this view has always faced what Basl calls the subjectivist challenge: i.e., how to make sense of the idea that a cactus or a virus particle—or any organism lacking minimal consciousness—nonetheless has a genuine interest. Ecoholism is an even more inclusive doctrine that extends moral standing beyond individual organisms to entire collectives such as species, communities, or ecosystems. However, ecoholism draws the line at human artifacts such as snowmobiles or shopping malls that are thought to lack moral standing.

The Death of the Ethic of Life argues that biocentrism is logically unstable. Any plausible theory attributing interests to nonsentient organisms must recognize that ecological wholes and inanimate artifacts possess them as well. This echoes Vogel's position in *Thinking Like a Mall: Environmental Philosophy After the End of Nature* (2015. Cambridge (MA): MIT Press). Indeed, biocentrism has been on the defensive in recent years, including a retraction by one of its earliest proponents (G. Varner. 2003. *Environmental Ethics* 25:413–416). However, Basl's dismantling of biocentrism is more systematic than any previous critique. He makes a serious attempt to resuscitate the patient before declaring it deceased.

The argument goes roughly like this. The most plausible response to the subjectivist challenge defines the interests of nonsentient beings in terms of their biological goals. Those goals are determined by natural selection, or what Basl calls an "etiological account of teleological welfare" (p. 62). The author argues that other (non-Darwinian) accounts of welfare either assign arbitrary interests to organisms, or else they assign interests that are parasitic on human interests (and are thus not truly biocentric), or else they collapse into the etiological view. However, once the interests of nonsentient organisms are recognized there is no way to constrain them to just living beings. Recent developments in multilevel selection theory, along with artificial selection experiments on mircoorganismic communities, suggest that biological collectives are candidate units of selection. Hence biological collectives can also possess interests. Synthetic organisms and domesticated animals are artifacts in the sense that their biological ends are determined by humans. Yet, these organisms clearly have a welfare akin to any naturally selected organism. Hence, some artifacts are also morally significant despite having ends that are derived from humans. In conclusion, biocentrism is a slippery slope descending into what Basl calls teleocentrism—a view that he ultimately endorses—where not only nonsentient organisms but also biological collectives and some artifacts have moral standing.

It is hard to do justice to the author's technical treatment of these topics in a short space. Anyone looking for a basic explanation of why philosophers reject biocentrism might find Basl's treatment a bit pedantic. However, for philosophers developing a position in environmental ethics this book is highly instructive. It is ideal for a graduate seminar in environmental philosophy. As for the death of biocentrism, I have never understood how the mere possession of an evolved interest makes something morally significant in the first place. That aside, the case for species- or community-level selection was rather flimsy. I suspect that stronger evidence could be presented for species selection, but that an acceptance of community selection would require shifting to a very different perspective in biology (e.g., W. F. Doolittle and S. A. Inkpen. 2018. *Proceedings of the National Academy of Sciences of the United States of America* 115:4006–4014). However, suppose that community selection occasionally occurs in nature or that artifacts sometimes acquire genuine interests. Would this really mean that biocentrism is dead? Why could not a reasonable biocentrist allow for a few exceptions? The point of biocentrism, I gather, is to draw attention to the negligent and disrespectful ways in which human institutions treat so many organisms. The fact that this doctrine permits a few unconventional entities to slip into the tent of moral considerability seems like a relatively minor issue.

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GENERAL BIOLOGY

A World Beyond Physics: The Emergence and Evolution of Life.

By Stuart A. Kauffman. Oxford and New York: Oxford University Press. $24.95. xii + 151 p.; ill.; index. ISBN: 978-0-19-087133-8. 2019.

Stuart Kauffman is known for his research in theoretical biology, complexity science, origins of life, and genetic networks; he was the recipient of a MacArthur Foundation "genius" award, is a Fellow of the Royal Society of Canada, an emeritus professor of biochemistry and biophysics at the University of Pennsylvania, and a medical doctor. Kauffman is as interdisciplinary as his six books, which include *The Origins of Order: Self-Organization and Selection in Evolution* (1993. New York: Oxford University Press), *Investigations* (2000. Oxford (U.K.): Oxford University Press) and, most recently, *A World Beyond Physics.*

In the first half of the book, the author lays the foundation for his later arguments. As this is only an overview, readers would benefit by having read his prior works to gain a deeper insight into these ideas. Kauffman first introduces the concept that the set of constraints on nonequilibrium systems

(such as living cells) allows these systems to do work (product of force and displacement) to construct the same set of constraints. This "work-constraint cycle" is proposed to allow living cells to temporarily stave off the second law of thermodynamics by building structure/order and reproducing faster than disorder. He then presents the idea that the universe is "nonergodic" above the level of the atom. For instance, most complex molecules will not come to exist on a timescale that is relevant for evolution (consider a typical human protein: only a very small fraction of the 20^{300} possible proteins from the arrangement of 300 amino acids have been made since the Big Bang 13.7 billion years ago).

