about selected topics of molecular evolution for which likelihood and Bayesian statistical methods have been most thoroughly developed. In contrast, this publication covers almost nothing about topics such as genome organization and analysis, gene duplication, concerted evolution, transposition, horizontal transfer, reticulation, alignment methods, molecular considerations of homology, or many other standard topics usually covered in courses about molecular evolution. In fact, the words "genome" or "genomic" appear nowhere in the index or the detailed Table of Contents, and there is virtually no consideration of genomic-scale analyses. As a result, the volume will better serve as a manual for practitioners interested in understanding particular statistical methods than as a textbook for an advanced course in molecular evolution. For the latter purpose, considerable additional resources would be necessary, including additional background readings and modern application papers. The few worked biological examples tend to be highly simplistic, and some topics (such as species delimitation) are covered from such a narrow perspective as to be seriously misleading, or at least incomplete.

Although this book is not well suited as a general introduction to the field of molecular evolution, it is nonetheless a valuable and highly useful contribution to the field. It is especially important as a reference and overview of likelihood and Bayesian statistical methods in phylogenetics, adaptive protein evolution, and molecular clocks.

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THE ENGINE OF COMPLEXITY: EVOLUTION AS COMPUTATION.

By John E. Mayfield. New York: Columbia University Press. $34.50. xv + 398 p.; ill.; index. ISBN: 978-0-231-16304-0. 2013.

In an extraordinarily ambitious and broad volume, John Mayfield, a professor emeritus of genetics at Iowa State University, wants readers to appreciate the power of evolution from a different point of view: that of computation. He writes: "The separation of computation from physical and biological processes is an historical accident of the way scientific understanding developed over the past four-hundred years" (p. 323), and although this insight (as he writes) may seem "a little unsettling" (p. 323), this is an insight that has been fairly commonplace among a widening group of researchers working at the intersection of evolutionary biology and computer science. Think, for example, of a protein and the complex structure it folds into after its sequence is generated by translation from the corresponding messenger RNA. The protein assumes the fold usually in less than a second without fail (often much faster than that). For proteins of moderate and longer length, our best supercomputers are unable to predict this structure, that is, they cannot complete that computation. How is it possible that a lowly protein can outperform our best computers? The answer is that our desktop and supercomputers are *universal* computers that are designed so that they can tackle any computation, while the protein is a jack-of-only-one-trade: to compute its structure. The protein performs this singular task lightning fast because it has to; failure to complete the "calculation" in time might spell doom for the organism. Indeed, the computational paradigm applies in particular to the process at the heart of Mayfield's book: evolution, and survival is of course one of the requirements for the continued participation in the planetwide process.

Although the author is a geneticist (but trained in biophysics), he is not known for his work on evolutionary theory. As a consequence, I was somewhat apprehensive about reviewing this book, because even workers in biological fields often get the more intricate aspects of evolution wrong. This fear was unwarranted in this case: Mayfield is sure-footed, and often displays an uncanny intuition when describing fields that are not his own. And venture beyond his bailiwick he does: the book sweeps from information theory to the theory of computation and complexity, over statistical physics and network theory to genetic algorithms, taking detours to describe the immune system, neurophysiology, and the brain.

Is all of this necessary to get the point across that evolution is a computation with enormous power, which has emerged multiple times and is at work at multiple scales? I think it is, and Mayfield does an admirable job of describing what is so special about evolution as a process, in particular when focusing on information as the key concept to understand evolution. The sections that deal with the importance of instructions to achieve high fitness should be required reading for anyone who wonders about where the power of evolution comes from.

This does not mean that the author gets everything right in this volume. For example, he remarks that something that is perfectly random is also the most informative (in the description of Kolmogorov complexity), but this statement (often made in the literature) is based on a confusion of the concepts of entropy and information. Something that is perfectly random is perfectly entropic, not informative. Similarly, he argues against my own information-theoretic definition of complexity (the "physical complexity"; see C. Adami. 2002. *BioEssays* 24:1085-1094) by describing it as "negentropy," when it is nothing of the sort. But these quibbles should not detract from a superb book, confidently written and spanning the gamut of complex systems research. Although it is perhaps less

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engaging than M. Mitchell Waldrop's *Complexity: The Emerging Science at the Edge of Order and Chaos* (1993. New York: Simon and Schuster), which has fired up the imagination of so many budding researchers, because Mayfield focuses more on the science and less on the scientists (as Waldrop does) I think that the current volume is in the end more valuable, because it teaches readers something, while Waldrop's book seeks to dazzle.

