PREFACE FOR THE ENCYCLOPEDIA OF COMPLEXITY AND SYSTEMS SCIENCE

The *Encyclopedia of Complexity and System Science* is an authoritative single source for understanding and applying the basic tenets of complexity and systems theory as well as the tools and measures for analyzing complex systems in science, engineering and many areas of social, financial and business interactions. It is written for an audience of advanced university undergraduate and graduate students, professors, and professionals in a wide range of fields who must manage complexity on scales ranging from the atomic and molecular to the societal and global. Each article was selected and peer reviewed by one of our 36 Section Editors with advice and consultation provided by our 15 Board Members and Editor-in-Chief. This level of coordination assures that the reader can have a level of confidence in the relevance and accuracy of the information far exceeding that generally found on the World Wide Web. Accessibility is also a priority and for this reason each article includes a glossary of important terms and a concise definition of the subject.

Complex systems are systems that comprise many interacting parts with the ability to generate a new quality of collective behavior through self-organization, e.g. the spontaneous formation of temporal, spatial or functional structures. They are therefore adaptive as they evolve and may contain self-driving feedback loops. Thus, complex systems are much more than a sum of their parts. Complex systems are often characterized as having extreme sensitivity to initial conditions as well as emergent behavior that are not readily predictable or even completely deterministic. The conclusion is that a reductionist (bottom-up) approach is often an incomplete description of a phenomenon. This recognition, that the collective behavior of the whole system cannot be simply inferred from the understanding of the behavior of the individual components, has led to many new concepts and sophisticated mathematical and modeling tools for application to many scientific, engineering, and societal issues that can be adequately described only in terms of complexity and complex systems.

Examples of Grand Scientific Challenges which can be approached through complexity and systems science include: the structure, history and future of the universe; the biological basis of consciousness; the true complexity of the genetic makeup and molecular functioning of humans (genetics and epigenetics) and other life forms; human longevity limits; unification of the laws of physics; the dynamics and extent of climate change and the effects of climate change; extending the boundaries of and understanding the theoretical limits of computing; sustainability of life on the earth; workings of the interior of the earth; predictability, dynamics and extent of earthquakes, tsunamis, and other natural disasters; dynamics of turbulent flows and the motion of granular materials; the structure of atoms as expressed in the Standard Model and the formulation of the Standard Model and gravity into a Unified Theory; the structure of water; control of global infectious diseases and also evolution and quantification of (ultimately) human cooperative behavior in politics, economics, business systems and social interactions. In fact, most of these issues have identified nonlinearities and are beginning to be addressed with nonlinear techniques - e.g. human longevity limits; the Standard Model; climate change, earthquake prediction, workings of the earth's interior, natural disaster prediction, etc.

The complex systems mathematical and modeling tools and scientific and engineering applications that comprise the *Encyclopedia of Complexity and Systems Science* are as follows:

Agent Based Modeling and Simulation
Applications of Physics and Mathematics to Social Science
Cellular Automata, Mathematical Basis of
Chaos and Complexity in Astrophysics
Climate Modeling, Global Warming and Weather Prediction
Complex Networks and Graph Theory
Complexity and Nonlinearity in Autonomous Robotics
Complexity in Computational Chemistry
Complexity in Earthquakes, Tsunamis, and Volcanoes, and Forecasting and Early Warning of their Hazards
Computational and Theoretical Nanoscience
Control and Dynamical Systems
Data Mining and Knowledge Discovery
Ecological Complexity
Ergodic Theory
Finance and Econometrics
Fractals and Multifractals
Game Theory
Granular Computing
Intelligent Systems
Nonlinear Ordinary Differential Equations and Dynamical Systems
Nonlinear Partial Differential Equations
Percolation
Perturbation Theory
Probability and Statistics in Complex Systems
Quantum Information Science
Social Network Analysis
Soft Computing
Solitons
Statistical and Nonlinear Physics
Synergetics
System Dynamics
Systems Biology

