world, to an industry that operates 450 reactors worldwide. With maturity comes complexity, however, and the generation and use of fission energy creates challenges both technical and social.

In Energy from Nuclear Fission: An Introduction, authors Enzo De Sanctis, Stefano Monti, and Marco Ripani survey their subject in a novel manner. The authors are able to draw from their own wide-ranging experience with nuclear science. De Sanctis is a director of research emeritus at Italy’s National Institute for Nuclear Physics (INFN); Monti, a nuclear engineer and former scientific secretary at the International Atomic Energy Agency; and Ripani, a senior scientist at the INFN. The volume has two parts; it is, in effect, two books. The first “book” is a 150-page technical tutorial devoted to the relevant nuclear physics. It is aimed, the authors claim, at bright undergraduates. The second is a 100-page survey of the engineering challenges associated with nuclear energy. The section is almost entirely independent of the previous material, uses few equations, and could be read by an interested citizen with little science background.

The first part of Energy from Nuclear Fission is titled “Nuclear Physics and Radioactivity.” The first chapter begins at the beginning, with the Greek philosophers Democritus and Leucippus, credited with developing the first notions of the atom. The authors then move on to a conventional overview of energetics, including discussions of mass defects, stability, and the Q values of reactions. The chapter concludes with an appealing section on nuclear abundances.

The next chapter is devoted to radioactivity. It begins by describing the several decay processes that characterize the phenomenon and then turns to many associated issues, including the penetrating power of several radiations and “softer” but important topics associated with dosimetry, biological effects, and applications in industry and clinical medicine. Indeed, room is found for comments on the controversial linear no-threshold proposal and on hormesis. In the rather amusing table 2.6, which is devoted to “activity,” the health risk associated with exposure to 0.1 millisieverts of radiation is shown to be about the same as for eating 40 tablespoons of peanut butter or spending two days in New York City. That table alone earns the authors their royalties. The rich section ends with a discussion of radiocarbon dating.

What is striking about the book is the quality of the writing and the presentation of material. The graceful prose makes reading the book a pleasure. The sections are illustrated with graphs, pictures, and worked examples and are supplemented with problems to challenge the reader. There is also the curious practice of attaching birth year and place and death year and place to every scientist mentioned in the text—for example, Ernest Rutherford (Brightwater, New Zealand, 1871—Cambridge, England, 1937). The topics chosen are lively and interesting. One encounters, for example, proton–proton fusion, the mass defect that follows the collision of two lumps of plasticine, and the life of the Sun.

The book is aimed at an undergraduate audience, and readers will not need an extensive mathematical background to understand the material—there is not a whiff of quantum mechanics. Most challenging, perhaps, is the authors’ decision to plunge into simple differential equations and devote seven pages to the topic of sequential radioactive decay and its mathematics.

The third, final chapter in part 1 centers on fission and chain reactions. It is rich in nuclear physics; for example, the thorium fuel cycle appears in detail. But part 1 contains only a minimal treatment of nuclear-reactor physics. It is, perhaps, a difficult topic to treat without introducing the challenging mathematics of diffusion processes in space and energy, but its inclusion would have enriched the chapter. The authors employ the mathematics of sequential decay to treat xenon poisoning, but they miss the opportunity to tell the story of John Wheeler, Enrico Fermi, and the poisoning of the Hanford Site’s B Reactor. The same mathematics might have provided a more mature discussion of delayed neutrons and reactor dynamics than the text contains.

Part 2 of Energy from Nuclear Fission brings the reader to the world of nuclear engineering and is a self-contained essay on the state of the industry. This second “book” is encyclopedic and perhaps deserves its own review. The authors quickly introduce the full nuclear-reactor zoo, with its many species and their associated technologies. The essay moves on to cover reactor generations I–IV and their features—mining, milling, fabrication, and storage; the management of the four types of radioactive waste; and safety and security. The six levels of the International Atomic Energy Agency’s International Nuclear Event Scale are explained and displayed handsomely, and 10 of the most relevant reactor accidents are described in some detail.

