BOOKS: PHYSICS

Quantum Mechanics at the End of the 20th Century

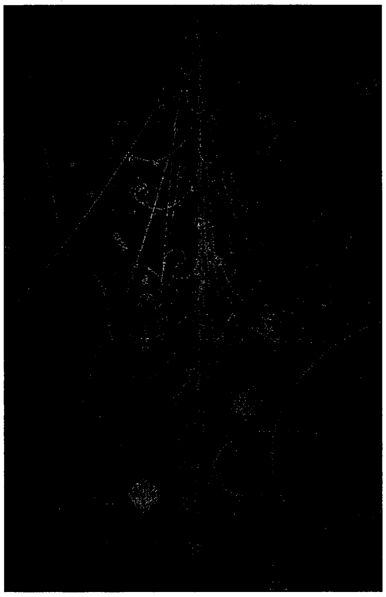
Hans Christian von Baeyer

Sam Treiman, emeritus professor of physics at Princeton University, died last November at age 74. His final book, *The Odd Quantum*, summarizes what he had learned about the craft of quantum mechanics over the course of his long, distinguished career. Using words like strange, unnerving, puzzling, awesome, weird, eerie, and outrageous, Treiman exposes the well established and amply debated oddities of quantum theory, but makes no attempt to resolve them. His attitude, which is shared by most practicing physicists, is one of resigned acceptance of the counterintuitive aspects of the atomic realm. At the end of the book a paraphrase of a Feynman quote succinctly expresses this view: Like it or not, "that's the way the world is."

The Odd Quantum
by Sam Treiman
Princeton University Press, Princeton, NJ, 1999. 270 pp. $24.95, £15.95. ISBN 0-691-00926-0.

Contrary to its dust jacket, which touts the book as popular science, *The Odd Quantum* is not for the lay public. It uses equations freely and assumes familiarity with calculus and complex functions. But it is not a textbook or monograph either. In a brief preface, Treiman explains his aim of filling an empty niche between the extremes of the broad public and his fellow practitioners. Who might feel comfortable in this niche? *The Odd Quantum* is for students beyond their introductory college course in physics, for graduate students in search of a refresher, for physics teachers at all levels, for physical scientists in other fields, and for lay readers committed to delve beyond mere words. In short, it is for anyone who is not afraid of seeing equations so long as they are not forced to manipulate the math.

None of the material is new, yet all of it is fresh. Like a master craftsman intent on reducing his accumulated skills into a compendium of traditions and practices for his apprentices, Treiman tries to be as clear, precise, and succinct as possible. A vast store of experience in research and teaching informs every page. Brief reviews of Newtonian mechanics, electromagnetism, and special relativity place the reader on a firm footing. The story then continues with the "old quantum theory," the subsequent formulations of Heisenberg and Schrödinger, and the notorious difficulties of their interpretation. After a sampling of illustrative applications of the formalism to real systems, and brief excursions into special topics such as angular momentum and quantum statistics, Treiman's account culminates in the standard model of elementary particles.



The last chapter, "Quantum Field Theory," is the payoff. Here the old master reveals what he considers to be the most profound lessons he learned in his half century of wrestling with this subject. Previously, he showed step by step why electromagnetic and electron fields are natural and powerful abstractions, and how they are made compatible with the requirements of special relativity and quantum mechanics. Here he demonstrates how these fields solve two deep problems that both classical physics and ordinary quantum mechanics are powerless to tackle.

The first problem concerns the identity of elementary particles. Given that in daily life no two snowflakes, no two pennies, are truly the same, how is it that all the electrons in the universe are absolutely identical? Since the dawn of the atomic theory, this question has been answered by fiat—that is just the way the world is—but quantum field theory finally explains the underlying reason for this assumption. Today particles are interpreted as ripples in an infinite, invisible continuum called a field and, like successive notes of A played on a perfect piano, must of necessity be identical. It is astonishing that a notion as trivial as the identity of two objects should turn out to be profoundly quantum mechanical in nature and that it had to await the mid–20th-century development of quantum field theory for its first theoretical examination.

The second, and more difficult, problem solved by quantum field theory is that of the creation and annihilation of matter. When particles collide (when, for example, an electron hits a proton) it may happen that they both vanish while two new ones (in this case a neutron and a neutrino) pop up out of nowhere. No model, no metaphor, no theory can account for these miraculous events, except quantum field theory. Treiman points out that inasmuch as particle creation and annihilation destroy the ancient picture of a material world composed of irreducible building blocks, they represent the first radical break with the atomic doctrine of Democritus. A consistent mathematical description of the creation and annihilation of matter must therefore be hailed as one of the supreme achievements of 20th-century physics. Treiman shows how quantum fields can provide this description.

Such luminous insight serves as a fitting capstone for Treiman's book, his life, and his era.

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BOOKS: METHODS OF SCIENCE

Tools for Thinking

Peter Imhof

How would you reply if I asked you what the solar system looks like? I suspect the image that comes to mind is something like the following: In the center is a yellow ball, maybe the size of an orange, called the sun. Smaller balls called planets revolve in circles around it, and they come in various colors (Mars is red and Earth, blue). But even if some of the details were different, I am confident that you think of outer space the way other people do: in terms of things they are familiar with, such as colored balls. People think of physical reality in terms of models.

