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Dreams of Earth and Sky; *Birds and Frogs: Selected Papers, 1990–2014* FREE

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Writings of a visionary

Dreams of Earth and Sky

Freeman Dyson
New York Review of Books, 2015.
$27.95 (298 pp.).
ISBN 978-1-59017-854-6

Birds and Frogs
Selected Papers, 1990–2014

Freeman J. Dyson
World Scientific, 2015. $58.00
(223 pp.). ISBN 978-981-4602-85-3

Reviewed by Frank Wilczek

Dreams of Earth and Sky and *Birds and Frogs: Selected Papers, 1990–2014* are new collections of pieces by Freeman Dyson. *Dreams of Earth and Sky* assembles essays originally published in the *New York Review of Books* and is intended for general readers. The texture of *Birds and Frogs* is more varied and on the whole more technical; it ranges from speeches for scientific audiences to thought-provoking pieces to journal articles. Leaving aside a couple of the latter, readers of PHYSICS TODAY will find both books easily digestible and will be prepared fully to savor many strikingly original ideas and viewpoints expressed in stylish yet always lucid prose.

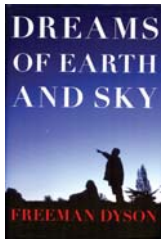
A 2009 essay published in the *Notices of the American Mathematical Society* lends *Birds and Frogs* its title. In that essay, Dyson puts mathematicians and physicists into two camps: frogs, who are serial problem solvers, and birds, who are visionary and system-building. Dyson locates himself firmly among the frogs, and the description clearly fits. Notwithstanding, one of his "problem-solving" efforts gave birth to the great system of modern quantum field theory: his synthesis of Richard Feynman's intuitive approach to quantum electrodynamics (QED) with the more securely grounded but less agile methods of Julian Schwinger and Sin-itiro Tomonaga.

These books leap, frog-like, from one topic to another—as will, necessarily, this brief tour of them.

Frank Wilczek is the Herman Feshbach Professor of Physics at the Massachusetts Institute of Technology in Cambridge and corecipient of the 2004 Nobel Prize in Physics. He is the author of a new book, *A Beautiful Question: Finding Nature's Deep Design* (Penguin Press, 2015).

One of the joys of both books is the pleasure of getting to know Dyson better. The greatest of biographies, James Boswell's *The Life of Samuel Johnson* (1791), is not so much a chronicle as an impressionistic portrait, wherein the remarkable subject emerges from accounts of witnessed conversations interwoven with episodes from his life.

With *Birds and Frogs* especially, Dyson is his own Boswell. In it, we meet Dyson in his school days, when a small band of scientists-to-be (including James Lighthill) constructed their own curriculum and taught one another; in his Cambridge days, when he fell under the spell of Russian mathematician Abram Besicovitch; and at his introduction to frontier physics under Nicholas Kemmer, an underappreciated hero of particle physics.



Especially fascinating is the essay "A Failure of Intelligence," in which Dyson recounts his work during World War II, when he analyzed the effectiveness of offensive and defensive strategies for strategic bombing. That candid and detailed account of the choices the air command personnel faced and the procedures whereby they reached decisions is an education in real-life game theory and a vivid illustration of the difference between what is optimal and what is politically possible.

Skipping ahead many years, we meet Dyson amongst a citizen committee assessing biohazards in Princeton, New Jersey. His joy in interacting with people from vastly different backgrounds shines through, as does his pleasure in entertaining contradictory answers to questions. The essay "Of Children and Grandchildren" is a beautiful coda.

Dyson's paper, with Thibault Damour, placing empirical limits on the possible time variation of the fine-structure and other fundamental "constants" is a gem within *Birds and Frogs*. There are also the provocative examinations of the Bohr–Einstein debate about the foundations of quantum mechanics ("Thought Experiments—In Honor of John Wheeler"), the necessity for quantum gravity ("Is a Graviton Detectable?"), and a suggested connection between quasicrystals and the Riemann hypothesis. Appearing in full is Dyson's remarkable—and remarkably readable—2012 paper with William Press on the iterated prisoner's dilemma, from the *Proceedings of the National Academy of Sciences*; that work has triggered something of a revolution in evolutionary game theory.

Dreams of Earth and Sky begins with the essay "Our Biotech Future," wherein Dyson pictures a near future in which genetic engineering is a hobbyist activity and teenagers sculpt life-forms and invent new species in their family's garage. A similar essay in *Birds and Frogs*—"Noah's Ark Eggs and Viviparous Plants"—sketches a strategy for expanding the biosphere to the outermost regions of the solar system and beyond, perhaps using some of those new species. No short summary can do justice to the wealth of imaginative brilliance and contagious enthusiasm of those visions. They are mind-expanding.

For me, the most problematic passages in both books are those that deal with science policy. Here I will mention two issues, both arising in *Dreams of Earth and Sky*.

Dyson is, in general, a champion of small science, as opposed to big science. In "Leaping into the Grand Unknown" he downplays the importance of high-energy accelerators. He specifically recommends precision studies of low-energy processes and more intense cultivation of cosmic-ray studies as cheaper, more nimble alternatives for accessing fundamental physics. But experimental particle physics turned from cosmic rays to accelerators long ago for very good reasons—incomparably higher rates of data acquisition under incomparably more controlled conditions—that today seem to me more valid than ever. We should by all means explore the frontiers of precision and look to the sky as a source of surprises. But accelerators have already given us crucial insights that, realistically, would never have emerged by other routes.

