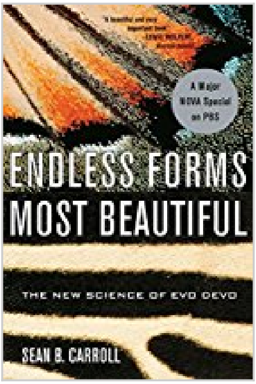


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# Endless Forms Most Beautiful: The New Science of Evo Devo

*By Sean B. Carroll*

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**“A beautiful and very important book.”?Lewis Wolpert, *American Scientist***

For over a century, opening the black box of embryonic development was the holy grail of biology. Evo Devo?Evolutionary Developmental Biology?is the new science that has finally cracked open the box. Within the pages of his rich and riveting book, Sean B. Carroll explains how we are discovering that complex life is ironically much simpler than anyone ever expected.

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## Editorial Review

Amazon.com Review
"Every animal form is the product of two processes--development from an egg and evolution from its ancestors," writes Sean B. Carroll in his introduction to *Endless Forms Most Beautiful*. The new science of "evo devo"--or evolutionary developmental biology--examines the relationships between those two processes, embryonic development and evolutionary changes, despite their radically different time scales. Carroll first offers a recap of how genes express themselves in a growing embryo, then peers into the life histories of real-life examples to explain how those genes have changed (or not changed) over millions of years of evolution. Paraphrasing Thomas Huxley, he asks us to consider evolution and development as two sides of the same coin.

> We may marvel at the process of an egg becoming an adult, but we accept it as an everyday fact. It is merely then a lack of imagination to fail to grasp how changes in this process that assimilated over long periods of time, far longer than the span of human experience, shape life's diversity."

The book's second half is where Carroll really gets at the meat of evo devo, explaining how regulatory genes control such mysteries as individual and population changes in butterfly's spots, jaguar fur, and hominid skulls. Evo devo is one of the hottest areas of study in 21st-century biology, and Carroll's outline of the field is a great place to start understanding it. --*Therese Littleton*

From Publishers Weekly
Cobb County textbook stickers aside, evolutionary natural selection offers a pretty straightforward explanation for the forward march of species through history; a mutation that better equips a given organism to survive is passed along to its heirs, becoming more common as successive generations flourish. The actual process by which mutations happen, however, was far more mysterious until scientists turned to the study of evolutionary development (known by the somewhat unfortunate moniker "Evo Devo"). One such scientist is Carroll, a genetics professor at the University of Wisconsin–Madison, who guides us along the broad contours of development ("the process through which a single-celled egg gives rise to a complex, multibillion-celled animal") and the ways in which its study sheds light on the underlying mechanisms of evolution. He explains in concrete terms how small changes in a species's genetic code of a given species can lead to dramatic differences in physiology is the "missing piece" of evolutionary theory, Carroll argues. The book is as much a salvo in the continuing battles between creationists and evolutionists as it is a popularization of science, and Carroll combines clear writing with the deep knowledge gained from a lifetime of genetics research, first laying out the principles of evolutionary development and then showing us how they can explain both the progression of species in the fossil record and outliers like a six-fingered baseball pitcher. *(Apr.)*


From Scientific American
It would be hard to imagine two more different timescales in the lives of organisms than development--the transformation of an embryo to an adult within a single generation--and evolution--the modification and transformation of organisms between generations that reach back 600 million years. Yet for the past two centuries, natural philosophers, morphologists and biologists have asked whether there is a fundamental relationship between development (ontogeny) and evolution (phylogeny). There is, and it finds expression in

