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Convergent Evolution: Limited Forms Most Beautiful

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various cases are handled lucidly in the book, and Ennos moves on to consider how some of the potentially disastrous failings of these ubiquitous structures are, instead, successfully modified in living organisms—in their innate design, as the creature grows, or in response to stress.

A predictable consequence of living in real environments is that organisms may be subjected to unpredictable stresses, either from winds or currents or from their own weight; they may also be stressed differentially in the to-and-fro movements of locomotion. Ennos discusses recent work that was focused on mechanical systems in both animals and plants that respond to such stresses in a way that improves their performance or helps them avoid damage. Natural selection, in fact, has exploited mechanics in structures where, for example, insect wings emulate umbrellas and tree trunks act as vertical cantilevers.

In such systems, mechanical interactions occur either between different organisms or between an organism and its substrate. How does one hold onto mud? How does one plant hold onto another as it grows toward better light? Many of these curiosities have been studied, and the observations of these organismal adaptations have led to inventions such as Velcro hook-and-loop fasteners and paste. *Solid Biomechanics* offers clear discussions of how such attachments—and their detachment—work; however, I feel that the area of hinges and articulations is treated somewhat cursorily. In human engineering, a great deal of effort and ingenuity is devoted to the design of movable joints and to minimizing the attendant frictional losses. I do not think that this is entirely the fault of the author; rather, it is a field that has been sadly neglected.

Early research on biomechanics relied on the classic methodology and instruments of engineering of the nineteenth and twentieth centuries, but, in a forward-looking final chapter, Ennos highlights the potential of submicroscopic techniques that have emerged in the present century. Biological systems are, let one not forget, constructed at the molecular level, making an examination at that level likely to be instructive.

As a whole, *Solid Biomechanics* is very well constructed, and its themes are readily accessible. The book is well illustrated with clear and effective line drawings and graphs, and its lucid text is supplemented by a useful eight-page glossary of terms used in engineering, physics, and biology. The extensive bibliography extends to 2010, with the majority of the references dating from after 1970, but I was delighted to note that it also includes Robert Hooke's *Micrographia* (1665)! It is noteworthy that Ennos has effectively confined himself to the mechanics of solids in biological systems, although it is clear that he is familiar with fluid dynamics, the mechanics of locomotion, and energetics. Others have written in this area, but his is the most comprehensive monograph so far. For me, the book works.

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EVOLUTION REPLAYED

Convergent Evolution: Limited Forms Most Beautiful. George McGhee. MIT Press, 2011. 336 pp., illus. $35.00 (ISBN 9780262016421 cloth).

How predictable is evolution? If the evolution of plants and animals were to be replayed, would the Earth have similar creatures? Would wings and eyes be formed? Would consciousness arise, and would the universe become aware of itself again? If carbon-based life forms were found on an Earth-like planet elsewhere in the universe, would their shapes look similar to our own? Or would there be a cast of wholly unrecognizable characters? Most evolutionists, I suspect, believe the last scenario to be the case: Evolution is not predictable any more than it is progressive. It is stochastic.

This perception seemed to belong to a whole generation of evolutionists of the last century, but author George McGhee stands apart. In his new book, *Convergent Evolution: Limited Forms Most Beautiful*, the question of directed evolution is not merely a matter of speculation and just-so stories. As a professor of paleontology at Rutgers University, McGhee has combed through and organized a rich body of published data regarding convergent evolution. In this compelling and thoughtful discussion, he includes the views of other evolutionary biologists who have pointed to convergent evolution to argue against a directionless and infinite diversity. *Convergent Evolution* complements McGhee's other landmark books, *Theoretical Morphology: The Concept and Its Applications* (1999) and *The Geometry of Evolution: Adaptive Landscapes and Theoretical Morphoscapes* (2007).

Much of Darwinian evolutionary biology has been focused on how species diverged gradually from common ancestors to illustrate a great branching tree of plant and animal diversity—species within genus, niche within niche. Darwin concluded in *On the Origin of Species* that "whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning, endless forms most beautiful and most wonderful have been, and are being, evolved" (1964, Harvard University Press, p. 490). But Darwin may have gotten carried away.

