radiation are believed to originate at the level of single cells, and thus proponents of microdosimetry argue that only by measuring energy deposition at this level can one hope to find meaningful correlations between biological effect and radiation exposure.

Harald Rossi and Marco Zaider's *Microdosimetry and Its Applications* defines the phrase chosen for its title as "the systematic study and quantification of the spatial and temporal distribution of absorbed energy in irradiated matter." It represents the most comprehensive text on the subject to date. Many of us who teach courses in microdosimetry to students of health physics, medical physics and radiological engineering have in the past relied upon *Report 36*, "Microdosimetry," of the ICRU (International Commission on Radiation Units and Measurements), supplemented by book chapters authored by Albrecht M. Kellerer and by Dudley T. Goodhead in Volumes I (1985) and II (1987), respectively, of the series The Dosimetry of Ionizing Radiation (Academic Press).

While a good reference, *Report 36* does not make a very satisfactory introductory text for students new to the field. Rossi and Zaider's text, however, has been beautifully devised to introduce new concepts gradually, with a variety of examples and illustrations to enhance student comprehension. The text is divided into seven chapters. Students new to the field should review chapters 1–3 (introduction, microdosimetric quantities and their moments, and interactions of particles with matter). Even those students who have a working knowledge of ionizing radiation will find several features of chapter 3 insightful, particularly in regard to the level of detail required to simulate charged-particle transport by Monte Carlo techniques. Students already familiar with the general concepts of microdosimetry may begin with either chapter 4 (experimental microdosimetry) or chapter 5 (theoretical microdosimetry), depending upon their research interests and particular applications.

The material given in these chapters is far superior to the corresponding sections in *Report 36* in terms of the material's organization, scope and presentation and the references to existing data and studies. Chapter 4, for example, contains an excellent collection of measured microdosimetric spectra for a wide variety of radiation sources (neutrons, photons, electrons, heavy ions and pions).

The authors conclude with two chapters on the applications of microdosimetry in radiobiology, radiotherapy, radiation protection, radiation chemistry, radiation effects on microelectronics and thermoluminescence. Two important concepts are presented in the section on radiobiology: The first is that any model of radiation action on living tissue must be consistent with the facts of microdosimetry. For example, the authors state that "a non-linear dose-effect curve implies causation of the effect by multiple events and a lower limit for the average dimension of the site where these events must occur." In fact, one of the major contributions of microdosimetry to radiation biology is the discovery of the size, and thus possibly the nature, of critical radiosensitive structures in the cell. The second concept is that the complex radiation interactions in tissue and their resulting biological effects do not have to be modeled in explicit detail; instead, one can rely on generalized cellular injuries defined as "lesions," "compound lesions" and "sublesions." While one may speculate as to the exact identity of these injuries, this does not preclude one from using theories such as the theory of dual radiation action in predicting biological effect.

Finally, the section on radiation chemistry is a particular delight in that it summarizes very succinctly the methods by which one can construct a mechanistic model of indirect radiation damage to DNA. At the same time, the authors relate these approaches to more traditional microdosimetry concepts presented earlier in chapter 5.

Rossi, the undisputed father of microdosimetry, and his colleague Zaider are to be commended for delivering a much-needed, comprehensive text on this important subject. As Federal funding for this area of research continues to decline, and in some cases is eliminated altogether, it is important that all available knowledge on this subject be brought together for younger practitioners.

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How Nature Works: The Science of Self-Organized Criticality

Per Bak
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The search for a minimal set of principles to describe natural phenomena is a time-honored practice in physics. This minimalist spirit is largely responsible for the historical success of physicists' search for unification of apparently dissimilar forces operating on different scales and, on the other hand, for universality and scale invariance in systems with dissimilar microscopic constituents. In a new book, provocatively titled *How Nature Works: The Science of Self-Organized Criticality*, Per Bak presents another aspect of this search for a common principle underlying a host of natural phenomena. Here, Bak describes the occurrence of power laws in a variety of phenomena in areas as diverse as geophysics, astrophysics, evolutionary biology, brain functions, traffic flow and the stock market.

Self-organized criticality is arguably one of the most interesting and seductive new ideas in physics. Although it originated in condensed matter physics, Bak and others seek to extract from it a paradigm for diverse systems of study, the common thread being that they are dynamic and far from equilibrium and have many interacting degrees of freedom.

