Is the Game Worth the Candle? People Must to Do the Arithmetic

Risk–Benefit Analysis

Richard Wilson and Edmund A. C. Crouch
Harvard U. Press, Cambridge, Mass., 2001 [1982]. $25.00 paper (370 pp.). ISBN 0-674-00529-5

Reviewed by John H. Gibbons

A recent US Geological Survey report on "pollutants" in US waterways catalogs widespread presence of all manner of chemicals, none of which are attractive to those of us who drink water. The mere detection of contaminants gives cause for concern, but to know whether or not to take action, we must understand the risks (costs) of consumption and the costs of preventing or removing the contaminants. What does 3.6 ppb of antibiotics in water mean? What about 2.0 ppb of reproductive hormones? Our present exquisitely sensitive ability to detect things can render decision-making more complicated.

"Risk" is arguably the most complex single-word topic I can think of. Life in all its forms constantly faces risk (assumed and imposed) and responds in manifold ways. In simpler forms of life, experiences with risk result over time in genetic (Darwinian) change. In more complex forms, learning from risk experiences leads to behavior modification. In still higher forms of life, cumulative experience (folk wisdom, for example) leads to the observation that "a wise person learns from experience but a wiser person learns from the experience of others." Risk processes for humans also include all the simpler responses but extend to quantitative analysis and integration of relevant information so that vastly more informed risk decisions can be made in advance of undertaking the risk. As a consequence we find human procedures, equipment, and services (medicine, for example) designed to minimize adverse risk to the user while providing maximum benefits.

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Richard Wilson and Edmund Crouch, the highly qualified authors of *Risk–Benefit Analysis*, provide copious examples of both the evolution of the ways analysts approach (model) risk estimation and the translation of analysis into meaningful terms. Wilson and Crouch make clear the pitfalls of incomplete analysis and insufficiency of good data. Their examples of actual cases are instructive in illustrating the seeming inability of some people, however well-meaning, to interpret the significance of numbers. One such example is the risk presented by the Cassini spacecraft's flyby of Earth on its way to Saturn a few years ago, with plutonium-238 on board for thermoelectric energy generation. Another is that of the Tennessee Valley Authority nuclear reactor disaster in 1975 at Brown's Ferry, Alabama, due to a "common mode" failure (bad construction design). Bertrand Russell once observed that "man would rather commit suicide than learn arithmetic."

Risk analysis can be useful to the informed individual in making personal decisions, but its greatest value lies in forming the basis for corporate and public policy decisions about acceptable risk. We must have "rules of the road" that are technically as well informed as possible but at the same time are acceptable to society. These constraints can lead to great consternation, amply illustrated in the book.

The book would be more useful if it contained more discussion of ways to accommodate better to the natural variability of reaction to exposure. It is not fair to assume an "average" or "randomly selected" person when setting permissible doses. Neither does it seem fair to set limits based on the most sensitive population independent of the costs. The authors should have gone more deeply into such questions.

More discussion would also have been helpful in the area of accepting assumed versus imposed risk, because our lives are increasingly confounded by both types. (By "assumed" I mean risks that could be avoided by voluntary action, smoking or charbroiling meat for example; "imposed" refers to natural and human-caused actions such as earthquakes and the production of environmental carcinogens from industrial sources.)

Chapter 4, "Perception of Risk," puts human nature squarely into the discussion: The perception of risk is deeply influenced by the past experience of the observer, which includes events that have affected trust. It appears that trust-decreasing events have considerably more impact than trust-increasing events. Risk managers should give special attention to this chapter.

All in all, Wilson and Crouch have given us an enlightening and entertaining tome on risk, risk perception, and public policy. I do hope that future editions will be graced by a more careful edit ("millions" on page 73 is not an acceptable substitute for "microns," for example). I believe that material on methods of risk calculation and estimation, in Chapter 2, could be less distracting if it were organized by types of models that are used with different types of data rather than according to old risks and new risks. The authors would also serve their readers better with less one-sided critiques of regulatory discussions.

Finally, while Wilson and Crouch focus on the risk side of things, it is disappointing (although not surprising) that they devote little energy to benefits. This is particularly the case for such noneconomic benefits as reduced risk to future generations, aesthetic considerations, and such nonhuman factors as ecosystem health that still lie outside the universe of traditional national income accounts. Such nonmarket values are emerging as subjects of public attention as we wrestle with governance and stewardship in the 21st century.

Read the book, enjoy the cartoons and quotes, and ponder the lessons learned.

A Century of Physics

D. Allan Bromley
Springer-Verlag, New York, 2002. $59.95 (114 pp.). ISBN 0-387-95247-0

D. Allan Bromley's *A Century of Physics* is a somewhat expanded version of the plenary talk Bromley gave

at the American Physical Society's centennial conference held in Atlanta in 1999. In this slim volume, he summarizes the great advances made by physics in the 20th century.

The accomplishments of physics in the 20th century are among the most illustrious achievements of our civilization, and Bromley is certainly one of those advocates of physics with the credentials to articulate them. Given so nearly impossible a task, Bromley nevertheless manages to pull it off. Although the book contains not a single equation, it offers a panoramic view of the physics landscape of the past century, in which are embedded an impressive number of major physics accomplishments. And it describes these accomplishments in a language that is comprehensible to an educated reader with or without training in physics.

