one generation to

another through genetics and the road map of deoxyribonucleic acid.

Thanks to the paleontologists like Neil Shubin, Hans Thewissen<sup>7</sup> and Mary Leakey, many of the so called missing links have been found and a more complete picture of the fossil record has affirmed dozens of transitional species, including hoofed whale ancestors; *Tiktaalik* (a recently discovered “fishapod”); and early human predecessors.

Thanks to the formulations of population biologists like Sewall Wright, Ronald Fischer, and J.B.S. Haldane<sup>8</sup>; thanks to field biologists like Peter and Rosemary Grant in the Galapagos<sup>9</sup>; thanks to the curiosity, persistence and creativity and rigorous research of scientists all over the world, Darwin’s great insight has been vindicated over and over again.

Today, in 2009, after 150 years of rigorous, intense, determined investigation, Darwin’s theory is still a cornerstone of modern biology. Today, Darwin’s “just-so stories” have given way to true narratives documenting natural selection. Take, for example, the finches of the Galapagos that inspired Darwin.

Rosemary and Peter Grant have spent 20 years in the Galapagos watching evolution in action. They have documented natural selection in action, as the proportion of various beak shapes changes in response to climatic change. Another group of researchers correlated changes in the finches’ beak shape with a gene that codes for a molecule known as calmodulin.<sup>10</sup>

One hundred and fifty years of tinkering under the hood, one hundred and fifty years of stream-lining and increased fuel efficiency, one hundred and fifty years of research and innovation have only refined the theory. Not only does the carriage still run, it is the vehicle that propels all biological research into the future.

---

4 Anon. “Random Mutations and Evolutionary Change.” Ronald Fisher, JBS Haldane, & Sewall Wright. *The History of Evolutionary Thought: Understanding Evolution*. UC Berkeley. 2 February 2009. <[http://evolution.berkeley.edu/evolibrary/article/\\_0/history\\_19](http://evolution.berkeley.edu/evolibrary/article/_0/history_19)>

5 Barbara McClintock. National Academy of Sciences. 23 March 2009. <<http://www.nas.edu/history/members/mcclintock.html>>

6 Anon. *The History of Evolutionary Thought*, *op. cit.*

7 *Tiktaalik roseae*. The University of Chicago. March 23, 2009. <<http://tiktaalik.uchicago.edu/>>

8 Anon. *The History of Evolutionary Thought*, *op. cit.*

9 Weiner, J. (1995). *The Beak of the Finch*. Vintage Press.

10 Gee, H., Howlett, R. and Campbell, P. (2009). “15 Evolutionary Gems.” *Nature*. 2 February 2009. <<http://www.nature.com/nature/newspdf/evolutiongems.pdf>>.

---

## CLASSROOM ACTIVITIES

The activities below are designed to help students negotiate a barrier to understanding that baffled even Darwin for many years: the manifestation of individual variation within and among species.

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. Research on children's cognitive approaches to science suggests that even the youngest children explain the world to themselves from a perspective of naïve essentialism.<sup>11</sup>

From the perspective of naïve essentialism, a species is an entity with an immutable essence that characterizes and defines it. Naïve essentialism is based on the naïve idea that members of a species represent more or less true versions of an ideal type. Individual variation is seen as a failure to perfectly embody the type. ***But in natural selection theory, individual variation is the fuel on which the engine runs.*** Without individual variation, what would Nature have to select from?

If you don't get *that* variation occurs, you're unlikely to care *how* or *why* it occurs. The door to understanding evolutionary theory remains firmly shut.

As a child and even as a university student, Darwin himself saw the world as a naïve essentialist. Like many children, Darwin was a collector, driven by an obsession to amass and name all kinds of objects, animate and inanimate. 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."<sup>12</sup>

Darwin did not break away from his naïve essentialism until cornered into it by a mountain of undeniable evidence. Years of collecting, naming and classifying forced him to write, at the age of 35:

I was so struck with distribution of Galapagos organisms &c &c & with the character of the American fossil mammifers, &c &c that I determined to collect blindly every sort of fact, which c<sup>d</sup> 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 murderer) immutable.*<sup>13</sup> [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 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 theory, then this is the place to start, with an introduction to variation.

The following activities are suitable 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 the following activities is to observe biological variation within and between species and to speculate on what might cause this variation.

