Order out of Chaos

Ilya Prigogine, Isabelle Stengers, and Heinz R. Pagels

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books

Is the irreversibility we see a fundamental property of nature?

Order Out of Chaos

by Ilya Prigogine and Isabelle Stengers
349 pp., Bantam, New York, 1984. $8.95

Reviewed by Heinz R. Pagels

Death, an inevitable and irreversible event, reveals the inexorable movement of time from the past to the future. The observation of the gradual deterioration of all things, the tendency for order to lapse into disorder illustrates what physicists call "time's arrow"—the irreversibility of time. We can certainly determine whether a movie of our macroscopic world is shown backwards.

Yet, if we were able to see a movie of the interactions of atoms and molecules, we would not be able to tell whether it is shown backwards because the fundamental laws of motion for microscopic particles are indifferent to the direction of time; from a microscopic viewpoint, death appears to be an illusion. How is it possible then, that from the microworld of reversible time emerges the observed macroworld of irreversible time?

This profound question, first addressed by the nineteenth century physicist Ludwig Boltzmann, became one of the great themes of the physical sciences. Boltzmann mathematically demonstrated that a statistical property, called the total entropy, always increased in time for an isolated physical system containing a large number of particles, thus giving time its arrow. According to Boltzmann, irreversible time emerges as an objective macroscopic property of a large number of particles, each moving in accordance with time-reversible laws of motion. In the century following Boltzmann's work, his viewpoint has been profoundly deepened; but it has never been disproven.

The origin of irreversible time is the central theme of the well-written and engaging book *Order Out of Chaos* by

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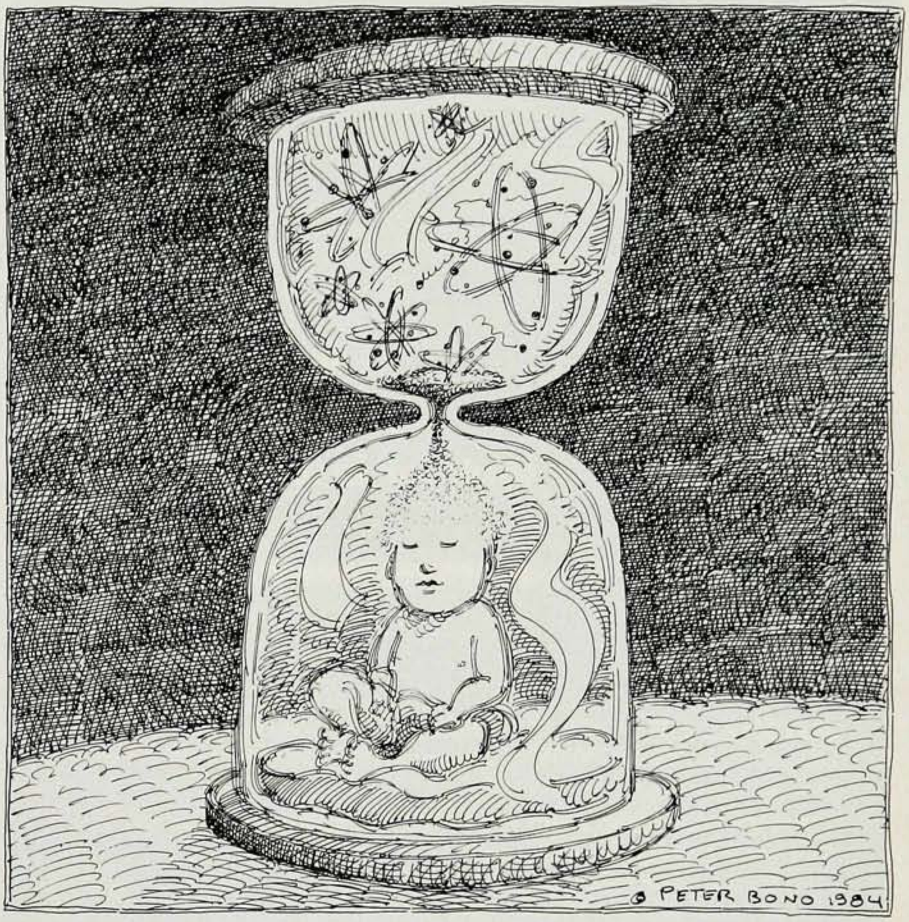

mathematical physicist Ilya Prigogine and Isabelle Stengers. The book is divided into three parts. The first, "The Delusion of the Universal," is a philosophical history of physics with quotations from Kant, Diderot, Hegel, Bergson and Whitehead, among others. These citations from eminent philosophers sound somewhat like that of an ineffectual chorus before the unfolding drama of modern science. The authors take issue with the reductionist tendency of science, what they call "the basic myth of science," held by most contemporary scientists, including Einstein. In Einstein's words, this "myth" is the view that the "the general laws of physics . . . claim to be valid for any natural phenomena whatsoever" and that "it ought to be possible to arrive at the description . . . of every natural process, including life, by means of pure deduction."

