Book review: Biology's first law: A manifesto against physics envy


By Phil Novack-Gottshall

Let’s face it, biology is tough science! We alone toil with the messy and rampant variation inherent in life’s onward march. To the physico-chemical reductionist, each chemical element and physical rule is infinitely unchanged, uniform, and stable. (Admittedly, isotopes exist and the effects of gravity vary under special circumstances, but these remain fully consistent with the basics of chemistry and physics.) These "rigorous" sciences don’t have to worry that the boiling point of pure water today depends on what happened to that water overnight. But biology does: the study of change and variation is our sine qua non. And it’s been a sore point, causing some (especially ecologists!) to conclude that our field will forever lack a firm, irresolute body of theory to rule each and every biological entity, a biologist’s companion to Newton’s laws.

But such pessimism withers under the elegant idea put forth in Dan McShea and Robert Brandon’s audacious new book Biology's First Law: The Tendency for Diversity and Complexity to Increase in Evolutionary Systems. Some ideas are so intuitively true, so simple and obvious that it takes sharp minds to recognize them in the first place. And that’s the case here. The authors argue that our emphasis on natural selection as the cause of diversity and complexity (D&C) is misplaced and potentially erroneous; that D&C are easily produced in nature, that they’re inherent in anything that reproduces using an imperfect form of reproduction, and we shouldn’t be surprised that life is amazingly diverse and complex. Diversity and complexity are easily produced in nature, they’re inherent in anything that reproduces using an imperfect form of reproduction, and we shouldn’t be surprised that life is amazingly diverse and complex.

Differentiation arises spontaneously "by the simple accumulation of accidents" (regardless of genetic, epigenetic, or environmental causes) that cause instantaneous variation, and because these variants can be inherited by future generations, the authors logically conclude that all evolutionary systems (i.e., anything with a means of inheritance and variation) have an inherent, driven tendency to become both more complex and more diverse through time. Furthermore, this increase requires no cause (aside from imperfect inheritance, a staple of all life). As the authors note, "in evolution, the expectation in the absence of forces is change," hence a bona fide zero-force evolutionary law (ZFEL). Although this tendency for change is always present (hence it’s description as biology’s first law), the authors emphasize it can be constrained, directed, stabilized, or made adaptive by natural selection or other forces (implying that Darwin’s serves as biology’s second law.) The authors use a delightful metaphor to demonstrate the relative action of ZFEL and natural selection: a tinkerer’s assistant randomly alters what’s available while the tinkerer works diligently to improve (ever imperfectly) the assistant’s changes. Given that these laws are quintessential the stuff of biology, perfectly suited to operating within and across different hierarchies, it is ironic that this positioning of laws is opposite that for Newton and his modern counterparts, for whom inertia (a lack of change) remains the background condition and change always demands some force.

Limited review space prevents a thorough discussion of the rich arguments and wealth of examples, implications, and philosophical underpinnings the authors, a paleobiologist (McShea) and philosopher of biology (Brandon) at Duke University, survey to marshal their case, but here’s a grab-bag: blind cave animals, developmental constraints and modularity, epithelial skin flaps, fluctuating asymmetry, gene linkage, genetic drift, Hardy-
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Weinberg, intelligent design (begrudgingly but deft in showing that complexity is easy and expected), “invariant” lab mice, irradiated mice, living fossils, mass extinctions, Mendelian genetics, morphological disparity, mRNA splicing, orthogenesis (in a positive light), parasites, pseudogenes, rudimentary organs, vertebral complexity, and a bit of Herbert Spencer. It’s as synoptic and persuasive as Darwin’s Origin, but packed in a concise, slim volume.

But two examples are especially relevant here. The first concerns trend mechanisms. McShea (1994) has been an important advocate for the distinction between passive trends (those lacking deterministic causes, often resulting in diffusional patterns) and driven causes (those with particular causation, typically pointing to natural selection). However, here they appear to re-evaluate such arguments (at least with regard to the currency of D&C) claiming that the zero-force (i.e., inherently passive) ZFEL is through-and-through a driven cause, tending for simultaneous increase in minimal, mean, and maximal D&T (or any other metric) within any particular system. (In this light, they argue that stability or decreases in D&C indicate the presence of some oppositional force, such as a constraint, absorbing boundary, or selective disadvantage.)

Organismal complexity across the Geozoic (i.e., the history of life; Kowalewski et al., 2011), therefore, does not appear to support their argument for the ZFEL because prokaryotes (the minimally complex life-form) are as non-complex today as they apparently were when they first existed. If the ZFEL acted upon complexity as expected, then the authors contend that organisms as simple as prokaryotes should no longer exist, having long ago given way to more and more structurally complex descendants. The authors conclude, apparently at odds with their intuition, that there must be developmental constraints or selective forces opposing this complexity-increasing tendency of the ZFEL, at least across the scale of life. (The ZFEL, however, does appear to offer an explanation for why even simpler protocells and proto-replicators that likely initiated life itself may no longer exist.)

The second example concerns their interpretation of Phanerozoic taxonomic, morphologic, and ecological diversity (or disparity). From the perspective of ZFEL, McShea and Brandon interpret the vast majority of Phanerozoic large-scale trends as being consistent with the ZFEL. Sure, different forces (such as key innovations, escalatory arms races, ecological specialization, etc.) may affect different lineages at different times, such that each lineage bears its own unique and distinctive history shaped by selection. But so long as such factors act independently among different lineages, the net effect is a driven increase in the diversity of species, genera, and all other taxonomic groups at all times, unless acted upon by external constraints or shared forces, such as mass extinctions.

Besides a compelling take on basic biological phenomena (and the authors have a zeal for showing how nearly any biological concept easily can be accommodated, nay, even predicted by, the ZFEL) their hypothesis will benefit from additional testing in particular instances. A good place to start for paleobiologists is to pay greater attention to variability itself, especially across different hierarchical units. Disparity and taxonomic richness are frequently used for larger taxonomic units, but less is known within smaller units, say populations and species. The studies of Hunt (2004) and Webster (2007) could serve as useful models for such finer-scale analyses.

Overall, this slim book is a great read, putting forth an intuitive and elegant case with significant implications that shed new light on all aspects of biology. It should be read by anyone interested in ecology and evolution and their manifestations across any scale of organismal complexity, from molecules to genes to communities and clades. In other words, every biologist should read it! But it should also be read by physicists, chemists and other reductionists, who might better appreciate the unique roles of biological variability and inheritance that makes our science more complicated, more historicist by nature, more hierarchically emergent, and ultimately innately worthwhile of study.

REFERENCES