### Vocabulary

trait	species
variation	predator
hypothesis	natural selection
organism	sample
individual	

*continued on page 12*

- 
- 11 Disendruk, G. and L. Haber. (2009). "God's categories: The effect of religiosity on children's teleological and essentialist beliefs about categories." *Cognition*. 110(1):100-114.
- 12 Darwin, C.D. (1993) *The Autobiography of Charles Darwin (1809-1882)*. Nora Barlow, Editor. W.W. Norton Company.
- 13 Darwin, C.D. Letter to J. D. Hooker January 11, 1844. *Darwin Correspondence Project*. University of Cambridge. 2 February 2009. <<http://www.darwinproject.ac.uk/darwinletters/calendar/entry-729.html>>.

---

## ACTIVITY #1 – OBSERVING VARIATION

### Purpose

To observe and describe individual variation. To develop hypotheses about the possible effects of variation on survival.

### Predict

Develop an hypothesis. In what ways do you think the individuals in your sample will resemble each other? Do you think they will be different from each other? If so, how?

### Materials

Find a group of the same kind of organisms. Here are some examples to choose from. You may think of others.

- a sack of potatoes or apples
- a bouquet of the same kind of flowers
- a flock of pigeons
- a tank of guppies at the pet store
- a flat of seedlings at a nursery
- a stand of trees

### Procedure

Observe your sample organisms. Record the following:

- The scientific name of the species you have selected. (Look in a field book, ask a store clerk, or consult an encyclopedia for this information).
- The number of individuals in the group you are observing (sample size).

- For each group, choose two traits to observe. Discuss whether these traits are quantitative (they can be measured or whether they are qualitative (e.g., color or texture).

### Observations

For each trait, indicate the following:

- Is there a “typical” state for this trait?
- How many variations on the trait can you observe?
- Is there a correlation between any of the traits?

### Discussion

- For each trait, develop an hypothesis about whether the trait might be mostly inherited, or whether it might be affected by something in the environment. Briefly explain your reasoning.
- Describe how you might test your hypotheses.
- Develop an hypothesis about whether some aspect of the trait may help the individual survive in its usual environment. How might you test your hypothesis?
- You have observed visible variation. In what other ways might individuals vary?

### Conclusion

What did you learn from this activity? Discuss what you learned with a partner and make a list of three things you discovered.

---

## ACTIVITY #2 – FIELD OBSERVATION

### Introduction for Teachers

This activity is designed to awaken students to individual variation within and among organisms.

### Purpose

In this exercise you will do field work to discover that there are many levels of difference among organisms living in a similar environment.

### Materials

Find an area where a large number of plants are growing. Measure out a small field approximately 1 meter square (about 3 ½ feet x 3 ½ feet), and mark

the corners of your “field” with stones or other small objects.

### Procedure

- Closely examine the living organisms in your field.
- How many individual organisms can you count in your field?
- Approximately how many different kinds of organisms do you observe (1-5; 6-25; 30 or more?)
- Select three different types of organisms (plant, fungus, or animal).

### Observations

- Describe each of the organisms you have selected in detail. Include a drawing or photograph of each organism. (Do *not* pick flowers or break specimens!)
- Find the scientific names of your organisms in the field book. Notice that each scientific name has two parts. What do these parts represent?
- What can you learn about the habits and habitat of your selected organisms from the field book?
- Count the number of individuals belonging to your selected species in your “field.” What percentage does this represent of the total number of organisms in the field?

### Discussion

- Describe three ways in which different individuals of the same type of organism may vary.

- Speculate on what might cause this variation.
- Discuss how variation might contribute to the organism’s survival and reproduction (“fitness”) and discuss why (e.g., brighter flower color might be more attractive to pollinating insects)
- Describe the kinds of variation you might find among different species. Discuss how this variation might enable different species to live together in a small area.

### Conclusion

What did you learn from this exercise? Ask students to discuss their findings with a partner. As a classroom assignment, ask students to write a brief summary of their conclusion.

## **ACTIVITY #3 - NATURAL SELECTION INQUIRY: OBSERVING, EXPERIMENTING, PREDICTING AND VALIDATING**

### Introduction for Teachers

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.

Students may be surprised to learn that in natural selection individuals vary, but do not change during their lifetime. What changes is the proportion of individuals with a given characteristic from generation to generation.

Students should take turns recording 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; older students should record their data in table form and display it in a more formal graph (see below).