The second half of the volume focuses on new arguments about the predictability of evolution. Kauffman argues that although physics may advance our understanding of biological systems, a reductionist scientific approach and the laws of physics cannot predict evolution; the complexity of living organisms and the biosphere is too great to state beforehand how life will evolve. The author says you cannot reduce biology to physics.

Kauffman acknowledges that we can seek statistical laws to describe certain aspects of evolution, however, discussion of how evolution spans many timescales, which differentially impacts our ability to predictively model evolution, is notably missing. Although macroevolution may not be predictable for practical and possibly fundamental reasons, progress is being made with quantitative models of microevolution (e.g., computational models can predict the distribution of mutations in evolving genetic networks). The author also states that the evolution of nonergodic systems is dependent on their history; it would be interesting to consider how the corresponding restriction of the "sample space" that biological systems can explore (e.g., fitness effects of new genetic mutations can depend on existing mutations), and the fact that living organisms are subject to the laws of physics, may aid rather than hinder predictive modeling. Perhaps regimes or timescales are beyond physics, but not an entire world beyond physics.

A World Beyond Physics is a well-written and thought-provoking book. It should prove a worthwhile read for anyone with an undergraduate knowledge of biology and physics who is interested in a more philosophical take on the origins, complexities, and evolution of life.

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ACROSS THE BRIDGE: UNDERSTANDING THE ORIGIN OF THE VERTEBRATES.

By Henry Gee. Chicago (Illinois): University of Chicago Press. $75.00 (hardcover); $25.00 (paper). xii + 312 p.; ill.; index. ISBN: 978-0-226-40286-4 (hc); 978-0-226-40305-2 (pb); 978-0-226-40319-9 (eb). 2018.

One of the more profound divisions in zoology is the dichotomy between vertebrates and invertebrates. This split, though, is largely a product of our own myopia as sentient vertebrates and less an accurate reflection of phylogeny. A more natural division occurs between the deuterostomes like us, as well as echinoderms (sea urchins and starfish), hemichordates (acorn worms), amphioxus (lancelets), and tunicates (sea squirts), and the protostomes, which includes arthropods and mollusks. Yet, to the untrained eye, our closer relationship with the radially patterned starfish and the sessile filter-feeding sea squirt can be difficult to appreciate relative to the fly with its more recognizable mouth, two eyes, paired limbs, and obvious cranial and caudal ends. It is this perceived gap between vertebrates and our deuterostome cousins that Gee attempts to bridge.

Unlike his earlier work *Before the Backbone: Views on the Origin of the Vertebrates* published in 1996 (London (U.K.): Chapman and Hall), this book is not concerned with scientific history, process, or personality. Instead, this is a scientific argument that proposes a particular scenario for vertebrate origins. He presents a data-filled narrative that takes advantage of the substantial advances made during the past two decades in molecular phylogenetics, evolutionary developmental biology, and paleontology. These new data provide surprising insights. One might anticipate an evolutionary record showing a slow accumulation of novel vertebrate features that ultimately results in our unified complex visceral feeding apparatus hafted onto our mobile body developed from segmented somites. Instead, we see that the vertebrate body plan is somewhat primitive. Pharyngeal slits have a common origin among deuterostomes as demonstrated by their shared dependence on the same set of six developmental control genes, and their absence in echinoderms represents secondary loss. We also learn that the simple segmented amphioxus with its prominent notochord and pharyngeal slits is, in fact, not the closest living relative to vertebrates. Modern molecular phylogenetics reveals that the highly derived tunicates are vertebrates' closest cousins. As opposed to seeing tunicates as having yet to achieve the integrated vertebrate somatic and visceral bodies, the author suggests that tunicates have ingeniously temporally displaced these structures with the mobile larval stage possessing the segmented body and the sedentary filter-feeding adult exhibiting the complex pharyngeal apparatus.