And in "The Question of Global Warming," Dyson downplays the widely perceived crisis and instead emphasizes that existing climate models contain major uncertainties. Maybe they do. But the community of special-

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ists in that field, which is large, diverse, and not unsophisticated, has, following many years of carefully documented and heavily scrutinized study, reached consensus that the danger of catastrophic anthropogenic climate change is real and imminent. Unfortunately, powerful economic and political interests are more than ready to exploit the ingenuousness of scientists who revel in good-natured contrarianism that in less grave contexts would be healthy and entertaining. Usually there is wisdom in abounding charity and tact. But when momentous choices are at stake, those virtues are luxuries one may need to sacrifice.

My brief tour of the new Dyson collections concludes with his appreciation for the virtues of blunders, in the introduction to *Dreams of Earth and Sky*:

> . . . my sympathetic treatment of dubious characters such as Immanuel Velikovsky and Arthur Eddington . . . William James and Sigmund Freud. . . . Each of these characters built a universe of his own imagination outside the limits of conventional science, and each of them was shunned by the upholders of orthodox beliefs. I present them as heroes because I like to break down the barriers that separate science from other sources of human wisdom.

And in the final essay of that collection, he gives a sympathetic reading to Mario Livio's wonderful book *Brilliant Blunders* (Simon & Schuster, 2013; reviewed in PHYSICS TODAY, August 2013, page 48), including this:

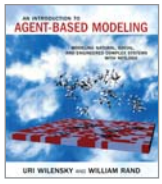
> The essential point of Livio's book is to show the passionate pursuit of wrong theories as a part of the normal development of science. Wrong theories are not an impediment to the progress of science; they are a central part of the struggle.

An Introduction to Agent-Based Modeling

Modeling Natural, Social, and Engineered Complex Systems with NetLogo

Uri Wilensky and William Rand
MIT Press, 2015. $65.00 paper
(482 pp.). ISBN 978-0-262-73189-8

Agent-based modeling is an approach to exploring the complex systems that arise in nature, societies, and engineering applications. In contrast to equation-based models of aggregate populations, agent-based models (ABMs) focus on the actions of heterogeneous individuals (agents), be they people, ants, countries, molecules, cancer cells, viruses, vehicles, or photons. The sometimes surprising behaviors of the populations emerge from the behaviors and interactions of the agents.



The best textbook available on this new approach is Uri Wilensky and William Rand's *An Introduction to Agent-Based Modeling: Modeling Natural, Social, and Engineered Complex Systems with NetLogo*. Using examples from physics, biology, sociology, economics, political science, anthropology, and computer science, the book describes how to design, build, verify, validate, and analyze ABMs.

Statistician George Box's famous quote, "All models are wrong, but some are useful," nicely encapsulates one of the authors' key points: Model design and analysis should be guided by the particular questions the researcher wants to answer. Another key point in the text is that often physical insight comes from focusing on the structure of processes and their interactions and not on the particulars of the phenomena under study. For example, ABMs reveal that fluid percolation and forest fires have very strong parallels. And both the spreading of rumors and the diffusion of innovation have much in common with percolation—though important differences also exist.

The book is much more than an introduction to the concepts and applications of ABMs; it also leads the reader through the process of designing, building, and analyzing such models. The authors adopt a sound strategy and recommend it to readers: Begin with very simple models and extend them step by step. Sometimes the general public, including policymakers, believe that ABMs are developed for their predictive value, but the authors correctly observe that explanation and understanding of phenomena are equally important reasons for creating ABMs. As they also point out, ABMs are widely accessible since they require only an understanding of the behavior of the individuals and not a mathematical understanding of the behavior of populations.

Despite the suggestion of the subtitle, the book is not a comprehensive guide to programming ABMs. It does, however, offer many well-reasoned and well-explained examples that should be accessible even to readers with no computer-programming background. The authors' ABM toolkit of choice is NetLogo, which is developed by a team that Wilensky leads. The program is both easy to learn (it is used in high school classes) and powerful (many ambitious research projects rely on it).

Another key and often neglected theme is the importance of paying attention to how the model's execution and output look. The authors present design principles, illustrated by well-thought-out examples, including how to choose effective colors, shapes, and sizes of the agents. Critically, those visualizations are dynamic and appear as two- or three-dimensional animations when executed.

All the example models covered in the book are freely available online and can be run on Windows, Macintosh, or Linux systems. Many of the example programs can also be run on the new online version of NetLogo, which is also available for free. The ability to visualize and control the execution of ABMs in any modern browser opens the door for them to be used as tools for engaging the public, educating students, and influencing policy.

The authors describe "restructuration" of knowledge as analogous to the new way of thinking about numbers that developed as people transitioned from Roman numerals to our Hindu–Arabic positional notation. Something beyond Roman numerals was needed: Consider estimating the number of days since PHYSICS TODAY was established by multiplying LXVII by CCCLXV to obtain $\overline{\text{XX}}$MMMMCDLV. A student who carefully reads *An Introduction to Agent-Based Modeling* and tries a few of the explorations suggested at the end of each chapter should acquire a new way of thinking about complex systems.

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Transition Metal Compounds

Daniel I. Khomskii
Cambridge U. Press, 2014. $125.00
(485 pp.). ISBN 978-1-107-02017-7

For the past half century, John Goodenough's classic text *Magnetism and the Chemical Bond* (Interscience-Wiley, 1963) has served as an introduction and guide for both experimentalists and theorists who studied transition metal (TM)

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