Nonlinearity

Nonlinear Phenomena in Physics and Biology. Proceedings of an institute, Banff, Alberta, Canada, Aug. 1980. RICHARD H. ENNS, BILLY L. JONES, ROBERT M. MIURA, and SADANAND S. RANGNEKAR, Eds. Plenum, New York, 1981. x, 610 pp., illus. $75. NATO Advanced Study Institutes Series B, vol. 75.

The past 20 years have seen remarkable advances in our understanding of nonlinear phenomena. There was always a steady development of such understanding in the 19th and early 20th centuries. Shortly after World War II, however, several significant developments took place that triggered much of the explosive growth of the past 20 years. The first was the now classic computational investigation by Fermi, Pasta, and Ulam, during a quiet period at Los Alamos in 1954–55, of the properties of masses coupled by nonlinear springs. They expected to find the energy equipartitioned among the harmonic modes of the system. Instead they discovered that the energy returned to the fundamental mode after appearing at only a few harmonics. Some 10 years later Kruskal and Zabusky reanalyzed the problem and, in a continuum approximation to the Fermi-Pasta-Ulam lattice, rediscovered the Korteweg-deVries equation for the propagation of waves in shallow water and the existence of solitary waves of finite amplitude interfering in a nondestructive fashion. Thus was conceived the modern notion of the soliton in the work of Gardner, Greene, Miura, and Kruskal and in that of Toda and others. The contribution of Gardner *et al.* was particularly crucial. They discovered that the Korteweg-deVries equations could be linearized by a transformation later identified as that introduced by Bäcklund in the 19th century and that the linearized equation was none other than the time-dependent Schrödinger equation. This discovery has opened up the way to numerous applications of soliton theory to solid state physics, acoustics, optics, hydrodynamics, plasma physics, elementary particle physics, and general relativity and astrophysics. The application to elementary particles is particularly interesting in that solitons turn up as the finite action solutions of Yang-Mills and Higgs equations in two-, three-, and four-dimensional field theories, where they are known respectively as vortices, monopoles, and instantons. There is currently intense activity on the part of theoretical physicists and mathematicians, particularly differential geometers, in these subjects.

The other major development began with the rediscovery of a paper by Hopf, originally published in 1942, which dealt with the conditions under which a stationary solution of a system of nonlinear differential equations loses its stability so that a stable periodic solution, or limit cycle, supplants it. This transition is now called a Hopf bifurcation. Such bifurcations were studied in the 19th century by Poincaré and others in connection with planetary orbits and in the period from 1900 to 1959, but it was not until the 1960's that bifurcation theory and related subdisciplines emerged as a major part of applied mathematics. Recently Sattinger and other have succeeded in bringing powerful group-theoretical methods to bear on bifurcation problems, much in the manner in which group theory was applied to quantum mechanics in the 1930's and subsequently, so that now applied mathematicians and others are very much interested in questions of symmetry and symmetry breaking in dynamical systems. At present there are numerous applications of such theories to fluid convection, chemical oscillations, pattern formation in biological systems, large-scale brain activity, nonlinear circuits, solid state physics, astrophysics, and more. Indeed, the number of publications on bifurcation and symmetry breaking and related topics rivals that of publications on solitons. Recently, Feigenbaum has demonstrated the existence of universal scaling laws in small-cell turbulence and has shown not only the relevance of the Kadanoff-Fisher-Wilson renormalization group techniques to such problems but also that low-order nonlinear equations may hold most of the secrets of turbulence.

The present volume comprises the proceedings of a conference dealing with the mathematical aspects of solitons and nonlinear waves and of bifurcation as applied to plasmas, chemistry, and biology rather than to particle physics, relativity, and turbulence. There are several excellent survey papers in the volume, including an introduction to nonlinear waves, written with characteristic enthusiasm by A. C. Scott, in which the entire history of soliton research is outlined. In addition Scott describes and analyzes a recent hypothesis of the Soviet biophysicist Davydov that energy transduction in biomolecules occurs via solitons. Even if this hypothesis seems dubious, it is interesting to see the details so clearly exposed. I cannot say the same for Scott's claim that solitons are likely to exist in large-scale nervous activity. Behind every traveling wave front of nervous excitation lies a refractory trough that annihilates any other wave; thus neuronal interference effects are highly destructive. The appropriate nonlinear equations for this situation are of a diffusion type that does not admit soliton solutions, except in very special circumstances. Papers by R. M. Miura and J. Rinzel describe such problems. Miura describes a model for what is known in neurology as "spreading depression," whereas Rinzel deals mainly with the propagation of impulses in nerve fibers. Though these are not the most interesting problems concerning large-scale nervous activity, they lend themselves to fairly rigorous mathematical analysis, and both papers are well worth reading.

Diffusion-coupled chemical reactions have been much studied ever since the publication of Turing's 1952 paper on the topic. In particular, chemical oscillations have been the subject of many investigations. There is a short but informative paper by L. N. Howard on the subject. The general topic of bifurcation theory itself is surveyed at great length and in great detail by G. Nicolis. This paper comprises what amounts to a course on how to bifurcate. In addition it contains a clear treatment of the Prigogine-Glansdorff-Nicolis approach to nonequilibrium statistical mechanics. I found the discussion of fluctuations to be particularly useful. It remains for the precise relationship to be demonstrated, if it exists, between the bifurcation theoretical treatments discussed in the paper and renormalization group techniques. Another theme that permeates this and other papers is that the states that supplant stationary equilibria, called dissipative structures by Prigogine, exhibit long-term stability and provide an account of the emergence and persistence of biological process and structures. This assertion has been heavily criticized by a number of theorists. For example, no less a physicist than P. W. Anderson has recently asserted that there is no theory for stable dissipative structures, and indeed Nicolis himself remarks that "macroscopic order is sandwiched between equilibrium thermal disorder and turbulent disorder." It is likely that very special conditions are required to obtain biological order from physical chaos. A paper by P. Schuster describes recent investigations by Eigen, Schuster, and others along such lines on the origin of the genetic code. The key idea, that self-replicating macromolecules must cooperate rather than compete to develop more organization, seems very plausible. There is also an excellent review by S. A. Kauffman of the topic of pattern formation in developing organisms, one highlight of which has been the formulation of rules for the regeneration of limbs and the like by French, Bryant, and Bryant and another the application of Turing's theory of pattern formation in diffusion-coupled chemical reactions to development and regeneration. The Turing theory gives a plausible account of such processes, but once again the stability exhibited by living tissues seems to be considerably greater than that exhibited by simple chemistry.

