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Book Reviews: *Books on Complexity*

Complexity: Hierarchical Structures and Scaling in Physics. Remo Badii and Antonio Politi, Cambridge University Press, Cambridge, 1997.

Dynamics of Complex Systems. Yaneer Bar-Yam, Addison-Wesley, Reading, Massachusetts, 1997.

Foundations of Complex-System Theories in Economics, Evolutionary Biology, and Statistical Physics. Sunny Y. Auyang, Cambridge University Press, Cambridge, 1998.

A complex system contains a large number of interacting constituents and exhibits collective behavior that cannot be readily derived from the basic properties of the constituents. Such systems have been studied for some time in the context of many specialized but overlapping fields like thermodynamics, nonlinear dynamics, chaos theory, cellular automata and neural networks. The ultimate goal of the complexity theory is to find universal principles and provide a unified approach to describing these disparate systems. It has been known for some time that quite different systems can exhibit universal behavior (e.g., Feigenbaum's universal route to chaos). Such observations, made in a variety of fields, gave rise to the hope that simple and universal laws can be found which apply to a wide variety of complex systems. The three books on the subject included in this review offer different approaches to the subject. Badii and Politi's book offers a mathematically rigorous approach; Bar-Yam's "Dynamics of Complex Systems" is written as a textbook to be used in a graduate course on complex systems and focuses on tools and methods used in study of complex systems, and Auyang's "Foundations of Complex-system Theories" is a relatively non-technical book with emphasis on philosophy and scientific methodology applied to studies of complex systems. Below, each book is described separately in the order in which I read them.

Complexity. Remo Badii and Antonio Politi

Badii and Politi's "Complexity" is focused on the formal description of complex systems. The book is divided into three parts. In the first part

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(Phenomenology and models), after a short introduction, several examples of complex behavior are mentioned, e.g., turbulence, fluid and optical instabilities, chemical reactions and DNA. Page-long descriptions of each example serve as a refresher to those already familiar with complex systems, but might discourage those who are not. Researchers interested in complex systems as applied to life and social sciences might find a surprising shortage of relevant examples. Despite the inclusion of an example based on the genetic code, my overall impression is that the authors' interests lie outside the biological and social sciences. At the end of the first part they give an overview of relevant mathematical models.

The second part of the book (Mathematical Tools) starts with chapter on "Symbolic representation of physical systems," which is the key to understanding the motivation for the remainder of the book. Simply, the goal is to reduce the nonlinear dynamics of an arbitrary complex system to one-dimensional symbolic dynamics. This is done by partitioning the phase space and labeling each cell with a symbol from a given alphabet. Thus a trajectory in the phase space can be associated with a particular sequence of symbols. As the authors recognize, the approach relies on the assumption that no relevant information about dynamics is lost in discretizing the phase space. The authors assure us that this does not restrict the generality of this approach, which now provides a unified framework to study a great variety of complex systems. In the remainder of the second part, and the beginning of the third part of the book, many powerful tools to analyze and characterize symbolic sequences are introduced. Theories and concepts from probability, ergodic theory, information, coding, thermodynamics, formal languages and automata theory, as applied to symbolic sequences, are now adopted to the study of complexity. A number of complexity measures are defined based on these concepts. For example, based on complexity measures derived from coding theory and data compression, a symbolic sequence that can be compressed to a concise form is characterized as simple, i.e., not complex. Knowing that a purely random sequence is not compressible, these complexity measures are, at the same time, measures of randomness; the two are therefore closely related. In the book the authors discuss. a great number of ideas developed in the field of complex systems and complexity, mostly in the past two decades. While reading these, a background in advanced computer science is more helpful than a background in physics. Although, the book is very well organized, the material is rather difficult and is overly succinct. I do not find this book well suited as an introduction to complex systems nor as a textbook, unless used in a very specialized graduate course. Those working on complexity theory will find this book an invaluable source since it offers a great number of stimulating ideas and guidance for future research.