### Purpose:

In this inquiry you will investigate how natural selection works in two populations of mice living in different environments.

### Materials:

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

### Method:

Lay out the two pieces of felt. On each piece of felt, scatter 12 gray pompoms and 12 brown pompoms. 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

*continued on page 16*

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?
- Write down your predictions in the form of a *hypothesis* (a guess about what will happen to the different colored mice).

### 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 easily visible mice (those that contrast with the background) as you can in ten seconds.
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. (Younger students should count the mice and draw what they see; older students should record their data in a table as shown below.)

#### **Analyze and Discuss:**

Older children should calculate and record the fraction of each type of mice on each background, and use their results to create a graph.

gray mice/total mice  
brown mice/total mice

How does the proportion of gray mice and brown mice in the first generation compare with the second and third generations? How does the proportion or fraction of mice change in each generation? Do you see more gray mice or more brown mice in a gray environment in the third generation? Compare this with the fraction of gray and brown mice in the brown environment in the third generation.

#### **Conclusion:**

- Did your observations match your predictions? Why or why not?
- What changed? Was it the individual mice? Or was it the proportion of each kind of mice from generation to generation? (This is how natural selection works).

**REAL WORLD EXAMPLE**

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.

***Examples of Graphs for younger students:***

Mice in a Brown Environment		
Generation	Brown Mice	Gray Mice
1	○ ○ ○ ○ ○	○ ○ ○ ○ ○
2	○ ○ ○ ○ ○ ○ ○ ○	○ ○ ○
3	○ ○ ○ ○ ○ ○ ○ ○ ○ ○	○ ○

Mice in a Gray Environment		
Generation	Brown Mice	Gray Mice
1	○ ○ ○ ○ ○	○ ○ ○ ○ ○
2	○ ○ ○	○ ○ ○ ○ ○ ○ ○ ○ ○ ○
3	○ ○	○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○

***Data Tables for Older Students (Feel Free to download and copy for classroom use).***

NUMBER OF MICE OBSERVED IN EACH ENVIRONMENT				
	Environment 1 (Gray Felt)		Environment 2 (Brown Felt)	
	Gray Mice	Brown Mice	Gray Mice	Brown Mice
Number of mice to start (first generation)	12	12	12	12
Number of mice in second generation				
Number of mice in third generation				

*continued on page 18*

FRACTION OF MATCHING MICE OBSERVED IN EACH ENVIRONMENT

	Environment 1 (Gray Felt)	Environment 2 (Brown Felt)
Fraction of mice matching their environment in the first generation	$\frac{1}{2}$ (= 0.5 or 50%)	$\frac{1}{2}$ (= 0.5 or 50%)
Fraction of mice matching their environment in the second generation		
Fraction of mice matching their environment in the third generation		

**ABOUT THE AUTHORS:**

**Dr. Anne Weaver's** award-winning book The Voyage of the Beetle has received critical acclaim for its “playful, creative, and beautifully conceived and executed” description of the natural selection theory and its “loving and erudite” portrayal of Charles Darwin. Dr. Weaver taught college-level classes in human evolution for many years. She continues to write (a second book, Children of Time, is in press), mentor middle school science teachers, and work with local organizations devoted to improving science education. Visit her web site at <http://www.voyageofthebeetle.com>.

**Brian “Fox” Ellis** is a storyteller, author and school consultant, who has been a frequent keynote speaker at science teacher conferences. He has published 11 books, including Charles Darwin and His Revolutionary Idea, based on his one-man show as Darwin, and the award winning children’s picture book, The Web at Dragonfly Pond, about aquatic ecology and the food web. For more information about performances and workshops please visit [www.foxtalesint.com](http://www.foxtalesint.com)

**Michigan Science Olympiad**

*Reawaken their curiosity.*



- Science Olympiad offers 23 events in each of two divisions that cover biology, chemistry, earth science, physics, problem solving and technology.
- Events have strong correlation to the Michigan GLCE’s and HSCE’s. (Matrix available at [www.michiganso.org](http://www.michiganso.org))
- Events can easily be brought into a whole classroom environment, used as enrichment activities, or run as a club.
- Competitions with athletic style awards ceremonies provide recognition for students and increase student motivation.



Visit us at [www.michiganso.org](http://www.michiganso.org) to learn how you can be a part of the renaissance in science education.