Phase Transitions

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Source: BioScience, 62(6) : 607-608

Published By: American Institute of Biological Sciences

URL: https://doi.org/10.1525/bio.2012.62.6.12

The Ubiquitous Dynamics of Complex Systems

Phase Transitions. Ricard V. Solé. Princeton University Press, 2011. 264 pp., illus. $35.00 (ISBN 9780691150758 paper).

The wonderful thing about complex systems is that seemingly different systems can display similar patterns in their structure and dynamics. This is the underlying theme of Ricard V. Solé's new book *Phase Transitions*, in which he presents a series of examples across biological, social, and physical systems in which the system changes abruptly from one state to another. He shows how, in each case, the underlying dynamics of this change can be modeled as a phase transition using a *mean-field approach*—one that treats all components as identical particles and assumes that the dynamics of the system can be predicted by averaging the behavior of all the particles.

Phase Transitions is intended to introduce the reader to the technical literature and the classic examples of phase transitions in complex systems. It is the third volume in the *Primers in Complex Systems* series published by Princeton University Press. The book is dedicated to the memory of Brian Goodwin, known for his pioneering work in studying emergence in biological systems.

Ricard V. Solé is a research professor and head of the Complex Systems Lab at Pompeu Fabra University, in Barcelona, Spain. He is also an external professor at the Santa Fe Institute, a leading American center for complex systems studies. His extensive experience in research and teaching about complex systems is clearly evident in the clarity and completeness of each example presented in the book. A logical progression of ideas is made, from the basic physical models of phase changes, through percolation theory and bifurcations, to applications of these models in biological and social systems.

The models presented in the book are based on the premise that complex systems—*composed of a large number of diverse and heterogeneous components in interaction—can be reduced to a mean-field approximation.*

The book opens with a concise introduction to the basic concepts and theory and then follows with each chapter presenting a simple model of a phase transition in a particular type of system. In a sense, the book becomes redundant, because again and again, we find the same mathematical model, formulated slightly differently and with different names for the variables, predicting a phase transition for the system being studied. And this is exactly Solé's point: The same phenomena exist across all complex systems.

For the seasoned complex systems researcher, most of the examples presented in *Phase Transitions* will not be new. There are examples of epidemic spreading of infectious disease, regime shifts in ecosystems, and the emergence of congestion in traffic and information systems, to name a few. The book's major contribution is that it unifies this body of work, published across various disciplines, within a single volume. However, each chapter is sufficiently complete to be useful as recommended reading for a course on complex systems. The book would also be a good starting point for a new graduate student unfamiliar with the topic.

What *Phase Transitions* lacks, however, is a discussion that places all of these examples in context. The preface is barely more than a page, and the book ends succinctly, if not abruptly. Perhaps this is for editorial reasons, but as a reader, I felt as if Solé had given the overall picture short shrift. Although he does mention, at the end of the last chapter, that these models are a first approximation of reality, I would have liked to read more on the topic. A concluding chapter, which could have provided some interpretation and insight about the degree to which such simple models can be useful for understanding the dynamics of complex systems, would have made the book more complete.

The models presented in the book are based on the premise that *complex systems*—composed of a large number of diverse and heterogeneous components in interaction—can be reduced to a mean-field approximation. These models are simple representations of reality that describe a system's state using two or three variables, whose dynamics are described by differential equations. As Solé acknowledges, such models ignore the local nature of interactions and assume that each component in the system is subject to the same average field that affects its behavior. Thus, these models ignore the diverse histories and alternate behaviors of system components, provide only a crude approximation of emergence, and do not accommodate explicit representations of interactions between processes operating across scales of space and time. Although these models may effectively reproduce

doi:10.1525/bio.2012.62.6.12

the generic patterns of phase changes in complex systems, in my opinion they have limited explanatory power and fail to capture the rich diversity of patterns and processes in real-world systems.