This fine book’s most notable flaw is, perhaps, the absence of an index. Though some readers may feel that a reference book without an index is no better than a doorknob, there are mitigating features in this case: The table of contents is quite detailed, and the book includes a helpful glossary of two dozen pages.

In sum, Energy from Nuclear Fission is a unique, rich, and valuable resource.

Noel Corngold
California Institute of Technology
Pasadena

Lyapunov Exponents
A Tool to Explore Complex Dynamics
Arkady Pikovsky and Antonio Politi

The title of Edward Lorenz’s 1972 American Association for the Advancement of Science talk, “Predictability: Does the flap of a butterfly’s wings in Brazil set off a tornado in Texas?,” elegantly conveys the hallmark of chaotic dynamics: sensitive dependence on initial conditions. The “butterfly effect” has captured the public’s imagination; it has been used as the title of three motion pictures and the name of an Australian hard rock group.

Public perceptions and misperceptions aside, how do physicists provide a quantitative description of sensitive dependence on initial conditions? The answer to that challenge is given in Lyapunov Exponents.
Lyapunov Exponents: A Tool to Explore Complex Dynamics. In simple terms, a Lyapunov exponent is derived by considering two close-by initial conditions in a system's state space. If the behavior is chaotic, the state-space trajectories originating from those initial conditions will diverge exponentially, at least for a while. The exponent that gives the rate of that divergence is a Lyapunov exponent, named after Russian mathematician Aleksandr Mikhailovich Lyapunov, who introduced the concept in his 1892 PhD thesis. Most systems have more than one Lyapunov exponent: Indeed, there is one for each of the state-space dimensions. For a system exhibiting chaotic behavior, at least one of the exponents is positive.

Authors Arkady Pikovsky and Antonio Politi are two distinguished and well-known researchers in the field of nonlinear dynamics and complex systems. _Lyapunov Exponents_ details how to determine the exponents for various dynamical models, including discrete-time, continuous-time, deterministic, and stochastic models, that are applicable to both simple systems with only a few degrees of freedom and complex systems with many degrees of freedom. The authors base their analyses on models that have been thoroughly studied in the field of nonlinear dynamics. But they emphasize that many of the results are independent of the underlying system details.

If Lyapunov exponents could be used only to characterize the divergence of nearby trajectories, it would hardly be worthwhile to devote an entire book to them. However, Lyapunov exponents also allow for the determination of other dynamical-system characteristics, including dynamical entropy, fractal dimensions, and system synchronization. Those connections are discussed clearly and comprehensively in _Lyapunov Exponents_. The authors end the book with a chapter devoted to short descriptions of how Lyapunov exponents help us understand the dynamics of Anderson localization, billiards models, transport coefficients, escape rates, molecular dynamics simulations, Lagrangian coherent structures in fluids, celestial mechanics, and quantum chaos.

The methods for extracting the values of the Lyapunov exponents from actual experimental time series data are discussed in only one section of the book. The practical difficulty is that for most experimental data, we do not know the number of degrees of freedom in advance. That information, like the Lyapunov exponents themselves, needs to be extracted from the data. Given the limited data of any time series and the contamination of that data by experimental noise, there are many ways for the data analysis to go wrong. It would have been helpful if the authors had provided a more detailed guide through the muddy swamp of data analysis.

I was surprised to find that the authors did not mention an interesting connection between how Lyapunov exponents change at “the edge of chaos” and certain thermodynamic features near critical points. For example, near the onset of chaotic behavior following a sequence of period-doubling bifurcations, a positive Lyapunov exponent shows a universal power-law dependence on a parameter, exactly paralleling the behavior of an order parameter as a function of temperature at a critical point in a thermodynamic system.

Although _Lyapunov Exponents_ assumes a readership with a basic knowledge of nonlinear dynamics, it should be required reading for anyone seriously engaged in the quantitative analysis of the dynamics of complex systems.

Robert C. Hilborn
American Association of Physics Teachers
College Park, Maryland