Journal of Scientific Exploration, Vol. 34, No. 1, pp. 141–145, 2020 0892-3310/20

## BOOK REVIEW

**Beyond Mechanism: Putting Life Back into Biology** edited by Brian Henning and Adam Scarfe. Lexington Books, 2013. 484 pp. ISBN 978-0-7391-7436-4.

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https://doi.org/10.31275/2019/1719


*Beyond Mechanism: Putting Life Back into Biology*, edited by Brian Henning and Adam Scarfe, is a collection of essays on the foundations of biology and its connection to other sciences. Its lengthy and profound foreword by Stuart Kauffman, a major figure in the quantitative analysis of biological regulation at the system level, summarizes the intended main point:

> we live not only in a world of webs of cause and effect, but webs of opportunities that enable, but do not cause, often in unforeseeable ways, the possibilities of becoming of the bio-sphere, let alone human life. But most importantly, I seek in this new worldview a re-enchantment of humanity. (p. 1)

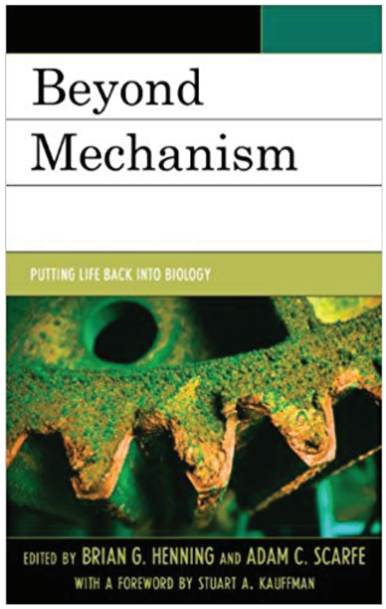
To some extent, it's meant as a reaction to what some perceive as demoralizing aspects of the mechanistic paradigm that is driven by recent advances in the molecular bio-sciences: "I believe we are partially lost in modernity, seeking, half-articulated, a pathway forward. Re-enchantment may be an essential part of this transformation" (p. 1). I do not agree that the current situation is as bleak as many critics of the scientific mainstream suggest, but this book should appeal to anyone interested in the larger questions of biology no matter where they stand on this issue.

All in all, it is an extremely enjoyable and valuable tour of important concepts and controversies. Roughly, the content (divided into sections) cover the following broad topics:

— recent mathematical approaches to biology, such as complexity, systems theory, and emergence
— biosemiotics (coding and communication)
— homeostasis and thermodynamics
— evolution and behavior
— teleology and mechanism
— epigenetics

The discussions cover many of the key questions facing the biosciences in the new century: questions of agency (e.g., decisionmaking) and how it can emerge from physical mechanisms, the origins of order and rise in complexity, information in its many guises, the relationship of physics and biology, organization and regulation, the nature of Life, and the place of reductionism (and alternatives to it) in a modern biological synthesis. It is grounded in mathematical approaches to life—not merely in the sense of quantification, but in the deeper sense of mathematics as the science of patterns, relationships, and logic. Some of the chapters are more focused on metaphysics, others are very practical and hew closely to experimental data. All are written in a way accessible to interested laypersons, and even in cases where something is beyond the reader's knowledge, a bit of reading within other sources should quickly get one to the point where the book becomes a valuable guide to deeper waters.

The chapters are very well-referenced, providing a lot of pointers for source material and deeper study. However, the illustrations/diagrams are uniformly scarce and minimal (and exhibit fairly rough production values when present). The book is excellent as-is, but perhaps could have been improved by additional graphical material to illustrate concepts throughout. The only other quibble is that the chapters generally do not contain abstracts. The exception is one chapter (by Brian Hall) that does provide an abstract: "It is not my aim to present epigenetic or genetic models for biological phenomena, to describe new phenomena, to derive predictions from models, or to offer tests of predictions from models. Thus, I do not aim to make an empirical contribution to epigenetics" (p. 348). This important list of what the subsequent chapter does not do highlights the need for abstracts that would outline the major claims (main points) that each chapter does seek to make—it would have been helpful to readers to have those summaries of the main points and their logic up-front, before each contribution.




The book consists of pieces by a very good selection of authors—there are no dispensable chapters, and all of the authors are primary contributors to their respective fields. Although the book is certainly not thin, there were some important and relevant areas that were not covered. Readers whose interest is piqued by this volume will want to also read up on the recent advancements in artificial life, synthetic biology, machine learning, active inference, top-down causation, and geometric information—all of these are beginning to enrich our understanding of life. Readers should be especially mindful about gaps, such as the one on epigenetics. For the purposes of the included chapter, "Epigenetics is a term and concept that embraces the regulation of gene activity during embryonic development, animal and plant ontogeny, organismal evolution, and some animal diseases and cancers" (p. 360). But in fact the more general (and interesting) meaning of "epigenetics" subsumes all kinds of non-genetic influences over biological form and function, such as cytoskeletal inheritance and other aspects of biophysics that affect inheritance of information unrelated to the DNA modifications most often discussed in contexts of epigenetics (Fields & Levin, 2017; Jablonka & Lamb, 1995; Levin, 2014; Nelsen et al., 1989; Neuhof et al., 2016).