The field of complex systems has evolved beyond such simple caricatures derived from physics. Recent research in ecological complexity, socioecological systems, and computational social science is leading to the development of whole-systems, agent-based models that incorporate diverse, interacting components, cross-scale interactions, hierarchy, uncertainty, memory, and adaptation. In my view, such models, which simulate emergence from the bottom up, will have considerably more practical applications in understanding and interpreting the complexity of integrated social, economic, and biophysical systems.

The real test of the field of complex systems studies will be in its ability to provide insight beyond simple models. As a multidisciplinary science, complex systems studies is well poised to deal with a number of pressing issues related to the environment, sustainability, and systemic risk in an increasingly interconnected and complex world.

Mean-field approaches constitute an elegant and considerable contribution to complex systems studies, and I commend Solé for his rigorous presentation. Given his mastery of the subject, however, I regret that he did not provide us with that final chapter to put these important theoretical contributions in the perspective of the challenges we face in understanding and describing the structure and dynamics of complex systems.

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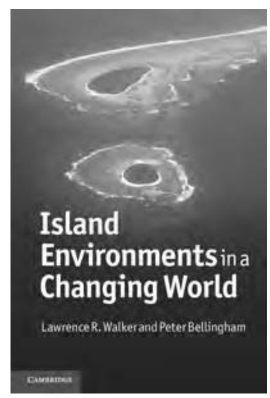
ENVIRONMENTAL TRANSFORMATION: ISLANDS BEYOND THE ILLUSION OF PARADISE

Island Environments in a Changing World. Lawrence R. Walker and Peter Bellingham. Cambridge University Press, 2011. 338 pp., illus. $49.00 (ISBN 9780521732475 paper).

The idea that islands are vulnerable ecological systems in which anthropogenic impacts can be catalogued in a compressed time frame is well established in the scientific literature (Fosberg 1963, Vitousek 1995, Kirch 1997). Island fragility is primarily associated with both isolation and small size, which limit resource availability, ecosystem resiliency, and the long-term provision of ecosystem services under increasing pressure from the human population. In *Island Environments in a Changing World*, authors Lawrence R. Walker and Peter Bellingham reinforce these facts in their sweeping and generally engaging account of environmental degradation on nine island groups. Despite this affirmation, they were also compelled to add a somewhat optimistic note in the concluding chapter of the book that describes the environmental degradation on these islands as not entirely irreversible. They draw attention to successful restoration efforts that have slowed deforestation, biodiversity loss, and soil erosion on several of the islands that they studied. Still, the authors caution that appropriate resource-management strategies need to be deployed on populated islands in order to raise any hope for the sustainability of island societies into the twenty-first century.

In this collaboration, Walker (a professor of biology at the University of Nevada) and Bellingham (an ecologist with New Zealand Landcare Trust) chose to write about the degradation of resources pertaining to the following islands, which vary in size and stretch across multiple climate zones: Tonga, Jamaica, and Puerto Rico in the tropics; Hawaii and the Canary Islands in the subtropics; New Zealand, Japan, the British Isles, and Iceland in temperate and subarctic latitudes. Although the selection of these particular islands seems to have been influenced more by the authors' desire to summarize their collective experience than by their desire to elucidate specific new theoretical perspectives, the evidence of threats to the sustainability of life on these islands, as well as on all of the Earth, is well worth reiterating. As renowned physicist Stephen Hawking suggested (Solar 2010), unless human societies can find additional planets to inhabit, the knowledge and values that drive the depletion of finite natural resources and undermine ecosystem stability must be reassessed, and alterations must be made.



The first four chapters of *Island Environments in a Changing World* are devoted to the natural settings and natural disturbances of the islands. Although the accounts are choppy and frustratingly minimal, they do provide synopses of key physical features within each group of islands (i.e., geology, topography, climate, and soils), describe the character of these highly evolved native ecosystems, and include a discussion of a local natural-disturbance regimen. Natural phenomena like typhoons, tsunami, and hurricanes can wreak havoc on coastal marine and terrestrial island landscapes, and these forces lead to disastrous scenarios when they intersect with human settlements. In addition, the general absence of wise land-use planning and

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