

Cells to Civilizations: The Principles of Change That Shape Life.

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that they are “active and prudently evaluating men’s humorous displays” (p. 339). Nevertheless, the empirical evidence to suggest that men are the *producers* of humor and that women are the recipients goes largely unexamined, with no effort made to detect potential biases that may have shaped how such studies are conducted. At best, it appears as if women are actively allowing males to place them in the passive recipient position. This lack of a more critical approach seems to be an opportunity missed, given that this is exactly the kind of finding where a more extensive feminist reappraisal might pay dividends.

Another point of contention found in the book is the thorny issue of the naturalistic fallacy. At the end of a very interesting and thought-provoking chapter on culture, traditions, and the role of mothers in sustaining cultural practices, Coe and Palmer note the irony in their suggestion that the stereotyped “domestic role” of women has been of great evolutionary significance. They go on to argue that “there is no need to fear that the patterns of behaviour favoured by natural selection in the past dictate what we should desire or what is possible to achieve in the future. To think otherwise is to commit the naturalistic fallacy” (p. 129). For those who subscribe to a particular school of evolutionary thought associated most prominently with Leda Cosmides, John Tooby, and David Buss, however, there is a strong and deeply held commitment to the idea that patterns of behavior favored by natural selection do dictate what we desire today, and, as a result, may place certain limits on what we can achieve. The argument is precisely that much of our current psychology reflects the influence of natural selection—a process that shaped the preferences of our ancestors in ways that ensured our current existence. Should Coe and Palmer’s proposition turn out to be true, it would force us to question how much of our decision-making is truly autonomous and to ask whether it is possible to eradicate certain biases and behaviors—and it

would raise the issue of whether to incorporate such knowledge into our legal and political systems.

Alternatively, a more integrative evolutionary psychology, resulting from the incorporation of feminist thinking, might allow a more nuanced view of the evolutionary process to permeate. The naturalistic fallacy occurs when one derives moral values exclusively from facts, and it is the word *exclusively* that matters: We can and do use facts about the world to inform our moral and value judgments, but we do not use *only* facts to decide what is right or wrong. To worry about whether naturally selected behaviors might influence our current desires is not, then, to commit the naturalistic fallacy. We are not imposing moral values on objective facts; rather, we are simply recognizing that what is is. On this basis, we can then decide how we wish to use those facts within the human moral universe.

Should you read *Evolution’s Empress*? Absolutely. As critical as the above may seem, one only bothers to criticize those things that are worth taking seriously, those that provoke thought and inspire deeper consideration, and this book certainly does that.

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SEEING THE FOREST—AND THE TREES

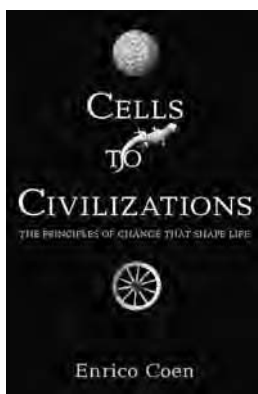
Cells to Civilizations: The Principles of Change That Shape Life. Enrico Coen. Princeton University Press, 2012. 360 pp., illus. \$29.95 (ISBN 9780691149677 cloth).

In *Cells to Civilizations: The Principles of Change that Shape Life*, author and plant biologist (and corecipient

of the Darwin Medal) Enrico Coen is one of the latest scientists to carry the banner claiming the existence of a pattern to the transformation of all living things—an evolutionary transformation that embraces the processes (or the four domains) of biological evolution, development, learning, and culture. Coen is in distinguished company, both past and present. Donald T. Campbell pressed for a structural parallel between evolutionary biology and evolutionary epistemology based on random variation and selective retention. Gerald M. Edelman’s “neural Darwinism” asserted a pattern between learning and other complex adaptive systems using the concept of feedback. Richard Dawkins and Daniel Dennett each strive to prove the existence of similarities between biological and cultural evolution. Stuart Kauffman ambitiously asserts that a single set of processes guides both evolution and development, as well as the dynamics of other complex systems. Peter J. Richerson and Robert Boyd together have developed an impressive multilevel account of evolution. All good company aside, Coen does not simply reiterate what has gone before; he develops and compares models of evolutionary transformation within four distinct domains, stating the presence of a formally similar set of mechanisms in each case.

