of current research, from bench-top wet chemistry to the most esoteric present-day laboratory instrumentation. An interesting historical sidelight, however, is that such chemists as Martin H. Klaproth, active in the late 1700s, had analyzed ancient materials like Roman colored mosaic glasses and coinage long before anyone ever imagined archaeology as an academic discipline. In other words, chemical archaeometry preceded archaeology.

In planning this book, Lambert must have been tempted to organize it in the pedestrian way, setting chapters to cover particular chemical methods and showing one by one how these methods could be applied to archaeological artifacts and remains. Instead, he came up with an unorthodox and brilliant scheme that sets the chapters to crosscut the materials that the archaeologist encounters—stone, pottery, glass, metals and organics—with the instrumentation used to investigate them in the chemical laboratory. I much enjoyed the fascinating history of ancient metallurgy and the slow, hard-won advances from copper to bronze, iron and steel, in the light of the most recent research.

Another chapter, on humans (chapter 8), also crosscuts a wide range of methodology and instrumentation, but is tied together by its focus on ancient humans. Here, Lambert tallies up the discoveries of paleodiet research, trace elements like lead (with its potential for harm to human health but carrying a load of useful dietary and lifestyle information for the archaeologist) and the dating of human remains by amino acid racemization, fluorine content and spin-resonance measurements. He also recounts the story of the famous Piltdown skull hoax. There are riveting discussions of ancient population groups and distributions as revealed by modern blood groups and of the use of DNA markers in the study of ancient remains. This is not *Jurassic Park* stuff, but rather the most recent promising results of paleogenetic research.

Lambert's chapter on color is a remarkable synthesis of years of research on the chemical nature of colored materials and color production in ancient times. He treats dyes and pigments that we have all heard of but never understood properly, like the famous Egyptian and Maya blues, the royal purple of Sidon and Tyre, cinnabar, madder and the cobalt blues of Chinese porcelain. It must have taken an enormous effort to gather together all the diverse threads of chemical and archaeometric research, and we are the richer for the author's effort. The generous use of color plates in the book adds greatly to the enjoyment of this and other chapters.

Who can use this book? The technical level is substantial. Scientific concepts are not ridiculously oversimplified, nor does the author pretend that scientific language can be presented to the uninitiate without some preparation. But having said that, I would maintain that the book will be most enjoyable to any intellectual reader who is curious about the material culture of ancient times and how modern science illuminates it. I am thinking about the reader who enjoys and understands *Scientific American* or *Science Spectra*. You certainly don't have to be a specialist. In fact, if you are not, you will learn a tremendous amount of chemistry (organic and inorganic), metallurgy, mineralogy and, of course, archaeology as a reward of reading.

This book will also find a place as a textbook for college courses similar to the innovative "Ancient Technologies and Materials" curriculum at the University of Illinois. In this connection I should mention the book's really helpful tables and bibliography. Right inside the front cover is a pair of tables, a "chemical timeline" and an "archaeological timeline." An excellent, extensive glossary and further reading bibliography follow the text.

This book offers a fine, comprehensive fast track through the history of human innovation, technology and even aesthetic progress. Lambert has made a significant contribution to scholarly enjoyment.

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An Equation that Changed the World: Newton, Einstein, and the Theory of Relativity

Harald Fritzsch
Translated by Karin Heusch
U. Chicago P., Chicago, 1997.
279 pp. $15.95 pb
ISBN 0-226-26558-7

Physicists will correctly guess that this book is about $E = mc^2$ and assume that it is just one more popular book on special relativity. But they would be grossly incorrect in assuming the latter. *An Equation that Changed the World* is a delight to read, even for a physicist who has taught this subject many times. In fact, I know of no other popular book that could provide a more enjoyable introduction to this subject.

Having written a nonmathematical book on relativity and quantum mechanics myself (*From Paradox to Reality*, Cambridge U. P., 1987), I am fully aware of the great difficulties of such an undertaking. But Harald Fritzsch is not only a well-known particle theorist, he has also written three other popular books on physics, which surely helped greatly in making the present one so successful. It is a pity that so many years had to elapse before this book—first published in German in 1988—became available in English. The translation is excellent.

