NO SIMPLE MODEL FOR COMPLEX SYSTEMS

1989 Lectures in Complex Systems

Edited by Erica Jen
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Reviewed by Philip Holmes

Several "new" sciences have recently swept through the pages of magazines and have even spawned their own research journals. Funding agencies have promoted "emerging fields" and fostered the creation of interdisciplinary centers. The three C's come to mind: catastrophes, chaos and now complex systems. Are these really new sciences or merely public relations stunts designed to attract attention and funding? I agreed to review this book partly in the hope of finding an answer. I failed, but found much of interest nonetheless.

The papers in this book, edited by Erica Jen, fall into two categories: those that address particular problems in "conventional" fields, such as solid-state physics and neurobiology (the papers of David Sherrington and William Bialek, for example); and those that concern modeling and analytical techniques, such as cellular automata and dynamical systems (Bruce Boghosian, Jen, H. Chen and coworkers, Stephen Eubank and Doyne Farmer). The latter range from the limited and rigorous (Lenore Blum on complexity, Jen on simple cellular automata) to the more speculative (W. H. Zurek on information and entropy and Seth Lloyd on measures of complexity).

Some of the papers in the book satisfy Thomas Kuhn's paradigm of "normal science," being increments to established fields (D. David and coworkers on nonlinear optics, George Oster and coworkers on morphogenesis), while others are lengthy reviews that raise more general questions than they answer (Alan Perelson on mathematical models in immunology, Bialek on reductivism and universality in physics versus the accumulation of detail in biology). Some papers present mathematical models with virtually no reference to the world outside (Jen, Eubank and Farmer on dynamical systems, Aviv Bergman on "simulated evolution"). Blum's paper on the theory of computation over the real numbers needs no world beyond its own. Others are rich in experimental detail: fluid flows, chemical reactions, optics, phase transitions, immunology, neurobiology—all are represented.

I sought in vain a common intellectual ground among this riot. There is no shared set of problems or analytical techniques. Deterministic chaos and nonlinearity are not the key: Most of Bialek's fascinating piece uses linear filtering and probability methods to address neural processing in fly vision. In the best papers, like this one, which address specific questions, the "systems" generally consist of many massively interconnected, but relatively simple units. There is often a concern with learning and adaptation.

But perhaps the key is supplied by Perelson's remark that "one hallmark of a complex system is that its essence cannot be captured by a single model." This brings to mind a remark of Michael Fisher: Interdisciplinary research cannot exist without the disciplines. With easy, cheap computation, the temptation to play simulation games with "floating models" is hard to resist. Established fields are necessary to keep us honest and direct our taste.

Happily, this collection shows that *some* complexity enthusiasts are paying attention to detail. In spite of his admission that "there is no general technique for going from P[artial] D[ifferential] E[quations] to L[attice] G[ases] or vice versa," Boghosian's article shows that rational connections can be made between certain partial differential equations of continuum mechanics and cellular automata, and hence that the latter are interesting as physical models. Jen's rigorous analysis of specific automata shows that they are also interesting mathematical objects.

In collections like this, each paper is usually too sketchy to serve alone as true instructional material: At best it stimulates us to further reading. Eubank and Farmer's "Introduction to Chaos and Prediction" cannot replace a textbook. But the best papers (Perelson on immunology, Blum on complexity, Bialek on neurobiology, Epstein on oscillating chemical reactions) succeed admirably in their lesser goal. There is much of interest here, even if this volume fails to justify its editor's claim that "complex systems [has emerged] as a distinct field... equipped with its own tenets, precepts, standards and ambitions."

The book's production seems better than that of many recent electronic proceedings, but there are occasional lapses. Most of Sherrington's bibliography is missing, and the time series on page 129 of Eubank and Farmer's article are transposed. The price is reasonable and the book provides accessible and stimulating introductions to several areas. However, it should be hidden from any aspiring researcher until he or she has trained in one of its disciplines, be it mathematics, physics, chemistry or biology.

Philip Holmes works on dynamical systems in fluid and solid mechanics. His relation to the field of complex systems remains unclear, since even after reading this book he does not know what one is.

The Nuclear Energy Option: An Alternative for the 90s

Bernard L. Cohen
Plenum, New York, 1990. 338 pp. $24.95 hc ISBN 0-306-43567-5

Bernard L. Cohen, a professor of physics and radiation health at the

University of Pittsburgh, has authored over 250 journal articles. For nearly 20 years he has also been waging a battle against public misunderstanding of radiation, radiation hazards and nuclear power. This book is a cry of frustration. Although Cohen is a well-publicized scientist, his (and similar) views seem to be passed over by journalists and the public in favor of the positions of people with far fewer scientific credentials. He writes: "The opposition to nuclear power among politicians started in the early 1970s when they stopped taking advice from the scientific establishment and instead began taking it from political activist groups." He believes "the American public must be educated . . . about nuclear power." This book is Cohen's attempt to provide that education.