In *Cells to Civilizations*, the author identifies a total of seven principles that are involved in evolutionary transformation, and the core of his approach is rooted in Alan Turing’s (1952) classic account of morphogenesis using the model of a reaction–diffusion system, in which Turing showed us that it is possible to generate interesting patterns of growth. Coen depicts two feedback loops, one positive and one negative, regulating a specific domain. The positive loop is described as *reinforcement* and the negative loop as *competition*. Using this dual-feedback system, Coen explains the developmental patterning within *Escherichia coli*, and specifically, how *E. coli* reliably divides in its midsection. When the organism prepares to reproduce,

two crucial proteins, MinD and MinE, are involved. As MinD attaches to a membrane, it improves the chances that other MinD will attach to the same region. This is the chemical reaction, or *reinforcement* stage. When MinE binds to MinD, MinD detaches from the cell membrane. Diffusion distributes the Min proteins throughout the cell, but with the right affinities and diffusion rates, the MinD proteins oscillate and begin to concentrate at opposite ends of the cell. This reaction–diffusion process continues until the partition of the cell forms in the middle, where the concentrations of proteins are lowest. According to Coen’s dual-feedback loop, the binding of proteins is positively reinforced, but as more MinD become present, a decrease in binding occurs; instead of uniformity, there is oscillation.



These sorts of dual-feedback loops are common in natural systems. Coen uses the term *transformation* to capture changes in living systems over time. *Cells to Civilizations* presents the various components of transformation and demonstrates how they regulate limited-density growth (competition) and patterning. Describing these seven principles, along with how they work and interact, is to offer what Coen calls “life’s creative recipe” (p. 60). These principles form the basic structure on which Coen builds his transformations in each of his favored domains.

According to the *principle of variation*, variation in a population is essential for change, and it can have a variety

of sources, including both mutation and recombination. The point is familiar in evolutionary biology: In the absence of substantial variation, there would be no evolutionary change.

In the *principle of persistence*, the necessity that change accumulates over time is emphasized. Organisms are relatively stable entities, as is the DNA that ensures their persistence. Coen uses persistence to cover both replication and simple continuity, noticing that, for evolutionary change to take place, there must be a trade-off between persistence and variation.

Some variations influence reproductive capacity, and this gives rise to the *principle of reinforcement*. Simple growth is a matter of reinforcement. If a population grows, it may not lead to a change in the relative numbers of variations; it would still count as reinforcement but not as a transformation.

Following the *principle of competition*, reinforcement is not sufficient for natural selection (or sexual selection) to operate. Competition, as Darwin saw it, emerges when limitations on resources are imposed by limitations on growth. Coen recognizes that, with competition, change can occur even in the absence of differences in fitness. When competition and reinforcement are both present, along with variation and persistence, the result is evolution by natural selection.

Coen also recognizes the *principle of cooperation*, which affirms that cooperation, as well as competition, can influence evolutionary outcomes. He uses the term *cooperation* in a broad sense to include, for example, a series of bases cooperating in order to produce a protein; likewise, it is cooperation when genes in the same organism form a phenotype.

Simpler elements can combine to form elaborate complexes, increasing what Coen calls the “richness of the world.” The *principle of combinatorial richness* acknowledges that linkage creates a greater variation. The genetic code is a simple illustration of this principle. If there are 25,000 genes in the human genome, each with thousands of base pairs, the number of possible genotypes is astronomical.

Evolution is constrained by history; organisms modify their own environments, creating a context for further evolution. This understanding that competition and cooperation occur in a context that the organism creates is what Coen calls the *principle of recurrence*. Bat wings and bird wings are very different structures, but the basic forelimb structure is preserved in both. The result is a historical trajectory that is “convoluted and idiosyncratic” (p. 51).

These principles were initially developed from the perspective of biological evolution, but the book aims to extend them to three other domains: development, learning, and culture. Development is not just growth but transformation. Whereas evolution results in diverse life forms arising over time, development is “the recipe [that] involves populations of molecules and cells within the same individual and leads to the emergence of an adult within a single generation” (p. 109). Within development there is selective reinforcement for some cell types and repression for others, with the result being not just growth but a change in conformation.

Likewise, learning is not a simple matter of conditioning, although conditioning does, of course, change expectations. Coen uses a model from Montague and colleagues (1996) called *temporal difference learning* to explain the change in expectations. The details are interesting, but the core idea is that conditioning incrementally alters synaptic strengths through feedback (reinforcement). This is matched with a decline in the response to rewards (inhibition): “At the heart of learning, we have a double feedback loop of reinforcement and competition, fueled by a balance of variation and persistence” (p. 167).

The same set of principles, Coen says, are at play in cultural transformations, and he uses the artistic trends of fifteenth-century Florence as an example. Artistic innovation fueled artistic innovation, and as innovations spread, so did competition. Once again, Coen sees the familiar dual-feedback loop, fueled by individual variation and

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persistence. In this domain, however, cooperation also plays a crucial role: “Cooperation and competition are partners in cultural change” (p. 257).

