Book Review

The Mermaid's Tale: Four Billion Years of Cooperation in the Making of Living Things. By Kenneth M. Weiss AND Anne V. Buchanan. xiv + 305 pp. Cambridge, MA: Harvard University Press. 2009. $35.00 (cloth).

The motivation for *The Mermaid's Tale: Four Billion Years of Cooperation in the Making of Living Things* is what the authors view as an overemphasis of the role of natural selection in evolution and the emergence of biological complexity and diversity. The book is written with a de-emphasis on detail, and although this has its merits (see below), ultimately, I found that many of the arguments amounted to "just so" stories, needing deeper development and justification. Below I describe why I came away from this book largely unconvinced and sometimes annoyed.

The Mermaid's Tale is presented in three parts. A common theme running throughout is the distinction and crucial roles that evolution (Evo), development (Devo), and ecology (Eco) play in explaining biological complexity. The modes, functions, and time scales of Evo, Devo, and Eco are very different, but complementary and interactive. Part One gives an overview of the patterns common to life. These are well explained and provide the backdrop for the rest of the book. In particular, the authors commendably describe biological complexity in simple terms, and stress the temporal and inheritance aspects of how complexity is built in the evolutionary process. Part Two of the book stresses the developmental and ecological mechanisms/phenomena of complexity, providing examples and discussion of how the structure we observe ensures (cooperative) interactions in our internal and external environments. Part Three attempts to provide the "why" and "how" complexity arose in the first place, and is maintained. The core of the argument is the relative importance of chance and natural selection in the evolutionary process, and these are compared and contrasted using real examples, analogies, and metaphors. Part Three is notably written in a more argumentative style than the first two sections.

My critical view on what the authors attempt to achieve, and especially how they do it, is not because I do not agree with some of their premises and conclusions, but rather if one seeks to reassess or overturn conventional wisdom or widely accepted theory, then much more ammunition is needed than this book actually delivers. I have three main critiques.

First, *The Mermaid's Tale* employs verbal arguments (hence the *Tale*), occasional analogies, and metaphors, and many examples or case studies. There is not a single datum brought to the fore to substantiate the claims, especially needed in the controversial Part Three. Moreover, for readability purposes, the suggested literature is entirely deferred to appendices. The literature cited in the appendices is indeed impressive, and the authors do comment on each article in the lists. The problem, however, is that specific studies are not directly associated with specific claims in the text itself, and some studies claiming or actually showing the general importance of natural selection are not given balanced/accurate commentaries. Thus readers not familiar with the (considerable) literature risk accepting the authors' arguments based on faith. I would have liked to see footnotes in the body of the book itself.

Second, Part Three comes across to this reader as a mission to minimize the importance of natural selection to biological complexity and diversity. Although there are places where the authors do give a balanced treatment, I came away feeling that they often went to pains to develop their point of view that much or most of what we see is due to chance. Many of their supportive statements are "matter of fact," and I found this annoying.

Third, certain affirmations in this book are incorrect or possibly misleading. For example, the authors dwell on a coin flipping metaphor to show that small fitness advantages (the fuel for natural selection to operate) are statistically difficult or impossible to detect. Thus, if a coin is biased by 1% to heads for a given flip, then it may well be that after a limited number of flips that heads are either more or less frequent than the expectation of 1% superiority. The problem is that their coin flipping metaphor is not how populations evolve through natural selection. In a simple scenario, there are two genotypes, call them A and B. A has a 1% fitness advantage over B, that is, we expect that A individuals will leave 1% more offspring than will B individuals. In its simplest form, population genetics shows that the probability of fixation of A types under natural selection is $\sim$1% (this figure can vary depending on species biology and the environment). This figure may seem small, but environments are complex, and so tens, hundreds, or even thousands of traits may be evolving at any one time, meaning that some will emerge, and others will not. Moreover, evolutionary history for a given trait (A for example) is not limited to a single mutational event (the 1% scenario above) and may be achievable through mutations at different genes. Thus, each trait may have many opportunities through evolutionary history to become established.

This simple example concerns fixation of a selected trait through natural selection. What about natural selection versus chance in explaining evolution? Population genetics can instruct here as well. The probability of fixation under a neutral (chance) model is 1 divided by the population size. Call this $1/N$. So an approximate condition for natural selection to be the more probable cause of the fixation event when the fitness advantage is 1% is $0.01 > 1/N$, or just $N > 100$. Thus, when a trait is fixed, natural selection will dominate chance effects for populations of more than about 100 individuals. Larger fitness advantages will require smaller populations for natural selection to dominate chance; smaller fitness advantages will require larger populations.

Chance can and does contribute to the evolutionary process, but its importance is not always as clear-cut as the authors argue. Different (chance) mutations may either independently or interactively, code for the same or similar phenotypic traits. Which one of the many alternatives actually appears has a chance element to it, but the actual spread through the population depends on fitness differentials and population size. As argued earlier, population genetics provides the approximate conditions for which natural selection or random drift (a type of chance, distinct from the appearance of random mutations) predominates.

Students of biology need to know the mechanisms behind the evolution of form, function, and the emergence

of diversity. They need to know how, when, and why natural selection and chance act separately or together. This is a phenomenal task. I believe that in taking a strong, provocative stance, the authors will indeed succeed in making scientists think about these questions.

As an ecologist and evolutionary biologist, I am not surprised by the conclusions of *The Mermaid's Tale*. Similar perspectives have been put forward by Niles Eldredge, Brian Goodwin, and Robert Wesson. I know that perfect "selection of the fittest" is a gross oversimplification of how natural selection works, that chance effects can play important or even dominant roles, and that phenomena such as self-organization and emerging complexity are not easily explained by selectionist arguments alone. Perhaps the natural selection bias perceived by some biologists merits the challenge waged in this book. Nothing can be better for the open but wary reader.

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