incisive questions to ask of a system like the proverbial cow that stubbornly refuses to be spherical.

Complexity needs to develop beyond its buzzword infancy to achieve concise mathematical definition of effective complexity, the utility of which any physicist could quickly acknowledge. A useful goal for such a definition would be its application to macromolecules as well as evolution—and even, perhaps, the mind.

According to James Crutchfield (a physicist and complexity aficionado at the University of California at Berkeley), however, scientists at the Santa Fe Institute (where complexity is a principal focus) agree that a consensus on mathematical formulation of effective complexity is plagued with difficulties. So it seems that the biological physicists need to formulate questions that will produce a mathematical measure of complexity for molecules and species—among the more striking quantitative imponderables of their discipline. A large step in that direction comes early in *Physics of Biological Systems* when Hans Frauenfelder, the American dean of molecular biological physicists, proclaims the importance of complexity, and Per Bak and Maya Paczuski discuss maximum effective complexity at the species level—under the guise of critical points. The potential of such a rigorous and robust definition notwithstanding, the more significant contribution of this book is in its grand scope and depth.

The book's editors, Henrik Flyvbjerg, John Hertz, Mogens Jensen, Ole Mouritsen and Kim Sneppen, have accomplished a Herculean task: surveying the immense intellectual landscape of biological physics with pedagogical excellence. Deferring the pedagogy, I will first address the contents of this delightfully sized (350-page) book: The articles in the first two sections, "Nucleic Acids" and "Proteins," are authored by the leaders in their fields. The section on proteins introduces the folding problem in four articles, by Frauenfelder; Peter G. Wolynes and Zan Luthey-Schulten; Joseph D. Bryngelson and Eric M. Billings; and Klaus Schulten, Hui Lu and Linsen Bai. But, unfortunately, the nucleic acid section has only one article, by Thomas Duke and Bob H. Austin. This imbalance could be interpreted as a signal to the molecular biological physics community that proteins are now the "biggie."

Membranes and microtubules are the focus of a fascinating series of four well-meshed articles, by Jonathon Howard and Frederick Gittes; Luca Peliti; Erich Sackmann; and Henrik Flyvbjerg. The complexity of the next section increases to the level of neurons and sensory signal processing. The two articles of this section, one by William Softky and Gary Holt and one by William Bialek, are intriguing to a molecular biological physicist. In particular, Bialek's article resoundingly demonstrates the point Adrian Parsegian made in his July 1997 PHYSICS TODAY article, "Harness the Hubris: Useful Things Physicists Could Do in Biology," about learning thermodynamics so that one can attack statistical problems in biological physics.

At the highest level of complexity is a stimulating series of four articles on micro- and macro-scale evolution written by Peter Schuster, Jacqueline Weber, Walter Grüner and Christian Reidys; Eschel Ben-Jacob, Inon Cohen and Andras Czirók; John O. Kessler and Nick A. Hill; and Bak and Paczuski. Those physicists who regret that the phrase "Darwin's equations" is oxymoronic will be treated to the delightful adventure of understanding the use of self-organized criticality to explain the part of evolution that Darwin could not manage.

The editors carefully guard the pedagogical excellence of each article; ensuring the lasting value of this book. A recent similar book, *Physics of the Living State* (T. Musha and Y. Sawada, IOS Press, 1994), poses the age-old question (posed for physicists by Erwin Schrödinger), What is Life? That book, however, makes few concessions to neophytes and limits its scope to substantive issues involving fluctuations and information in systems from molecules to brains.

For readers of *Physics of Biological Systems*, learning is greatly enhanced by the reinforcement of concepts between articles within a section of the book. For example, Flyvbjerg's article "Microtubule Dynamics" strongly reinforces the cellular organizational concepts that are presented earlier in Howard and Gittes's article, "Motor Proteins." Each article is of a delightful length—20 pages on average, with the first half of each article serving as an outstanding primer on its subject.

To graduate students in physics who have a modicum of formal training in biochemistry, these articles will provide pleasure while expanding their horizons in biological physics. A physicist with no training in biology or biochemistry will also appreciate the friendliness of this volume. For example, the article by Bryngelson and Billings, "From Interatomic Interaction to Protein Structure," provides a very complete figure on the structure, hydrophobicity, pKa and charge characteristics of each amino acid. A biologist would need more than the preface's proposed requisite "some grasp of mathematics" to understand Peliti's introduction to the Helfrich Hamiltonian of a model membrane. But with a reasonable smidgeon of mathematical sophistication, one would certainly be prepared to understand Bialek's Bayesian formulation of the problem in sensory signal processing.

Biological physicists need artfully to supply their graduate students with a source that will help them decide which level of biological complexity best fits their individual talents and dreams. That goal is outstandingly served by this book, because it offers an extraordinarily deep and superbly pedagogical background for physical research at all levels, from molecules to evolution. This volume is a truly inspiring contribution to the field.