Among the most admirable aspects of *A Century of Physics* is the huge collection of photographs that the author has gleaned from friends, his own collection, and especially from the remarkable Emilio Segrè Visual Archives at the American Institute of Physics. Among the photographs you will encounter some old favorites, but there are also some that you probably have not seen before.

Naturally, in a volume containing 116 figures in only 114 pages, little room is available for subtleties or qualifications; on occasion great accomplishments reduce to short descriptions of only a few sentences each. This brevity inevitably leads to the question, To whom is this volume addressed? Readers of PHYSICS TODAY will find the volume useful to help reinforce their enthusiasm for their chosen profession: How truly wonderful it is! The book can also be used as a tool to expound the value of physics to government, industry, and academic decision makers. For me it was a welcome refresher course in physics history that, for physicists of a certain age, is a reminder of what we have lived through. The physics of the second half of the 20th century is within the living memory of many physicists who have entered or are nearing retirement age, and no more than several degrees of separation connect virtually any physicist to the original masters. However, Bromley does not restrict himself to the distant past—his work is quite up-to-date, including mention of recent developments in everything from string theory and gravitational radiation to atom cooling and Bose–Einstein condensation.

In choice of topics, Bromley is about as complete as can be imagined, including arguably topics that other disciplines, such as chemistry, might claim as their own. I would, however, add to the ten choices he enumerates in his final figure, "some open questions in physics." In my own opinion, apart from the obvious questions of origins and final fate of the universe, there is the ultimate mystery of physics: the nature of quantum mechanics itself. Where does this beast come from or, as I. I. Rabi might have said, "Who ordered this?" One might ask a similar question about relativity. Furthermore, recent advances in the exquisite tweaking of simple quantum mechanical systems in both gas and condensed matter phases, and in the not-too-distant future, possible observation of gravitational waves, offer real promise that some new insights into these may appear in the next few decades.

To be sure, I yearned for a somewhat heavier book that included considerations of nuances. Above all, I would have liked a more calibrated discussion of the ways in which physics has contributed to some of our society's darker aspects. This would, in my opinion, not in any way have derogated physics; rather, it would have revealed the immense impact physics has had on society beyond the obvious contributions it has made to improving our living conditions and adding to our intellectual achievements.

We have by now learned that the march toward the light, while perhaps inevitable, contains pitfalls, traps, and detours that in the end may confound us all. There is an irony about the optimistic presentation of the century of physics. The cover photograph is a picture of the Super-Kamiokande detector, taken, of course, before its disastrous implosion. The image could be read as a metaphor for the other side of the wonderful physics story: that, as with all else in our culture, the dark side can rear its ugly head at most inauspicious moments. However, the Bromley presentation in Atlanta and this book that grew out of it are in the spirit of celebration. They honor a century of physics and the almost exact coincidental centennial of the American Physical Society, occasions for great pride and satisfaction.

I found the volume to be an immensely entertaining and illuminating read, and I was greatly impressed by the amount of thought and just plain hard work the author imposed on himself to get it done.

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Navier–Stokes Equations and Turbulence

C. Foias, O. Manley, R. Rosa, and R. Temam
Cambridge U. Press, New York, 2001. $90.00 (347 pp.).
ISBN 0-521-36032-3

Physical Hydrodynamics

Etienne Guyon, Jean-Pierre Hulin, Luc Petit, and Catalin D. Mitescu
Oxford U. Press, New York, 2001.
$ 100.00, $50.00 paper (505 pp.)
ISBN 0-19-851746-7,
ISBN 0-19-851745-9 paper

Turbulence is one of the most difficult problems in classical physics. In spite of tremendous progress on both the experimental and theoretical fronts, it still is far from being completely understood. The apocryphal discussion between Wolfgang Pauli and God, in which God considers turbulence a harder problem than calculating the value of the fine structure constant, is still valid in the 21st century. Some of the leading physicists and mathematicians of the 20th century contributed to the study of turbulence: Richard Feynman, Lev Landau, Werner Heisenberg, Andrei Kolmogorov, Jean Leray, Eberhard Hopf, David Ruelle, Robert Kraichnan, among many others.

The two books reviewed here are written at quite different levels. *Navier–Stokes Equations and Turbulence*, by Ciprian Foias, Oscar Manley, Ricardo Rosa, and Roger Temam, is an exposition of the known mathematical facts about turbulence and is aimed primarily at physicists and engineers; *Physical Hydrodynamics*, by Etienne Guyon, Jean-Pierre Hulin, Luc Petit, and Catalin D. Mitescu, is a highly original introductory text. Nonetheless, the two books do complement each other nicely.

I will devote most of this review to the first book. But I want to bring the second one to the attention of the physics community because of its interesting and unusual approach to the subject, emphasized in a beautiful foreword by Pierre-Gilles de Gennes.

Navier–Stokes Equations and Turbulence is part of the series Encyclopedia of Mathematics and its Applications; its explicit aim is to serve as an introduction for physicists and engineers to recent developments in the mathematics of turbulence. It is also intended to be an introduction for mathematicians to some of the