the thriving discipline of evolutionary developmental biology (evo devo, as it has been called since the early 1990s). Endless Forms Most Beautiful examines one of the most exciting aspects of evo devo--the incorporation of molecular biology that followed the discovery of classes of conserved regulatory (developmental, or "switching") genes: the homeobox, or Hox, genes. Carroll, who is a professor of genetics at the University of Wisconsin–Madison, writes in a lively style, peppering the book with endlessly fascinating examples that are beautifully illustrated by color and black-and-white drawings and photographs. To appreciate where this latest book devoted to evo devo is situated in the long history of the discipline, we need to go back almost 200 years. The study of embryonic stages across the animal kingdom--comparative embryology--flourished from 1830 on. Consequently, when On the Origin of Species appeared in 1859, Charles Darwin knew that the embryos of all invertebrates (worms, sea urchins, lobsters) and vertebrates (fish, serpents, birds, mammals) share embryonic stages so similar (which is to say, so conserved throughout evolution) that the same names can be given to equivalent stages in different organisms. Darwin also knew that early embryonic development is based on similar layers of cells and similar patterns of cell movement that generate the forms of embryos and of their organ systems. He embraced this community of embryonic development. Indeed, it could be argued that evo devo (then known as evolutionary embryology) was born when Darwin concluded that the study of embryos would provide the best evidence for evolution. Darwin's perception was given a theoretical basis and evo devo its first theory when Ernst Haeckel proposed that because ontogeny (development) recapitulates phylogeny (evolutionary history), evolution could be studied in embryos. Technological advances in histological sectioning and staining made simultaneously in the 1860s and 1870s enabled biologists to compare the embryos of different organisms. Though false in its strictest form, Haeckel's theory lured most morphologists into abandoning the study of adult organisms in favor of embryos--literally to seek evolution in embryos. History does repeat itself; 100 years later a theory of how the body plan of a fruit fly is established, coupled with technological advances, ushered in the molecular phase of evo devo evaluated by Carroll. As Carroll discusses in his book (the title of which comes from the last lines of The Origin of Species), the discovery of Mendelian genetics in 1900, and soon after of the gene as the unit of heredity, thrust a wedge between development and evolution. Genes were now what mattered in evolution; embryos were merely the vehicles that carried genes from one generation to the next. Embryology was divorced from evolution, devo from evo. Even the discovery in the 1950s of the nature and role of DNA did not bring them back together. In the late 1970s, however, all began to change as several revolutions in theory and technology produced a mind shift as dramatic as the one that followed Darwin's The Origin of Species. New methods for generating phylogenetic relationships brought comparative embryology back to the forefront; now we can assess the direction of evolutionary changes in development. When we find a species of frog that has lost the tadpole stage from its life cycle--a remarkable evolutionary change in form and function--we can determine whether that loss was an early or late event in the evolution of frogs. Stephen Jay Gould's seminal book Ontogeny and Phylogeny (1977) rekindled interest in 19th-century evolutionary embryology and resurrected an old idea--heterochrony, change in the timing of development in a descendant relative to an ancestor--in a form that could be tested. Important as these developments were, they were carried out against the then current wisdom that organisms differ because they possess unique genes not found in other organisms--lobster genes for lobsters, human genes for humans, and so forth. The discovery of homeobox genes turned this approach upside down and inside out. The body plans of lobsters and humans, flies and fish, barnacles and mice, are initiated using the same families of genes that are conserved across the animal kingdom. The consequences of this discovery are the stuff of the first half of Endless Forms Most Beautiful, in which Carroll presents homeobox genes as the switches that contain the fundamental information required to make a fly's eye or a human hand. The second half of the book explores what Carroll calls "the making of animal diversity," beginning with animal life as exemplified in the justly famous 500-million-year-old fossils of the Burgess Shale formation in British Columbia. Carroll is concerned with evolutionary tinkering with genetic switches and the production of patterns in nature--spots on butterfly wings, stripes on zebras. He devotes less attention to the downstream gene cascades and gene networks that allow similar signaling genes to initiate, for example, the wing of a bird or a human arm. Nor are the cells and cellular processes from which the endless forms are constructed given prominence. Consequently, statements such as "the anatomy of animal bodies is really encoded and built ... by constellations of switches distributed all over the genome" could be taken to mean that switching genes contain all the information required to generate form. Were that true there would be no need for evo devo; indeed, there would be no development. It would all be geno evo. But, as Carroll demonstrates, "the evolution of form occurs through changes in development," which is precisely why evo devo is so central to understanding how animals have been and are being evolved.

*Brian K. Hall is George S. Campbell Professor of Biology and a University Research Professor at Dalhousie University in Halifax. He is author of Evolutionary Developmental Biology and of Bones and Cartilage: Developmental and Evolutionary Skeletal Biology, among other books, and co-editor with Benedikt Hallgrímsson of the forthcoming Variation: A Central Concept in Biology.*

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