Although the author is clear to make distinctions among the domains of evolutionary change, development, learning, and cultural change, what is emphasized in *Cells to Civilizations* is that, at the appropriate level of abstraction, their similarities can be enlightening. There is much more in this book that I have not mentioned. It is replete with biological examples—from the stripes of zebras to plant genetics—that illustrate the author’s claims, all accomplished with clarity and grace. *Cells to Civilizations* is an intelligent and entertaining book by a distinguished biologist.

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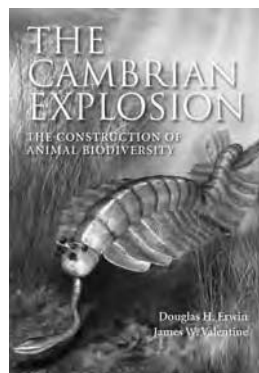
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BREAKTHROUGH ON THE CAMBRIAN EXPLOSION

The Cambrian Explosion: The Construction of Animal Biodiversity. Douglas H. Erwin and James W. Valentine. Roberts and Company, 2013. 416 pp., illus. \$48.00 (ISBN 9781936221035 cloth).

Three unsolved problems, above all others, command the attention of the scientific community. The first is whether there is or was life on Mars. The second concerns the origin of life. The third—arguably the most difficult of the three to answer—is what happened during the Cambrian

explosion. In their book *The Cambrian Explosion: The Construction of Animal Biodiversity*, Douglas H. Erwin and James W. Valentine present a courageous effort to address this third problem. The book’s subtitle pays homage to the closing paragraphs of *The Origin of Species by Means of Natural Selection*, in which Darwin reflected that “elaborately constructed forms, so different from each other, and dependent on each other in so complex a manner, have all been produced by laws acting around us” (Darwin 1872 [1859]). Why did these elaborate forms, so different from one another, appear so suddenly in the Cambrian Period of the Paleozoic Era?



Fossils occurring at the base of the Cambrian confront Darwinism with its greatest challenge. Do they constitute a fatal stumbling block for theories of morphological evolution for which the natural selection of small changes over geologic time is posited? Darwin admitted in *Origin* (1967 [1859]) that the sudden appearance of complex animals was problematic for his evolutionistic schema. No surprise then that Darwin was the first scientist to rationalize away the abrupt appearance at the outset of the Cambrian with an appeal to the incompleteness of the fossil record. Darwin compared the rock record to a damaged folio volume, for which we have only a page here and a paragraph there.

Charles D. Walcott, who famously discovered the Burgess Shale fossils in British Columbia, Canada, attempted to address Darwin’s difficulty by proposing the *Lipalian interval*—a vast stretch of geologic time not represented

by strata. Walcott realized that a gap in the record would rescue Darwin’s schema by providing a ready excuse for the missing ancestors. Field studies, however, have shown that many Precambrian–Cambrian stratigraphic boundary sections show no evidence for such a gigantic gap.

In one of the great ironies in the history of science, Walcott’s discovery of the Burgess Shale had a result diametrically opposed to his Lipalian gambit. Burgess creatures look distressingly modern. Making matters worse, the 1985 discovery of Early Cambrian soft-bodied fossils of the Chengjiang biota in the Yunnan Province of China further compounds the problem. Chengjiang reveals fossils even more modern looking than those of the Burgess Shale, among them being the first fossil fish, *Myllokunmingia*.

Erwin and Valentine admit that the creatures of Chengjiang are “no less complicated than those of today” (p. 327), thus recognizing the danger of the Darwinian view. They argue (unconvincingly, in my opinion, considering that soft-bodied fossils also occur in the Proterozoic) that these “newly opened taphonomic windows [Burgess and Chengjiang]... have surely made the explosion appear to be more abrupt than was actually the case” (p. 328). It is here that the primary purpose of the book becomes clear. Their effort to defend neo-Darwinism shows that gradualistic evolution is no mere straw man but, rather, a strong bias among top paleontologists. They uncritically accept Zhu and colleagues’ (2008) assignment of the spiral Ediacaran *Eoandromeda* to the ctenophores as support for gradual evolution across the Cambrian boundary. *Eoandromeda* is far better assigned to the weird Ediacaran vendobiont clade. Implying that cnidarian cnidae are “derived” products of sequential evolution, Erwin and Valentine ignore that cnidae are the evolutionarily abrupt result of a symbiotic acquisition of microsporidians.

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