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Why Toast Lands Jelly-Side Down: Zen and the Art of Physics Demonstrations

Robert Ehrlich
Princeton U. P., Princeton, N.J., 1997. 196 pp. $35.00 hc ($14.95 pb)
ISBN 0-691-02891-5 hc (0-691-02887-7 pb)

Robert Ehrlich, a professor of physics at George Mason University, is an outstanding teacher as well as an excellent and prolific writer. This delightful little book combines the best aspects of his physics teaching style with an informal and witty presentation of a nice collection of interesting physics demonstrations. The style is similar to that of his earlier collection of physics demonstrations, *Turning the World Inside Out and 174 Other Simple Physics Demonstrations* (Princeton U. P., 1990; Reviewed in PHYSICS TODAY, June 1991, page 112).

As director of the Physics Lecture–Demonstration Facility at the University of Maryland for the past 25 years, I am always looking for both new physics demonstration ideas and different techniques for presenting demonstrations. This book contains a large variety of information that I found helpful, and it should be very useful to teachers of physics at the high school level and to teachers of introductory physics at the college level. In addition, many of the demonstrations described use materials that can be found in the home or are otherwise easily attainable, so this book would also be useful to students who would like to investigate physics on their own. I have eagerly incorporated this book (along with Ehrlich's earlier book) into a bibliography of precollege physics demonstration books that I have prepared for both teachers and students.

In *Why Toast Lands Jelly-Side Down*, Ehrlich goes deeply into the details of specific demonstration experiments. But first he engages the reader in an informative discussion of some ways in which demonstrations can play a significant part in physics teaching. For those with limited teaching experience, I suggest a careful reading of Ehrlich's thoughtful introductory summary of appropriate and inappropriate uses of demonstrations, as well as some of his helpful hints on construction of clear experiments. In a time when computer simulations are becoming an alternative to classroom demonstrations, Ehrlich's comments serve as a strong reminder that real-world physics can often be illustrated much more effectively using simple equipment than with a computer.

Each demonstration begins with a clear statement of its purpose, how it is to be carried out and the effects to be observed. These are followed by a list of required equipment and assembly instructions. Clear line drawings are used to illustrate key points. The ensuing discussion describes the experiment in some detail, including background information and the important physical concepts. Key references are listed at the end of each chapter. Where possible, elementary mathematical relations are derived and discussed. I found this particularly appropriate, in that these analyses are presented in a way that will be understandable to students at the introductory physics level and clearly demonstrate that physics is a science in which mathematical analysis is pivotal to the understanding of the subject. Much to my delight, the title of the book refers to an actual experiment described in detail, complete with development of equations, experimental data and even references.

The twelve chapters contain all of the standard topics found in most general physics textbooks, including such esoteric ones as relativity and nuclear reactors. A few of the demonstrations deal with upper-level physics. The style is fast-moving and easy-to-read, and the text is packed with simple figures. The book was carefully edited and proofread; I found only a few minor errors.

I will use the ideas in this book regularly, especially when I provide materials to teachers and students outside the University of Maryland to whom I present demonstration programs. I wholeheartedly recommend this book to anyone who works with physics demonstrations or who teaches elementary physics or physical science.

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An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements

John R. Taylor
University Science Books, Sausalito, Calif., 1997. 2nd edition. 327 pp. $44.50 hc ($29.50 pb)
ISBN 0-935702-42-3 hc (0-935702-75-X pb)

The analysis of errors in physical measurements is much used and abused by physicists. Their inappropriate uses of statistics often arise from the poor training in error analysis they receive, in part because there are few adequate texts at the introductory level. John Taylor's *An Introduction to Error Analysis*, often remembered for its cover as "the book with the locomotive hanging out the window," is now in its second edition, the first edition dating from 1982. This text provides a rational, step-by-step introduction to understanding and estimating random uncertainties in physical measurements. Although the text is intended primarily for undergraduate students, I find it useful as well at the research level, to introduce graduate students to unfamiliar topics in the study of experimental uncertainties.

Error Analysis is organized as two parts. In part I, the key concepts of uncertainties are introduced and developed through very clear presentations, many examples and extensive discussions of limitations of the formulas. Among the topics covered are reporting and using uncertainties, propagation of errors, statistical analyses and the normal distribution. Derivations of formulas are often postponed until the statistics background is introduced at the end of this part. In part II, Taylor presents topics that are more advanced, such as criteria for rejecting data, weighted averages, least-squares fitting, correlation and three distributions (binomial, Poisson and chi-square) and their uses. The appendices include short tables of error integrals, correlation-coefficient probabilities and chi-square probabilities. All of this material is presented clearly and with numerous worked examples relevant to physics. These include "quick-check" exercises within the text (with answers provided for odd-numbered ones), plus extensive problems at the end of each chapter.

Taylor's *Error Analysis* may be compared to several other texts that have appeared since the first edition. Overall, its explanations are more thorough and complete than are those in Roger J. Barlow's *Statistics: A Guide to the Use of Statistical Methods in the Physical Sciences* (Wiley, 1989) and in Louis Lyon's two books, *A Practical Guide to*

Cover illustration for *An Introduction to Error Analysis*.