The final two parts of the book attempt to provide the scientific support for the integrative philosophy espoused by the authors. In the second part, "The Science of Complexity," one finds clear descriptions of experiments and theoretical models that serve as an introduction to the formidable subjects of statistical mechanics, nonlinear dynamics and the study of physical systems far from equilibrium. But most physicists who devote their lives to these subjects will find their treatment disturbing. For while this book contains much that is new and correct, all too often that which is correct is not new and that which is new is not correct.

Prigogine had the good taste to work upon the most profound problems in physics. To his own surprise (as noted in the foreword) and that of other scientists, he received the Nobel Prize in chemistry in 1977. In collaboration with P. Glansdorff, he devised "The Universal Evolution Criterion," which was misinterpreted by some scientists to be an important generalization to far-from-equilibrium systems of earlier mathematical work of Boltzmann and Lars Onsager (the Norwegian physicist) on close-to-equilibrium thermodynamic systems. But, already in 1974, it was clear from the critical work of the Americans Ronald Fox and Joel Keizer that this "universal criterion" was not universal. Much to his credit, Prigogine in this book finally abandons his claim to have found a universal criterion, which figures prominently in his previous writings. Reversing his previous view completely, he writes, "In contrast with close-to-equilibrium situations, the behavior of a far-from-equilibrium system becomes highly specific."

The idea that living organisms are examples of self-organizing physical systems is not new. Boltzmann, who admired Darwin's evolutionary theory, described the leaves of a tree growing in sunlight as examples of organizing open systems. Alan Turing, the English mathematical genius, began the modern theory of chemical self-organization in his 1952 seminal paper, "The Chemical Basis of Morphogenesis." This work is referred to in one sentence in this book. The main idea is that if the physical parameters that characterize chemical reactions that might occur in an organism exceed critical values, then the reactions may exhibit unusual "self-organizing" behavior.

Yet, in view of what is known by biologists, the suggestion of the authors that "life, far from being outside the natural order, appears as the supreme expression of the self-organizing processes" is simply incorrect. Most scientists would agree with the critical view expressed in *Problems of Biological Physics* (Springer-Verlag, 1981) by the biophysicist L. A. Blumenfeld, when he wrote: "The meaningful macroscopic ordering of biological structure does not arise due to the increase of certain parameters or a system above their critical values. These structures are built according to program-like complicated architectural structures, the meaningful information created during many billions of years of chemical and biological evolution being used." Life is a consequence of microscopic, not macroscopic, organization.

In the final part of the book, "From Being to Becoming," the authors take on the giants—Boltzmann, Einstein, Planck and just about everyone else who holds the conventional idea of time in physics. They present their own unusual idea that the origin of macroscopic time irreversibility is a consequence of a previously unrecognized time irreversibility in the microscopic laws of physics down "to all levels"—even to quantum levels—provided that "a minimum of complexity is maintained." In short, they maintain that time irreversibility is not derived from a time-reversible microworld, but is itself fundamental. The virtue of their idea is that it resolves what they perceive as a "clash of doctrines" about the nature of time in physics.

Most physicists would agree that there is neither empirical evidence to support their view, nor is there a mathematical necessity for it. There is no "clash of doctrines." Only Prigogine and a few collaborators hold to these speculations which, in spite of their efforts, continue to live in the twilight zone of scientific credibility.

Great advances in mainstream science—the study of nonlinear dynamics; the understanding of critical phenomena by Kenneth Wilson, Leo Kadanoff and Michael Fisher; the exciting link between thermodynamics and the geometrical properties of black holes pioneered by Steven Hawking and Jakob Bekenstein—portend a deep unification of our understanding of nature. Unfortunately, little or none of this appears in this book. The reader of this intellectually stimulating book will get a rather distorted picture of what is one of the most exciting areas of research in physics.

Concepts in Particle Physics, Vol. I

K. Gottfried and V. F. Weisskopf
183 pp. Oxford U.P., New York, 1984.
$22.50

Quarks and Leptons

F. Halzen and A. D. Martin
379 pp. Wiley, New York, 1984.
$29.95

The physics community's tradition of broad but rigorous undergraduate preparation, coupled with the increasingly demanding mathematical and technical background required for productive research, places heavy burdens for continual revisions on early-stage graduate courses. Because progress in physics occurs incrementally, with more ideas and conceptual tools being added than discarded at each step, the problems encountered in trying to incorporate all this into courses already crowded with essential material grow more and more vexing. Thus the publication of a textbook based on the struggle to accomplish this—especially in particle physics, where developments have been rapid and profound during the last two decades—is sure to be greeted by students and instructors alike with a combination of relief, enthusiasm, and just a little doubt that it will "work."

The two books reviewed here are surveys of the "new physics" of particles, and while the one by Gottfried and Weisskopf is not intended specifically as a graduate text in the field, it still deserves consideration as an introduction for the sophisticated novice. Although both could be used profitably by a few undergraduates, these books will find their largest audiences among budding particle physicists in the early stages of graduate study, and among workers in other branches of physics wishing to acquaint themselves with those developments of the last 20 years in particle theory and phenomenology that are now firmly established.

In fact, in the first sentence of their