My own reactions to the overall perspective in the book are as follows. First, the positioning of "true agency" (real cognitive systems that make decisions, have memories, etc.) and "as-if agency" (systems that only seem as though they are making decisions but in reality are "mere physics") as binary choices is a fundamental error. Like most other biological traits, it evolved as a continuum from the simplest biophysical systems (with primitive homeostatic dynamics) to very complex ones with 2nd-order cognition and the ability not only to pursue counterfactual future goals but to actually re-specify those goals and reason in a meta-cognitive way. Viewed thusly, mechanism does not have to be disenchanting—many systems around us have varying degrees and types of agency, enabled by the laws of physics and computation. Understanding their structure and function is an important complement to the equally important top-down view of living systems as cybernetic or cognitive agents. Indeed, it is no longer tenable to view machines as predictable, boring, limited devices totally divorced from the plasticity and robustness of life. Quantum events, Turing limits, Gödel limits, deterministic chaos, and environmental (and swarm) interactions all suggest that beyond a minimal level, autonomous robotics will have just as much freedom, surprise, and evolutionary creativity as we see in the carbon-based world (Rahwan et al., 2019). Views of biological organisms as machines, computational devices, thermodynamic engines, cognitive selves, etc., are all metaphors; the ultimate judge of which metaphors are misleading and which are valuable is not a philosophical stance but empirical research: A metaphor is appropriate based on the extent to which it helps predict and control phenomena, and to drive novel research programs.

Second, any discussion of the origins of order and evolution have to focus significantly on developmental biology. Mutations occur in DNA, but selection judges function. Between DNA and the functional anatomy of the organism lies a critical layer of controls that still holds many mysteries about the relationship between the genome and anatomy. This book, like many other discussions, ranges from physics and genetics all the way to mind and evolutionary selection, but little emphasis is placed on the critical question of what actually determines specific complex anatomy and its ability to repair itself (in regenerative species) in light of unpredictable injuries. It is essential, for any discussions of what evolutionary mechanisms can and cannot do, to understand the software of life that is implemented by the physiology and signaling that lies between the genomic specification of hardware and the function of a living being in the environment.

All in all, a very enjoyable read and highly recommended, together with the following additional reading for those who enjoy these topics:

Bray, D. (2009). *Wetware: A computer in every living cell*. Yale University Press.
Chaitin, G. J. (2012). *Proving Darwin: Making biology mathematical*. Pantheon.
Damasio, A. R. (2010). *Self comes to mind: Constructing the conscious brain* (1st ed.). Pantheon.
Davies, P. C. W. (2019). *The demon in the machine: How hidden webs of information are solving the mystery of life*. The University of Chicago Press.
Friston, K. (2013). Life as we know it. *Journal of the Royal Society Interface, 10*. https://doi.org/10.1098/rsif.2013.0475
Jablonka, E., Lamb, M. J., & Zeligowski, A. (2014). *Evolution in four dimensions: Genetic, epigenetic, behavioral, and symbolic variation in the history of life* (rev. ed.). Bradford Book, The MIT Press.
Mitchell, M. (2009). *Complexity: A guided tour*. Oxford University Press.
Niklas, K. J., & Newman, S. (2016). *Multicellularity: Origins and evolution*. MIT Press.
Noble, D. (2017). *Dance to the tune of life: Biological relativity*. Cambridge University Press.
Turner, J. S. (2017). *Purpose & desire: What makes something "alive" and why modern Darwinism has failed to explain it* (1st ed.). HarperOne.
Walker, S. I., Davies, P. C. W., & Ellis, G. F. R. (2017). *From matter to life: Information and causality*. Cambridge University Press.

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Fields, C., & Levin, M. (2017). *Multiscale memory and bioelectric error correction in the cytoplasm–cytoskeleton-membrane system*. Wiley Interdisciplinary Reviews: Systems Biology and Medicine, e1410-n/a. https://doi.org/10.1002/wsbm.1410

Jablonka, E., & Lamb, M. J. (1995). *Epigenetic inheritance and evolution: The Lamarckian dimension*. Oxford University Press.

Levin, M. (2014). Endogenous bioelectrical networks store non-genetic patterning information during development and regeneration. *The Journal of Physiology, 592*, 2295–2305. https://doi.org/10.1113/jphysiol.2014.271940

Nelsen, E. M., Frankel, J., & Jenkins, L. M. (1989). Non-genic inheritance of cellular handedness. *Development, 105*(3), 447–456. https://doi.org/10.1242/bio.020149

Neuhof, M., Levin, M., & Rechavi, O. (2016). Vertically- and horizontally-transmitted memories—The fading boundaries between regeneration and inheritance in planaria. *Biology Open, 5*, 1177–1188. https://doi.org/10.1242/bio.020149

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