LITERATURE REVIEWS

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A RESPONSE TO IRREDUCIBLE COMPLEXITY

Compositional Evolution: The Impact of Sex, Symbiosis, and Modularity on the Gradualist Framework of Evolution. Richard A. Watson. 2006. Cambridge, MA: The MIT Press. 324 p. Hardcover, $50.00.

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A gradualist Darwinian framework pervades public discourse about evolution. Critics of evolution urge the impossibility of evolving complex, interdependent biological systems in a gradual, step-by-step manner because the intermediate steps would be non- or maladaptive and thus would not be preserved by natural selection (e.g., Behe 1996). Evolutionary apologists counter by arguing for the feasibility or even inevitability of such gradual, cumulative evolutionary pathways (e.g., Dawkins 1996).

Which argument is correct? Perhaps neither is — or so claims Richard Watson in *Compositional Evolution*. Watson, a University of Southampton lecturer in computer science, primarily supports this claim by formal analysis of models in evolutionary computing, a discipline inspired by biological variation and natural selection that seeks to develop problem-solving strategies. Fortunately, Watson is also well informed on biological theory, and his analysis is explicitly shaped by (and brought to bear on) concepts of biological evolution.

Watson develops two interrelated arguments. First, he contends that the gradualist framework of evolution is wedded to a particular class of evolutionary algorithm (random-mutation hill-climbing procedures) that focuses procedurally on step-by-step accumulation of favorable mutations *within* a single evolving lineage. This approach works well when the individual attributes of the evolving species may be optimized more or less independently, but fails otherwise. Second, he claims that certain "compositional" processes of evolution (more on this below) are not tied to this gradualist framework, represent a distinct algorithmic class of evolution (so-called divide-and-conquer procedures), and can readily find optimized solutions to complex evolutionary problems that stump gradualism. Thus, he offers a broader framework for understanding evolutionary capability.

Compositional evolution denotes "evolutionary processes involving the combination of systems or subsystems of semi-independently pre-adapted genetic material" (p 3) — processes such as sexual recombination, hybridization, lateral gene transfer, and symbiotic encapsulation (that is, capture of one organism within another to form an integrated whole). In the ecosystem populated by evolutionary computing models, such processes readily solve certain irreducibly complex problems that baffle gradualism — if the attributes of the evolving "lineage" display modular structure in their degree of independence. (In these theoretical organisms, attributes are grouped *within* a module if they show relatively great interdependence — you can't change one without significantly affecting the others — whereas attributes are placed in *separate* modules if they vary independently.) Given this structure, the various modules (attribute sets) can be semi-independently "optimized" in a diverse array of evolving lineages. This diverse set of locally fit "specialist" modules can then be swapped around by compositional processes to find more globally fit "generalist" combinations.

Fortunately for mere mortals such as me, the first 3 chapters provide an excellent, intuitive overview of his argument and access to the relevant theory in biology and evolutionary computing. The final chapter (Ch 10) is similarly accessible, and explores the impact of his argument on the way we view evolution. The core of his argument — complete with dense, formal model articulation and computer simulation — is offered in Chapters 4–9. Watson formally develops a modular test problem (Ch 4), shows that it cannot be solved by gradually accumulating favorable variations within a lineage (Ch 5), and demonstrates that the problem is readily solved by evolutionary computing simulations based on sexual recombination (under certain circumstances — Ch 6) or symbiotic encapsulation (under all circumstances — Ch 7). Watson then formalizes the claim that complex evolutionary problems involving strongly interdependent attributes are essentially unsolvable by gradualistic mechanisms in rational time frames (Ch 8), and shows that compositional mechanisms can exploit variation expressed at various levels of complexity (Ch 9).

For readers of *Origins*, the most important question is whether Watson successfully offers a viable natural mechanism to evolve the complex, interdependent systems so characteristic of life (e.g., Behe 1996). That depends, of course, on the degree to which his computer models mimic salient features of life. For example, compositional evolution only works when a complex problem displays modular structure in attribute interdependency (see preceding discussion). If attributes of a lineage display strong but arbitrary interdependencies (that is, some attributes are strongly interdependent — change of one strongly affects the other — but these interdependencies are not ordered into a modular structure), both gradual and compositional evolution fail. Which of these conditions is characteristic of real-life problems, such as evolving a bacterial flagellum, cellular postal system, or immune system (Behe 1996)? More work is in order.

All Watson's modeling requires a computer — a very complex, designed machine that mimics, with carefully designed programming, aspects of heredity, self-replication of instructions, variation, and selection. Similarly, evolutionary mechanisms, whatever their potential and limits, are only plausible with the biological equivalent: a remarkably complex "machine" capable of heredity, self-replication (of instructions *and* of the machine itself), variation, and responding to selection. Can computational evolution craft the computer? I doubt it.

Compositional Evolution offers important arguments about evolution, which should stimulate further work in evolutionary computing and evolutionary biology as well as discussion among evolution's critics. The excellent introductory and concluding chapters, along with periodic summaries in other chapters, flow well and allow the careful reader with a general knowledge of genetics and evolution to grasp the core arguments, at least conceptually. However, readers who lack significant computer science background will have difficulty assessing the validity of his formal argumentation.

On a final note, I appreciated the professional, civil tone of Watson's work. In particular, Watson repeatedly and directly addressed Michael Behe's critique of evolution (Behe is listed 8 times in the index) without resorting to design-bashing. He disagreed with Behe, but seemed to take his arguments seriously. I wish all participants in the debate — both apologists for and critics of evolution — would follow his example.

LITERATURE CITED

Behe MJ. 1996. *Darwin's Black Box: The Biochemical Challenge to Evolution.* NY: Free Press. 307 p.

Dawkins R. 1996. *Climbing Mount Improbable.* NY: W. W. Norton. 340 p.