The Biophysicist

So Simple A Beginning: How Four Physical Principles Shape Our Living World by Raghuveer Parthasarathy

Catherine H. Crouch

Department of Physics, Swarthmore College, Swarthmore, PA, USA

So Simple A Beginning: How Four Physical Principles Shape Our Living World by Raghuveer Parthasarathy. 2022. Princeton University Press, Princeton, NJ. 336 pp. ISBN 978-0691200408.

So Simple A Beginning sets out to show its readers that the endlessly fascinating and varied living world nonetheless has a "surprising elegance and order" that can be found "through the lens of physics" (p. 1). While the readership of *The Biophysicist* probably does not need to be persuaded by this statement, nevertheless I am sure they will greatly enjoy Raghuveer Parthasarathy's take on the four unifying principles of the physics of life, each illustrated with a variety of examples ranging from the microscopic world of molecules and cells to large organisms and ecosystems. Parthasarathy's writing is exceptionally clear, concise, and vivid; the watercolor illustrations (also prepared by the author) are simple and beautiful.

Written almost entirely without mathematics, with only four of the dozens of illustrations showing data, this book is written for a general audience (on his blog, the author describes it as his "pop-science book" (1)). Nevertheless, it is thoughtful and lively enough to be a delightful read for a fellow physicist.

Not only is this book wonderfully written, Parthasarathy is to be commended for revealing the human process of science to the reader. He briefly (and nontechnically) describes the experiments in which the ideas presented were discovered or confirmed. For the reader with a scientific background, he provides citations for these experiments as well as more general sources in 38 pages of references, provided as endnotes connecting to short text quotes or summaries listed by chapter and page. I also greatly appreciate that when appropriate, he names more than one scientist associated with a discovery—for example, I learned from this book that three scientists each independently developed explanations of the mechanism of Brownian motion (Albert Einstein, Marian Smoluchowski, and William Sutherland; p. 91)—and he gives first names, thereby emphasizing the humanity of the scientific enterprise.

Parthasarathy's four principles are self-assembly, regulatory circuits, "predictable randomness" (encompassing both statistical phenomena and Brownian motion), and scaling. After introducing these principles, they are illustrated first at the molecular and cellular level ("Part I: The Ingredients of Life"), in which he presents the key features of DNA and the processes by which it is rendered into proteins (commonly called

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the "central dogma of molecular biology"), including a high-level look at transcriptional control, as well as the nature of cell membranes and examples of microscale random and directed motion.

Subsequently, he turns to the organismal and ecosystem level ("Part II: Living Large"), in which he considers pattern formation in development (with a hefty dose of genetics along the way), the role of the extracellular matrix and mechanical stimuli in cell differentiation, the gut microbiome, several examples of body plan scaling, and a variety of surface effects, including insects' ability to walk on water and the critical role of lung surfactant in the challenges faced by premature infants. Congruent with his emphasis on the process of science throughout, this section also includes a laudable look at a still-unanswered question in which some previously advanced explanations seem to have failed (chapter 12, "Mysteries of Size and Shape")—namely, to determine whether the observed power law scaling of basal metabolic rate with mass reflects an underlying mechanism and, if so, what it might be. The final section of the book discusses prospects for using biotechnology to design, modify, and control living systems ("Part III: Organisms by Design"), with explanations of past and current biotechnology ranging from DNA sequencing to CRISPR.

Parthasarathy's four principles and the illustrative examples are congruent with the themes and illustrations presented by numerous more technical textbooks (2–8), several of which are cited at the beginning of the references, as well as curricula for undergraduate courses, including introductory physics courses designed specifically to address the needs of undergraduate life science majors (9–14). Nevertheless, Parthasarathy brings a distinct voice and perspective to these themes and examples. (Although I am not exhaustively familiar with every one of these other treatments, I have taught or developed courses that use many of them.) Also, because he writes for a general audience, this format gives him the freedom to focus on the big picture, which, together with his beautiful, concise writing, makes for very enjoyable reading. Thus, I am confident that the readers of *The Biophysicist* will enjoy reading this book, as I did. Whether it is accessible to a general audience beyond those with a scientific education, I am less sure, because it is written more at the level of *Scientific American* than *Newsweek*.