This view of natural systems marks a philosophical departure, Bak argues, from the notion that natural systems are in equilibrium, a presupposition inherent in our attempts to understand and describe them. The systems considered here evolve dynamically into a critical state without external tuning; hence the term "self-organized." This critical state, often described by a "sandpile" model, corresponds to a configuration in which the addition of sand leads to avalanches of all sizes. The smallest ones, occurring locally, are most frequent, while the largest ones, spanning the entire system, are rare. This leads to a power law distribution of avalanches characteristic of the scale invariance of the critical state. These states are ubiquitous in nature, and so are the power law distributions: Gutenberg-Richter law in earthquakes, Zipf's law in urban population patterns, the extinction rate of species in evolutionary biology or stock prices on Wall Street. The author argues that all these systems are examples of self-organized criticality, a central idea with which one has to begin to understand "complexity" in nature manifested in the occurrence of self-similarity (fractals) in spatial structure and temporal response.

The book describes Bak's explorations of various "natural" systems almost chronologically, ending with the construction of a theoretical (computer) model, in each case, which leads to a self-organized critical state with typical power law distributions. As a result, the book has the flavor of a scientific memoir in which the reader is guided through the process of scientific investigation—the successes, failures, doubts, dead-ends, turnarounds and eventual discoveries. Such candid descriptions are rare in scientific writing and help in demystifying the process for the nonscientific reader. Scientists, on the other hand, will recognize the process immediately. The descriptions are often entertaining, peppered with the author's views (politically correct and otherwise) of various aspects of the sociology, politics, aesthetics and philosophy of science and contain amusing anecdotes that illustrate the perils of interdisciplinary research for a physicist.

The author has a gift for getting to the heart of the matter without jargon. But the book is also overly concise; some important ideas that need a good deal of elaboration are stated briefly. The observations need to be digested by the reader and, most important, the analogies between theoretical (computer) models and the natural processes they seek to represent need to be analyzed and questioned in some detail.

The reader easily recognizes that this is not a book written by a dispassionate outsider providing a balanced view of a subject, explaining counterarguments and alternative scenarios and judging the merits and inadequacies of these ideas fairly. What we have instead are the zealous efforts of a believer. As a result, the descriptions of debates and disagreements are often contentious, impatient, less than evenhanded and not wholly fair, especially when they concern methodologies and cultures of scientific disciplines other than the author's own. Nonetheless, these occasionally exasperating arguments are always thought-provoking and seldom dull, and the readers will enjoy them even when they disagree with the author.

Among my more specific criticisms: I would like to have seen a discussion of non-power-law histograms very early in the book. The Gaussian distribution or the bell curve (which is also ubiquitous in nature) does not make its appearance until four pages from the end. Also, while 1/f noise is hailed as the hallmark of self-organized criticality, the book has no serious discussion of one of the examples of 1/f noise that are best-known to physicists: resistance noise in electronic conductors. It would have been useful to state the less glamorous ways of obtaining 1/f noise, for example, by a superposition of Lorentzians. This would have helped the reader to determine whether or not the same ideas could be meaningful in other instances. Bak gives much importance to the explicit value of the exponents in the power laws obtained in the computer models or in the empirical data, but there is no clear discussion of the implications. Are there universality classes for these exponents as in the conventional critical phenomena? Could one have constructed an equivalence table for the various systems considered and made an effective sandpile analogy for all of them? The author attempts this in words throughout the book, but a table would have been helpful. I also identified several errors in the text. Lynn Schneemeyer and Stewart Brown's names were omitted from the discovery of the pulse-duration memory effect in charge-density waves; T. D. Lee and C. N. Yang won the Nobel Prize for their work on parity violation, not *CP* violation. I hope that these and other minor errors will be corrected in future editions.

On balance, this is an unusual and important book not because it succeeds in establishing self-organized criticality as the central paradigm for the ways that nature works (because it does not) but because it presents an exciting idea in physics from an unabashedly partisan and personalized viewpoint. The book is better viewed as a status report on the development of self-organized criticality by one of its originators, who will, one assumes, remain a leading participant in further explorations of this field. One hopes the field will continue to challenge theorists to attempt analytical attacks on the models and experimentalists to devise and perform stringent tests of the central premise.

The fate of the viewpoints expressed by Bak (how *some* phenomena in nature "work") will depend, ultimately, on the outcome of these endeavors. One can only agree with the author when he states: "I can assure the readers that my scientific colleagues can be relied upon to debunk what should be debunked."

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Electrons and Phonons in Semiconductor Multilayers

Brian K. Ridley
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A confident pronouncement in the early years of wave mechanics was that empirical chemistry had become obsolete, since quantum physics could and therefore would calculate all properties of molecules. The same view might