At the end of the book, Mayfield invites us to contemplate what the future may hold, given the insights about the nature of evolution as a powerful computational paradigm he just conveyed. He traces the history of life on Earth and remarks that four seminal events have shaped us, accelerating progress each time in a manner reminiscent of Moore's law. The first is the origin of life, which is tantamount to the first instantiation of the eponymous engine of complexity. The second (according to him) is the origin of thought some 200 million years ago (I would have not skipped the origin of multicellularity). The third turning point is the origin of speech, and the fourth the invention of the evolutionary algorithm, which makes it possible to use the process inside of computers. Mayfield chose these events because each of them changes how evolution acts: first on bare information, then acting in the brain, then culturally and, finally, in the computer. He then wonders what the next "origin" or turning point might be, which according to his timeline should occur just about now (as the engine of complexity is ever accelerating). It is curious that he does not notice that the next revolution is an obvious consequence of his entire book: to use the computational engine of complexity to create artificial brains that rival the ones that the biological engine has brought forth. Indeed, several laboratories (including my own) have charted this new path toward machine intelligence and consciousness, and we are determined to see it through.

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BEHAVIOR

The Homing Instinct: Meaning and Mystery in Animal Migration.

By Bernd Heinrich. Boston (Massachusetts): Houghton Mifflin Harcourt. $27.00. xv + 352 p.; ill.; index. ISBN: 978-0-547-19848-4. 2014.

I had the pleasure of reading this book snowed in by a nor'easter on the Kennebec River, a few miles downstream from much of the action in this very personal narrative. The title is misleading: of the 16 chapters, only one is heavily focused on the mystery of migration and homing. On the other hand, four are mostly about animal architecture, one is on the history of fire, one is devoted to hunting deer, another to a detailed history of the land the author's cabin occupies, and so on. As with many of his previous publications, Heinrich uses migration merely as a starting point for a series of biological reflections centered in many cases around memorable anecdotes, circling back obliquely to the topic at the end for a thought-provoking look at extinction and the future of our species. As readers of his previous works will expect, the volume is full of obscure but uniformly interesting bits of scientific history.

The book opens with a visit to friends in Alaska as cranes return to court and nest. It continues with beelining and a glance at ant and bee orientation. Heinrich then examines what makes for a good home, considering such migration-challenged species as aphids, ladybird beetles, and tent caterpillars (along with long-distance travelers such as monarchs and eels). Actual migration comes next, although the emphasis is on animal compasses rather than the mysterious map sense. A brief chapter on salmon and one on how bees pick their nesting sites wraps up this first of the book's three sections.

Part II (Home-Making and Maintaining) is mostly about nestmaking, although more concerned with the evolutionary logic of homes than the ways in which animals select the right materials and suitable locations, then bring to bear complex construction techniques and highly refined building designs. Heinrich chooses bees, moths, caddisflies, spiders, frogs, weaverbirds, and beavers for his examples. As with Part I there are occasional sketches, but none of the maps, graphs, or diagrams that would be an essential accompaniment for a more detailed or mechanistic account.

Part III (Homing Implications) devotes three chapters to Heinrich's experiences as a boy and then later in the Maine woods. The last two chapters of the book are the richest and most compelling. The first is on the spread of humans from Africa to every corner of the globe. He is convinced—quite reasonably—that our mastery of fire is a key element of the story. Fire frees us from the year-round warmth of the tropics, and through cooking roughly doubles the nutritive value of food. But was our spread a result of the innate "pull" of an exploration instinct or the "push" of competition with other humans? After a look at other species, Heinrich concludes it was a bit of each.

The culmination of *The Homing Instinct* is a fascinating chapter on orientation to the group: animals that seek out their own kind rather than a traditional territory or home range. The author argues that several extinctions—desert locusts, passenger pigeons, and (almost) the bison—can be attributed to this excessive

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