Dynamics of Complex Systems. Yaneer Bar-Yam

The object of this book differs from that of Badii and Politi's book. Instead of aiming toward a formal description of complexity, the author's central goal is, as is stated in the Introduction, "to develop models and modeling techniques that are useful when applied to all complex systems." This becomes evident immediately in the first chapter which describes a number of tools and methods of study that can be applied to diverse complex systems. It includes sections on iterative maps and chaos, thermodynamics and statistical mechanics, activated processes and glasses, cellular automata, information, computation, among others. The list is very similar to what Baddi and Politi describe in their chapter on mathematical models. Bar-Yam, however, does this at great length. This chapter alone provides enough material for a good course on complex systems. In the remaining eight chapters the author provides examples of complex systems. These examples are essentially divided into four main groups: neural networks, protein folding, life, and human civilization. Interestingly, there is hardly any overlap in the choice of examples between the Badii and Politi's book and this one. Since I have previously complained about the shortage of biological examples in the former, it would be only fair to assume that those whose interests lie outside of life and social sciences will find the Bar-Yam's choice of examples also objectionable. For the topics covered author provides an enormous number of examples worked out in great detail, and yet some important complex phenomena such as turbulence are neglected. Since the author's goal was to develop models and modeling techniques that are applicable to all complex systems, one could complain that in several sections and in the whole Chapter 9 (Human Civilization II) these techniques are completely ignored. In other sections, however, the use of such techniques to explain phenomena like consciousness seems far too ambitious and probably obscures the more modest goals of complexity theory. Nevertheless, my criticism applies only to a small portion of the book and, considering that the author's goal is to write a textbook on complex systems, students might find these topics both motivating and fun to read. Overall, the book is ideally suited as a textbook for a graduate course in complex systems, and it also offers a wealth of material that can be used for an advanced undergraduate course. It is very clearly written, heavy formal discussions are avoided, and it provides numerous interesting problems and questions for which solutions and answers are given. Despite the fact that book focuses on phenomena related to biology, a general approach to complex systems can be taught particularly-through the material described in the Introduction. I have no reservations about recommending it as a textbook for a graduate course, or to anyone who wants to know more about complex systems. Also, physics researchers and students interested in the life sciences will find this book a valuable resource.

Foundations of Complex-system Theories. Sunny Y. Auyang

Sunny Auyang's "Foundations of Complex-system theories" is a rather non-technical book and contains no equations, but is not a popular account of the complex systems. At times I found the book very difficult to read mainly due to its jargon. It is still not clear to me whether the terminology used in this book are the author's definitions or are standard in the literature of philosophy. The use of new and more general notions might be a consequence of the author's larger goal of providing a unified framework not only for complex systems, but to scientific thought in general. Aside from the language barrier, I found the author to be a skillful writer with an interesting perspective on complex systems.

The book is divided into two main parts. The first part titled Equilibrium, starts with the theory of composite systems, collective phenomena, and emergent phenomena. The author states that we "carve nature at its joints, and analyze a whole into typical parts that interact only weakly with each other." To use the author's terms, we study complex systems not through microreductionism, but rather through synthetic microanalysis. Translated into the language of physics, we do not deduce the macroscopic properties of the complex system from the microscopic properties of the isolated elements, but rather we analyze the system as a whole to find its microstructure. The analysis defines new constituents of the system which absorb the properties of the original constituents and their complex interactions into one concept. These new constituents often interact only weakly or are independent, thus simplifying a description of the complex system. The author shows that similar conceptual framework is found also in the theories of evolution and economics. In the second part, titled Dynamics, author explores complexity in the temporal domain with familiar concept's from chaos theory, probability, and stochastic dynamics with emphasis again on the common conceptual structure in methodology between statistical mechanics, evolutionary biology, and economics. Although the book does not offer any breathtaking revelations, it gives a refreshing and general look at methods for studying complex systems. For scientists in many disciplines, and particularly for philosophers interested in scientific methodology, this book will be a valuable addition to their library.

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