Nuclear power is widely used around the world: In 1989 nuclear power supplied 75% of France's electricity, 28% of Japan's and 45% of Sweden's. Even in the United States, where nuclear power is seen as having died, last year 20% of our electricity came from nuclear power plants, and concern about global warming has led to a rekindling of interest in nuclear power. Cohen's book is quite timely and brings the perspective of a knowledgeable scientist. Cohen is a proponent of nuclear power. He foresees electricity shortages after 1993, and he believes that they should be met by nuclear power. He writes: "the new generation of nuclear power plants . . . will not only provide electricity at a lower cost than coal-generated electric power, but they will also be a thousand times safer than plants of the present generation." Cohen does not claim to be a nuclear reactor expert, and his descriptions of the potential to be realized by new designs should be viewed quite cautiously. Those designs remain, as Admiral Rickover might say, paper reactors.

Cohen argues that it is impossible to understand radiation effects without numbers. His discussion of background radiation stresses radon. He notes that people living near the Three-Mile Island reactor "get more radiation exposure from radon in their homes every day than they got from the 1979 accident." In a chapter devoted to understanding risks, Cohen addresses decreased life expectancy from many causes, including smoking, being overweight, being unmarried, being uneducated level and being poor. Examination of the last provides a discussion and a summary that are worth the price of the book: "Wealth makes health, and poverty kills."

Regarding another major nuclear power issue, disposal of high-level waste, he writes: "Radioactive waste . . . is a rather trivial technological problem." He calculates that if it were buried, the high-level waste from one year's operation of one large nuclear plant would eventually cause 0.018 deaths after many millions of years. This is to be compared with 50 eventual deaths due to the emissions from one year's operation of a large coal plant. In one of several attacks against the media, Cohen criticizes journalists' coverage of the high-level waste issue: "What more despicable suppression of information can there be than refusing to transmit the truth about important questions to the public?"

Believing that "citizens of the distant future will look upon [plutonium] as one of God's greatest gifts to humanity," Cohen devotes a chapter to demystifying plutonium. He expresses puzzlement that "the antinuclear movement has devoted so much energy to trying to convince the public that [plutonium] is an important health hazard. Those with scientific background among them must realize it is a phony issue."

This book is an excellent source of reference information on radiation effects, particularly by those who want a compendium of data and are willing to work around the occasional pro-nuclear tilt given to the information. The book is well written, easily understandable by a good high school science student or a liberal arts graduate. Although the scientific reader can benefit from the data, the main intended audience is the educated lay person.

This book is not as witty or as well developed on risk as the book *Technological Risk* published earlier this year by Harold Lewis (Norton, New York, 1990). Cohen however is as concerned as Lewis about the waste of resources in the United States. Cohen asks the reader to "consider how much money our society is willing to spend to save a life. Typical amounts are: programs in Third World nations, $200; cancer screening, $75 000; highway safety, $120 000; air pollution control, $1 million; natural radioactivity in drinking water, $5 million; nuclear plant safety, $2.5 billion."

This book will not be pleasing to the antinuclear movement. It also will not be particularly pleasing to the pro-nuclear movement, because Cohen bases his arguments on facts, not rhetoric. He is not easily characterized, for example, when he predicts that in the far future, nuclear power will provide base load electricity generation and photovoltaics will handle the intermediate and peak loads. Setting aside Cohen's descriptions of his frustrating interactions with the press, this is an enjoyable book.

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The Superfluid Phases of Helium 3

Dieter Vollhardt and Peter Wölfle
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The discovery of superfluidity in ^{3}He by Douglas Osheroff and his colleagues at Cornell in 1972 was one of the truly exciting developments in low-temperature physics. I still remember vividly the electricity in the air at the APS meeting in the spring of that year when Osheroff first presented the susceptibility data that clearly showed that the "transitions" seen at Cornell were associated with the ^{3}He liquid. The response of the theoretical community was prompt and dramatic, led in critical ways by Tony Leggett.

The Superfluid Phases of Helium 3 by Dieter Vollhardt and Peter Wölfle is an attempt to present the theoretical status of the field as it exists today, following nearly 20 years of intense effort by a dedicated theoretical and experimental community. In the authors' words, "the time has come to write a book that collects not only the ideas and concepts of superfluid ^{3}He that have been developed in these years, but also the methods of theoretical physics used and the results obtained."

The authors have done a remarkable job of synthesis and exposition; Work represented by nearly 1500 papers is mentioned in roughly 560 pages of text. In addition to the subject index, there is an author index that is cross-referenced to a complete alphabetical index listing all of the published works cited. Each chapter concludes with a brief list of suggested further reading, which points the reader to particularly helpful articles, books or reviews. As a practical guide to the theoretical literature, the book is an essential reference for anyone active in the field. Any reader with a background in quantum mechanics and statistical physics will find the book accessible; no prior knowledge of superfluidity or the superconducting state is required.