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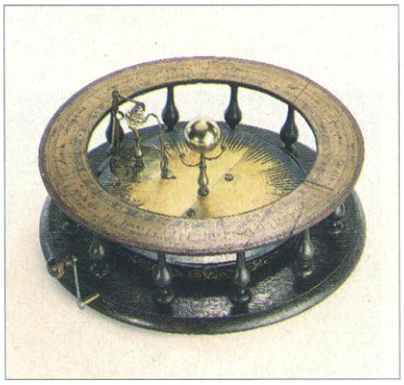
This is the main theme of *Models as Mediators*, edited by Mary Morgan and Margaret Morrison. The volume comprises 10 case studies that examine mental, physical, and computer models in physics, economics, and chemistry. The contributors (historians and philosophers of science) report that the use of models to aid thinking underlies not only the layperson's understanding of the world, but also scientific reasoning. They explain that scientists are not a select few intelligent enough to think in terms of "broad sweeping theoretical laws and principles." Instead, scientists are people specifically trained to build models that incorporate theoretical assumptions and empirical evidence. Working with models is essential to the performance of their daily work; it allows them to construct arguments and to collect data.



Mechanical model. A 1720 orrery constructed by Thomas Wright, with Earth, Moon, Venus, and Mercury positioned around the sun.

This conclusion is all the more valuable today because scientific knowledge is increasingly produced and displayed through computer simulations, which are nothing but a special type of model. Where people once visited science museums that featured actual balls revolving around one another, they are now much more likely to view science programs in which round shapes representing planets blaze through a black void, leaving white lines behind them on the television screen. The computer revolution has also taken hold of the laboratory. Amplified by the visual style of knowledge distribution, computer simulations have become an increasingly popular species of scientific model. For example, economists and meteorologists now use computer models to produce displays that summarize past and projected trends for broad audiences and that further the researcher's own comprehension. If one aims to understand this approach to science, it seems worth taking a closer look at models in general.

Models as Mediators
Perspectives on Natural and Social Science
Edited by Mary S. Morgan and Margaret Morrison
Cambridge University Press, Cambridge, 1999. 413 pp. $64.95, £42.50. ISBN 0-521-65097-6. Paper, $24.95, £15.95. ISBN 0-521-65571-4.

The insight that scientists use material models as well as abstract theory in their reasoning is an important one. It draws attention to the production of scientific arguments as part of the research routine. But the complexity of the topics covered in the case studies often makes it hard for those from other disciplines to follow the authors' arguments. Trained as a physicist, I found it easy enough to understand the examples from physics; however, the chapters on economic modeling left me puzzled on more than one occasion.

The case studies are problematic in another respect. They often lack the theoretical background that could and should guide the analysis of original scientific papers, which is the authors' preferred empirical method. In an exception, Ursula Klein fruitfully uses her notion of "paper-tools" to show how quasi-mathematical chemical formulas contributed to the early development of organic chemistry. But most other chapters are not as successful at incorporating useful concepts for the analysis of empirical material (*1*). In her study on the use of a pendulum and a miniature water tunnel to explore boundary layers, Morrison dismantles the only theoretical account she discusses—realism—and offers no alternative. And even when the relevant descriptive terminology is discussed, the consequences for the analysis are not necessarily obvious. For example, R. I. G. Hughes discusses how to conceptualize models only after he presents the case of modeling approaches to critical point phenomena in physics. Although the chapters make many interesting points, the authors generally fail to explain how the findings build upon and add to existing knowledge. For the most part, questions that reach beyond the immediate cases come as mere afterthoughts. This is not to say that the case studies are not interesting, but it is frustrating to find potentially remarkable observations buried by, or left implicit in, the historical material. These missteps are the major weakness of the volume.

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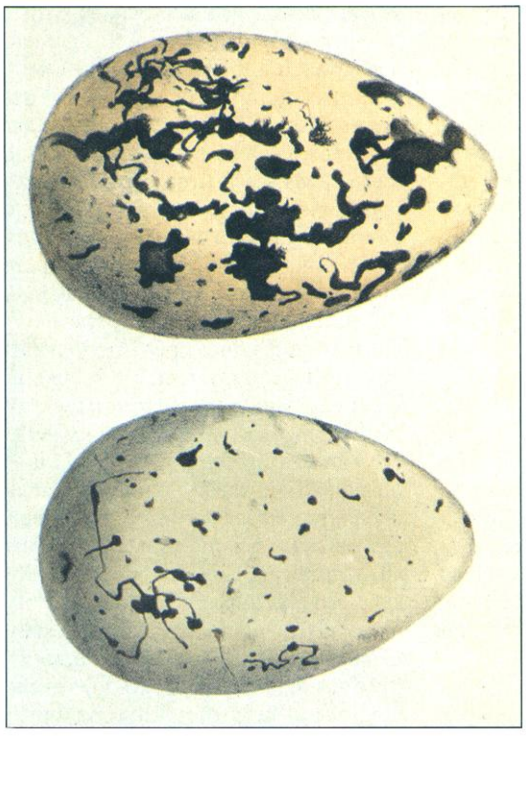
Practitioners of economics, physics, and chemistry with an interest in the histories of their fields will enjoy individual case studies. Readers who have a distinct interest in scientific modeling and simulation might want to complement *Models as Mediators* with more structured work on instruments in scientific research.

References and Notes

1. A useful framework for the analysis of such case studies is presented in D. Gooding, T. Pinch, S. Schaffer, Eds. *The Uses of Scientific Instruments* (Cambridge Univ. Press, Cambridge, 1989).

BROWSINGS

The Great Auk. ***Errol Fuller.*** **Abrams, New York, 1999. 448 pp. $75, C$115, £48. ISBN 0-8109-6391-4.**



Large, plump, and flightless, the great auk was hunted by humans for thousands of years. Two of these "penguins" of the North Atlantic killed near Iceland in early June 1844 proved the last reliable record of this icon of extinction. Fuller's comprehensive catalog of auk lore includes more than 400 illustrations and covers the species' natural history, its decline, and its numerous appearances in art, literature, and commerce. Fuller also recounts the histories of every known specimen and surviving egg (among them the two 12.5-cm-long examples, left, presumed to have come from Newfoundland).