Nonlinear Dynamics, Psychology, and Life Sciences, Vol. 3, No. 3, 1999

Book Review

Physical Theory in Biology Foundations and Explorations, by Charles J. Lumsden, Wendy A. Brandts, and Lynn E. H. Trainor (Eds.). Singapore: World Scientific, 1997, ISBN 9810230826, 486 pp + xvi.

There have been a number of books written in recent years on the subject of mathematical biology and on the application of physical methods to the study of biological systems. For the most part these texts have emphasized fairly conventional applications of fairly standard mathematical and physical tools and theory. Although I am overstating the point, many of these texts have not seriously addressed some of the more difficult, subtle, and ultimately interesting aspects of biology which distinguishes it as a science. In addition they have ignored some of the more exciting developments in theory arising from the burgeoning study of complex systems. The present work is an attempt to fill this gap and it is a welcome addition to the available literature.

The book is a collection of papers, some written by the editors, others solicited especially for this volume. All of the authors are experts in their respective fields and the topics covered span the range of modern biology. The book is divided into five sections: Foundations, Development (two sections), Cellular and Organismic Biology, and Evolution.

The section on foundations begins with an article on the subject of 'Emergence in Physics and Biology' by L. E. H. Trainor. This is a central topic in the theory of complex systems and of considerable importance for understanding many of the more interesting questions in biology, especially as it relates to development and evolution. The next chapter, 'Holism and Reduction,' by C. J. Lumsden, was one of the most interesting in the book. Lumsden attempts to lay out a formal theory of reduction in physical theory, and in so doing addresses the important issue of irreducibility and the relationship between the various scientific disciplines. The approach is logical and categorical and leads to the idea of a layered statistical mechanics. The approach invokes ideas of averaging to explain the change in theoretical forms as one moves up the scale hierarchy. Fully developed, it offers the promise of a formal analysis of the effect of scale on theory. The next

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chapter 'Complexity: A Pluralistic Approach' by W. A. M. Brandts provides a general overview of the concept of complexity for a nonspecialist audience. 'Dynamics, Complexity, and Computation' by P. A. Dufort and C. J. Lumsden provides a detailed discussion of symbolic approaches to dynamics. All too frequently, dynamics is presented in terms of differential equations following the pattern of classical physics. Such an approach, while useful didactically, is woefully inadequate practically, since few systems in biology readily admit descriptions via differential equations. Most of the data from biological experiments, especially naturalistic and field studies, is discrete in nature, and seldom of sufficient accuracy to permit a differential model to be built. Instead, discrete approaches, and in particular, those based upon symbolic representations of dynamical systems offer a descriptive and analytical language which is more readily applicable to the laboratory setting. This chapter provides a detailed and thorough, yet accessible, discussion of models of dynamics based upon computational systems, beginning with a description of Turing machines, progressing through grammars, symbolic dynamics on to Crutchfield's epsilon-machines and Sulis machines. It thus takes the reader from fairly standard, though not necessarily well known literature, to the cutting edge of the field.

The first section on development focuses primarily upon issues of pattern formation. 'Vector field models of morphogenesis' by W. A. M. Brandts and J. Totafurno introduces a gradient based model of morphogenesis and shows its applicability to the problem of limb regeneration. The next chapter 'Symmetry breaking bifurcations' by T. M. Hart and L. E. H. Trainor, nicely compliments the first by providing a demonstration that the production of supernummaries in a graft in the gradient based model results from the presence of a symmetry breaking bifurcation. In so doing the authors provide a striking illustration of the value of group theoretic methods to provide a qualitative analysis of the behavior of a dynamical system.

The second section on development focuses upon the principles of self organization. 'Generic dynamics of morphogenesis' by B. Goodwin discusses the search for generic patterns of behavior underlying morphogenesis. The search for generic behavior is important since it provides an overall 'road map' for the study of large classes of complex systems, orienting oneself before embarking upon the detailed study of specific systems. 'Toward a model of growth and form in living systems' by F. W. Cummings introduces the reader to the techniques of differential geometry, another powerful tool for extracting qualitative information from a dynamical system. 'Living organization, the coherence of organisms and the morphogenetic field' by M. W. Ho, Y. M. Zhiu, and J. Haffegee was another unique and intriguing article. Here the authors discuss the concept of coherence as a fundamental aspect of the organism. They define coherence as a collective

mode of activity, coupled together, and existing over all spatiotemporal domains. They argue for a role for quantum coherence in the dynamics of organisms and provide an fascinating description of some of the relationships between electromagnetic fields and morphogenesis. Finally, 'Is spatial pattern formation homologous in unicellular and multicellular organisms' by J. Frankel, discusses the role of homology versus analogy in pattern formation.

The section on cellular and organismic biology introduces the reader to a variety of techniques rooted within the field of statistical mechanics in physics. F. P. Jones and P. Tevlin provide a fairly straightforward application in 'Statistical mechanics of the main phase transition in lipid bilayers'. Hopfield style neural networks are applied in the next three articles: 'Multi neuron interactions in neural network models of associative memory' by A. E. Busch and L. E. H. Trainor, Network hierarchies in neural organization, development and pathology' by J. P. Sutton, and 'Category switching—a neural network approach' by L. E. H. Trainor, W. A. M. Brandts, and J. L. Torres. That latter was particularly interesting for its application to the problem of task allocation in social insect colonies, particularly the desert dwelling ant Pogonomyrmex barbatus.

Finally, no book on modern biology is complete without a section on evolution and this book is no exception. Again, the methods discussed are eclectic, from the use of the maximum information principle in 'A model of molecular evolution based on the statistical analysis of nucleotide sequences' by L Luo, to neural network based cluster analysis in 'Codon space: exploring the origins and development of the genetic code' by L. E. H. Trainor, G. W. A. Rowe and G. J. Nelson, through 'Evolution of development: the shuffling of ancient modules by ubiquitous bureaucracies' by E. W. Larsen, and ending with an introduction to 'Game theory in biology' by G. W. A. Rowe.

The authors admirably achieve their stated goal which is to expose the reader to a broad sampling of some of the more innovative and exciting ideas beginning to emerge from the interaction between the physical sciences and biology. They clearly demonstrate that a mutually beneficial interchange of methods and ideas is to be had for those willing to take the time to step outside of one's normal discipline. This book deserves to be on the shelf of everyone interested in the formal analysis of biological questions.

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