

Kicking the Tires of Natural Selection: The Carriage Still Runs after 150 Years

Science is both tentative and durable. This is its great strength: as we discover new evidence, or find new ways to interpret existing evidence, scientific ideas can be modified, offering us a more complete and reliable picture of the universe. Helping your students understand this aspect of science not only reduces their resistance to learning about evolution, but also encourages deeper understanding about how science works.

Evolutionary Theory has Stood the Test of Time

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*.

After a century and a half, the carriage still runs, and nowadays it is a capacious vehicle with enormous explanatory power. To be sure, the chassis has been significantly refurbished: modern evolutionary theory comes with standard equipment Darwin could not have imagined. Improvements include extensive observations and refinements contributed by field biologists, geneticists, geologists, paleontologists, and computer modelers. A transmission has been added to reflect the variable tempo and mode of evolutionary change. But natural selection theory has incorporated and responded to these insights from various fields and still rumbles along.

Development and Testing of Evolutionary Theory

Darwin jotted down his first tentative thoughts about natural selection theory in a notebook started 1838, three years after his return from his round-the-world voyage on the H.M.S. Beagle. He sketched out his idea in more detail in an essay in 1842, which he expanded in 1844 and circulated among his scientific friends. 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 by Means of Natural Selection was finally published in 1859. It laid out a vast and detailed body of evidence in support of natural selection theory. But Darwin's scientific integrity was also evident in his conscientious recitation of where evidence was lacking and where his theory needed further testing. Three categories of problems were especially hard to account for: In the mid-nineteenth century the fossil record for crucial transitions on the history of life was abysmal. Nor was there a good understanding of the mechanisms of inheritance. How did valuable traits get passed on from generation to generation? Furthermore, neither Darwin nor anyone else had documented natural selection in action.

Fossil Transitions

Darwin could only speculate about critical turning points of life: from water to land and back again; from land to air; from reptile to bird; from slime to shell. But fossils discovered over the last 150 years now document early feathers, wings, legs, jaws, ear bones, eye sockets, teeth, skulls, braincases, and tail flukes. Thanks to the work of paleontologists like Neil Shubin, Hans Thewissen and Mary Leakey, a more complete picture of the fossil record has affirmed dozens of transitional species, including hooped whale ancestors and early human predecessors. And thanks to the observations of scientists like George Gaylord Simpson, Ernst Mayr, Stephen Jay Gould and Niles Eldredge, we know that those transitions are sometimes slow and gradual and sometimes occur in bursts of speciation after long periods of stasis.

Inheritance

Even as *The Origin of Species* rolled off the presses, Gregor Mendel was at work with his pea plants in a monastery in Brno, investigating patterns of heredity. Thanks to Mendel and later geneticists, including Theodosius Dobzhansky and Barbara McClintock; and thanks to the work of scientists like Rosalind Franklin, James Watson, Francis Crick, Ernst Mayr and Lynn Margulis, we have answered many questions about how traits are passed on from one generation to another.

Natural Selection in Action

The process of natural selection involves changes in the proportion of traits in a population from generation to generation. This makes it challenging for laboratory scientists to document evolution in action. But population biologists, including Sewall Wright, Ronald Fischer, and J.B.S. Haldane managed to show how to measure genetic

changes at a population level; and field biologists like Peter and Rosemary Grant are documenting the evolution of species in real time.

Today, in 2009, after more than 150 years of rigorous, intense, determined investigation, Darwin's theory of natural selection is still a cornerstone of modern biology. Yet evolutionary theory today goes far beyond Darwin. For science is a social endeavor that continues to build on the work of the past and involves the contributions of many players from many scientific disciplines.

One exciting example of how interdisciplinary dialogue leads to scientific progress is to be found in a cluster of studies focused on the very Galapagos finches that inspired Darwin. Rosemary and Peter Grant have spent 20 years in the Galapagos watching evolution in action. They have documented how the proportion of various beak shapes change in response to climatic fluctuation, even leading to an incipient branching of new species. Another group of researchers led by Arhat Abzhanov of Harvard University has correlated beak shape in Galapagos finches with a specific gene (calmodulin).

One hundred and fifty years of tinkering under the hood; one hundred and fifty years of streamlining and increased fuel efficiency; one hundred and fifty years of research and innovation have only refined and augmented the theory of natural selection. Not only does the carriage still run; it is the vehicle that propels all biological research into the future.

Further Reading

Two excellent sources with accessible information about the history of evolutionary thought and experiments where Darwin's ideas have been tested, modified, and augmented, consult:

Anon. *The History of Evolutionary Thought: Understanding Evolution*. UC Berkeley.
http://evolution.berkeley.edu/evolibrary/article/_0/history_19.

Gee, H., R. Howlett, and P. Campbell. 15 Evolutionary Gems. 2009, *Nature*.
<http://www.nature.com/nature/newspdf/evolutiongems.pdf>