The book contains a number of papers concerned with solitons, fluid dynamics, and plasmas and with nonlinear equations in general. There is a very useful paper on the numerical computation of nonlinear waves by B. Fornberg, for example, in which many different numerical algorithms are discussed. Nevertheless it is fair to state that applications to biological problems dominate the volume, so that it will be of most interest to mathematical biologists. The volume itself is well produced. There are almost no errors in the text, and the format makes it easy to read.

JACK COWAN
Department of Biophysics and Theoretical Biology, University of Chicago, Chicago, Illinois 60637

Desert Biology

Biology of Desert Invertebrates. CLIFFORD S. CRAWFORD. Springer-Verlag, New York, 1981. xvi, 314 pp., illus. $39.30.

Deserts are hot, dusty, generally uncomfortable places to be, and biologists working in them must have surely wondered at times about the cost-benefit ratio involved in extracting information about desert life.

Yet deserts have a diverse biota that, living under conditions that are often very stressful, provides an excellent opportunity for studying how plants and animals adapt to ecological constraints. Such constraints may be seen in the physiology, behavior, life history, and community assemblages of desert organisms. Often the constraints may be expressed as ecological convergence in form and function, as is seen among the cacti of North America and the cactus-like euphorbs of the Old World.

Among desert organisms, the most numerous are the invertebrates. Commonly found in deserts are protozoans, nematodes, mollusks, arachnids, millipedes, centipedes, and a variety of insects. Many of these have a great impact on desert life. For example, termites in the Sonoran desert can consume over 90 percent of the dead wood that falls in one year.

Despite their importance to the dynamics of desert systems, finding information on the ecological, behavioral, and physiological roles of desert invertebrates has been difficult. A number of excellent studies of single species, or even groups of species, have been published in diverse journals, but the information has been difficult to piece together.

Crawford has made a major contribution toward our understanding of desert invertebrates by arranging the details into patterns. Without sacrificing the particulars, he has assembled information from many sources and organized it around the themes of behavioral and physiological adaptations, life history adaptations, and community roles.

Crawford has done an excellent job of putting things together, and perhaps just because of that I found myself wishing for somewhat more synthesis. There are questions that touch on some important concepts in ecology that are not addressed in the book. For example, how are communities of desert invertebrates structured—randomly, by competition, by predation, or by historical constraints? What is the role, if any, of competition in a stressful environment? In a harsh environment, how much leeway does selection have in affecting the physiology and behavior of an animal without colliding with phylogenetic inertia?

Crawford's book nevertheless represents an excellent start. Now that we have the particulars organized into comprehensible patterns, we can ask broader questions that before could not be asked intelligently.

C. N. SLOBODCHIKOFF
Department of Biological Science, Northern Arizona University, Flagstaff 86011

Bioenergetics

Chemiosmotic Proton Circuits in Biological Membranes. In Honor of Peter Mitchell. V. P. SKULACHEV and PETER C. HINKLE, Eds. Addison-Wesley Advanced Book Program, Reading, Mass., 1981. xviii, 634 pp., illus. $29.50.

This book consists of 39 papers covering a wide variety of topics in bioenergetics. The unifying theme connecting topics as seemingly disparate as oxidative phosphorylation, proton transport in the stomach, photosynthetic electron flow, catecholamine storage in the adrenal medulla, and the mechanism of flagellar motion and bacterial active transport is the central role of the electrochemical proton gradient ($\Delta\bar{\mu}_{H^+}$) in all these processes. Thus the book clearly fulfills its stated aim of honoring Peter Mitchell on his 60th birthday. For it was Mitchell who, some two decades ago, almost single-handedly focused the attention of workers in bioenergetics on the central role of the electrochemical proton gradient in biological energy coupling. As Racker, in the introduction to his paper, aptly says, "his conceptual contributions . . . have revolutionized our thinking as well as our experimental approaches." The level of the book is too advanced and in some papers too specialized to serve as a first introduction to this revolution. However, a moderately well informed reader will find the book provides a nice overview of the effects of these revolutionized approaches.

The book opens with an excellent introductory paper by one of the editors, Skulachev, outlining the central concepts of Mitchell's chemiosmotic hypothesis, the history of its grudging acceptance by the bioenergetics community, and the subjects of chief current concern to workers in the field. The review, although brief, will be of particular interest to those of my generation who as graduate students or young postdocs saw the chemiosmotic hypothesis greeted with something close to ridicule in the early 1960's and watched as acceptance of Mitchell's ideas culminated with the award of the Nobel Prize in Chemistry in 1978. Skulachev also succeeds in giving the reader a good feeling for the wide variety of biological energy transducing systems that have been successfully analyzed by means of the chemiosmotic hypothesis.

Next there are 21 papers describing systems the editors have described as "$\Delta\bar{\mu}_{H^+}$ generators." Two highlights of this section of the book are a fair discus-