As the book's subtitle suggests, evolution does not produce unlimited forms. Constraints exist that limit possibilities. Some are functional; others are developmental. Certainly, there is great divergence from common ancestry, but characteristics in those

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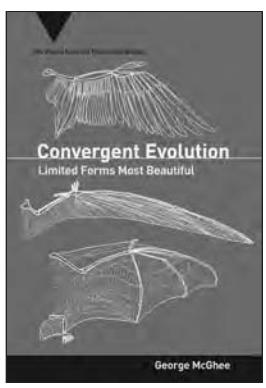
genealogical lineages often converge in both form and function. The similarity of evolved characters in different lineages reveals evolution's repeated paths.

Repetition of similar forms is easily understandable in terms of structure and function: Given the same function in similar habitats, evolution will produce a similar form to serve that purpose. The exemplar of convergence is that of the ichthyosaur and the porpoise. The two creatures have a fusiform body, snout, and fins that are remarkably similar. However, the former evolved from lizards some 240 million years ago, and the latter evolved from a mammalian lineage some 190 million years later. Indeed, McGhee surmises that if large animals were to be found under the methane seas of Titan, they would also have a fusiform body.

When the saber-toothed cat once roamed North America, Europe, and Asia, so too did its analog: a marsupial mammal of South America that looked morphologically almost identical. There are the retractable claws of both dinosaurs and cats and the raptorial beaks of diverse bird species. Flying squirrels have emerged independently all over the globe. The wings of birds and the wings of bats are a case of parallel evolution: The former developed from modified dinosaurian forelimbs, the latter from mammalian.

It was once thought that convergence was mainly a result of similar function, but developmental constraints also result in convergence. McGhee explains that some cases are based on a developmental bias or genetic channeling; others are caused by what he terms *deep homology*. For example, an ancient, highly conserved regulatory gene in the animal genome (the *Pax-6* gene) has been modified many times in evolution, resulting in convergent traits such as the many kinds of eyes in animals. As such, eyes evolved as 49 independent lineages. One of the most remarkable examples of convergence in animals is the evolution of *viviparity*—the development of the embryo inside the mother, which results in a live birth of offspring. This convergent trait has also evolved many times in animals. There is ecological convergence—when different species play similar roles in different ecological communities—and the evolutionary convergence of various social behaviors, nest building, and tool use throughout the animal kingdom, as well as self-awareness evolved independently in various lineages, including primates, corvid birds, and cetaceans. Convergence in the evolution of plants is exemplified by the development of seeds and by various relationships that plants have with animals. McGhee also discusses the convergent molecular evolution of proteins, and he even includes conjectures on directed evolution of the genetic code. The scope and significance of convergent evolution (often resulting from horizontal gene transfer) in the microbial world is not explored in the book, however.



Taking issue with those who view evolution to be unpredictable, McGhee addresses the false dichotomy between the factors of contingency and chance on one hand and directed evolution based on supernatural forces on the other. In the history of evolutionary biology, it is chance, the struggle for existence, and contingency that have always been on the side of evolution; goal-driven physiological change was always on the side of supernaturalism and the antievolution movement. This dichotomy has been maintained by an ongoing conflict between scientists and creationists, but life can be directional without being teleological. As McGhee observes, "Water flows downhill, from a state of higher potential energy to a state of lower potential energy under the influence of gravity. It is mindless" (p. 272).

Evolution does not involve an intelligent design toward a predetermined goal for McGhee any more than it does for other evolutionists. Still, he argues, one can speak of "improvement" in evolution: "Natural selection has a direction only in the sense that it will, in general, operate to move evolving organisms up the slopes of the adaptive landscape to higher states of adaptation" (p. 272). The phenomena of convergent evolution abundantly demonstrate that the environment does have a priori standards of overall value. "The laws of physics impose the functional constraints, the a priori standard, that fast-swimming organisms must be fusiform in shape and that flying organisms must have wings, and so on, for all the myriad examples of convergent evolution…" (p. 273). *Convergent Evolution* is a timely synthesis—an engaging book that will surely be widely read and discussed among evolutionists.

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NEW TITLES

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