I did find it surprising, and slightly disappointing, that he uses mathematics so little; there is only one equation in the book, in his discussion of scaling, although he does use numbers occasionally and provides a few quantitative graphs (again predominantly in the scaling chapter). Given the centrality of mathematics to the "lens of physics" he seeks to use, I wonder if it should have played a slightly more prominent role. His explanation of scientific notation (including a brilliant rationale for why $10^0 = 1$) shows that he explains mathematical ideas in a clear, captivating manner. I would have liked him to put his talents to work with more material, particularly in the discussion of "predictable randomness." However in my mind, this is a modest shortcoming of an extremely well presented book in which the author simply chose differently.

The significant shortcoming of *So Simple A Beginning* is that Parthasarathy attempts to offer some brief reflections on the ethical implications of the science, which stand in disappointing contrast to the rigor and intellectual richness of the rest of the book. While I commend him highly for calling attention to the ethical dimensions of the field, which many general-audience science books do not, and for his expressions of humility and efforts at even-handedness, unfortunately his discussions of the ethics related to embryonic trait selection and the use of CRISPR/Cas editing and gene drives to alter humans and ecosystems (chapters 14 and 16) are disappointingly simplistic and fail to acknowledge some relevant and important ethical traditions. Furthermore, his reflections fall short of the high intellectual standards he has set in the rest of the book. When writing about the science, he takes care to reference and interact with the scientific literature. In contrast, his brief discussion of ethics gives readers no resources for identifying or engaging with expert bioethical or philosophical

reflection on these issues, either in the text or the references. Regrettably, this omission and the nature of his reflections leaves open the question of whether Parthasarathy himself has engaged with such thinkers.

I asked several colleagues who are philosophers or ethicists to recommend a few open-source, peer-reviewed, reasonably accessible resources, which I share here for readers of *The Biophysicist* who are interested in investigating these ethical issues further (15–17), although this list should not be taken as exhaustive. I greatly benefited from this dialogue with my colleagues and encourage interested readers to consider doing the same.

Given the limits of his ethical reflections, a better approach would have been to acknowledge that some of the science he presents is accompanied by profound ethical issues but not attempt to address them. Indeed, Parthasarathy takes this approach the first time he mentions ethics, in the discussion of growing human cerebral organoids. There, he writes "Though the possibility of cerebral organoids developing sensation or consciousness is very far off, scientists and philosophers are already collaborating to map the ethical issues involved, including the question of how to assess and interpret the capabilities of a collection of neural cells" (p. 131). Here, I greatly appreciate that he highlights that scientists need to collaborate with experts in ethics and applaud his wisdom and restraint. I think Parthasarathy would have been wise to take this approach throughout.

For the work of science to thrive, scientists need to promote meaningful collaboration with ethical experts around the challenges raised by scientific discoveries and technologies. As a science educator, I am proud that increasingly my students are conscious of these challenges and attentive to the manner in which they are addressed.

Most book reviews in *The Biophysicist* so far have been of textbooks, whereas this book is manifestly not a textbook. Nonetheless, given the stated mission of *The Biophysicist*, I think it appropriate to consider in what ways this book can serve as an educational resource. I am confident it could be a great resource for the biophysics community in sharing the excitement and elegance of the field of biophysics with others within higher education. Its approach could also be a valuable guide for biophysicists preparing for outreach events or producing resources for K-12 teachers, although those events or resources might need to take an even less technical approach than this book.

Could this book be useful as a text for undergraduate students? In an advanced undergraduate course in biophysics taught with any of the previously cited textbooks, I could imagine *So Simple a Beginning* could be a useful supplement for physics majors who have little previous knowledge of biology. Such students often struggle to keep the big picture in sight when learning lots of new biology alongside biophysics. This book might help them gain that big picture before diving into a more technical treatment, as well as helping reinforce the importance of experiments. (One caveat: I wonder how well someone with no background in genetics or development could follow the discussion of chapter 7, "Assembling Embryos.")

By contrast, I would not recommend using this book for a general education course for nonscientists, unless it was combined with other complementary resources. I do not think this book provides enough depth to equip novice students to work with the ideas it presents. The essence of learning science is to be able to analyze new situations meaningfully with the ideas that have been learned. I do not see how I could construct student assignments or tasks from these readings alone, in which students could do anything more than repeat what they had read. This impression should not be taken as a criticism because I do not believe the book was written for this purpose—this advice is only for those who might consider using it this way. Parthasarathy indicates in the acknowledgments that, although he teaches a general education course on this topic, the book has diverged substantially from the course.

So Simple a Beginning is a beautifully crafted book that contagiously shares its author's joy and delight at the common themes unifying the tremendous variety in the physics of living systems. I commend the author on its many great strengths.

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