Traffic Management, Complex Dynamics of
Unconventional Computing
Wavelets

The 15 members of our Editorial Advisory Board include: Ahmed Zewail of Caltech, Nobel Prize in chemistry, who provided guidance in chemistry and physical biology applications of complexity and systems science; Thomas Schelling, Nobel Prize in Economics, provided guidance in economics and political science applications; Mario J. Molina, Nobel Prize in Chemistry, whose current interests include: atmospheric chemical processes and science-policy issues related to urban and regional air pollution and to global change; Manfred Eigen, Nobel Prize in Chemistry, who is expert in molecular self-organization and evolutionary biotechnology; Benoit B. Mandelbrot of Yale University and Battelle Pacific Northwest Laboratories, Wolf Prize for Physics, who provided guidance in physical, mathematical or social phenomena that are characterized by abundant data but wild variability; Richard E. Stearns, 1993 Turing Award, whose current interests include computational complexity, automata theory, analysis of algorithms and game theory; Pierre-Louis Lions, 1994 Fields Medal, whose interests are nonlinear partial differential equations and applications; Leroy Hood of the Institute for Systems Biology, Lasker Award, whose specialty is systems approaches to biology and medicine; Steven Wolfram, creator of Mathematica®; and Lotfi Zadeh, Honda and Okawa Prizes and IEEE Medal of Honor, whose current interests are fuzzy logic and soft computing. Sadly, Paul Lauterbur, Nobel Prize in Medicine or Physiology, who provided guidance in evolution and origin of life and overall relationship of determinism to complexity passed away during the project. A complete listing of our Board is presented immediately following this Preface.

Our 36 Section Editors, who supervised the 35 Sections, represent some of the best and brightest in their respective fields. It is notable that some are rather young, and yet are highly accomplished, as seems appropriate for the very modern scientific approach inherent in complexity and systems science. The Section Editors have selected both the articles (described below) and also nominated our authors and either provided peer review or supervised outside peer reviewers. A complete listing of the Section Editors is presented immediately following this Preface.

The efforts of the 41 members of our Board and Section Editor team have resulted in near 300 articles on the mathematical and modeling basis of complexity, e.g. fractals and multifractals, cellular automata, game theory, quantum information processing, unconventional computing, ergodic theory, percolation, non-linear ordinary differential equations, non-linear partial differential equations, perturbation theory, probability and statistics, solitons, wavelets, agent based modeling and simulation, complex networks and graph theory, data mining and knowledge discovery, granular computing and soft computing; as well as near 300 articles describing progress using these tools in physics, econometrics, ecosystems, climate prediction, nanoelectronics, complex networks, quantum computing, chemistry, astrophysics, geophysics, systems biology,

bioinformatics, medicine, system dynamics, engineering, control and dynamical systems, traffic management, and robotics as well as social, economics and political sciences.

This Encyclopedia in total comprises 590 peer-reviewed, in-depth, 15-20 page articles presented alphabetically as prepared by more than 700 authors. The result is a carefully organized, accessible, and easily searchable 10,000-page reference work that places complexity and systems science at the center of modern scientific, engineering, and societal problems and potential solutions. A complete alphabetized listing of articles, extensive cross-references, glossaries of terms, and a detailed index are all included. We believe that there is no other treatment of this field with near the depth and authority of that prepared by our team of prize winning Board members, Section Editors and authors. This new publication will extend the influence of complexity and systems science to a much wider audience than has been possible up until now.

Robert A. Meyers
Editor in Chief
Larkspur, California
June 2008

How to Access the Articles

Each Section Editor prepared an introductory article describing their field, the articles comprising the section and the interrelationship of the articles. Thus, our readership can utilize each section introduction as the reference point to the individual articles or can look up individual articles by alphabetical entry. The 35 sections with section editor information are presented immediately following the Board listing, while the introductory articles occur alphabetically, under the section name, among the near 600 alphabetically listed entries.