What makes the book so appealing is its setting. Just imagine Isaac Newton, age 46 (shortly after the publication of the *Principia*), being transposed to the 20th century. Eager to learn what progress has been made since his work, he meets Einstein, who, at the age of 27, teaches him relativity. That dialogue is enriched by the presence of a fictitious, currently living physicist (called Adrian Haller), who brings both of them up-to-date. The reader, who is put into Sir Isaac's shoes, is thrilled to be able to learn the subject in Newton's company, and from no less an authority than Einstein.

The frame that brings about such an unusual meeting is simple: Haller, a professor of physics at the University of Bern, is in Cambridge visiting Trinity College, where Newton studied. There, Haller falls asleep on the lawn and dreams that he meets Newton, recognizable from his 1688 portrait. They start to talk physics, and soon Newton expresses a wish to meet Einstein. Together, Newton and Haller travel back to Bern, where Einstein had lived when he worked in the Swiss patent office. There they find Einstein himself, looking just like his photograph from that period.

Thus Newton learns the basic ideas of special relativity and thereby realizes the limitations of his own theory. All three then travel to Geneva and to CERN. This change of scene corresponds to the topic of discussion: The question arises whether a conversion from mass to energy or *vice versa* actually occurs in nature, and whether such a conversion can perhaps even be done in the laboratory. This leads first to a discussion of the energy source of the Sun and then to artificial fission and fusion. The topic on creation and annihilation of particle–antiparticle pairs begins with a visit to the Super Proton Synchrotron and the Large Electron Positron collider at CERN. Elementary-particle physics is only touched upon, with a brief mention of the composition of nucleons and the lifetime of protons.

The carefully thought-out scenario is not without some awkward situations. Thus, Haller has to tell Einstein (here as he was circa 1906) that he (Einstein) and others will write letters to President Roosevelt in 1939 concerning the danger of the development of nuclear weapons by the Germans and of the need for the World War II Allies to beat them to it.

The dialogue form is ideal for convincing a skeptic entrenched in an old point of view of a new and revolutionary idea. Galileo was well aware of that when he wrote his *Dialogue of the Great World Systems*, and Harald Fritzsch learned from him.

The book is enriched by a number of illustrations, from line drawings to photographs. There is also a page of suggested readings and a glossary of technical terms. A detailed index makes it easy to locate particular topics.

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Interpreting the Quantum World

Jeffrey Bub
Cambridge U. P., New York, 1997.
298 pp. $49.95 hc
ISBN 0-521-56082-9

What is the quantum world like, and how can our measurements tell us about it? There was a time when physicists would have dismissed such questions as uninteresting or even meaningless; they were content to advance quantum theory and to apply it successfully to an ever-increasing range of physical phenomena; they felt secure in the conviction that Niels Bohr and the founding fathers of quantum mechanics had honed a satisfactory understanding of the theory and successfully defended it against the challenges of apostates like Albert Einstein and Erwin Schrödinger.

Objections to Copenhagen orthodoxy by David Bohm and other physicists provoked only brief (and, in retrospect, quite inadequate) responses, while those of Karl Popper and other philosophers were either ignored or dismissed as uninformed. But technically minded philosophers of science have continued to worry about the conceptual foundations of quantum mechanics, and a significant minority of physicists has now joined them (especially since the penetrating analyses of John S. Bell), thereby constituting what one recent author has dubbed QUODS, for quantum orthodoxy doubting subculture. For over 30 years, Jeffrey Bub has been a prominent member of QUODS, first as coauthor with Bohm of a hidden-variable theory of wave-packet collapse and then as a professional philosopher of science.

In his powerful new book, Bub clearly lays out the measurement problem faced by P. A. M. Dirac and John von Neumann's interpretation of quantum mechanics. He then constructs a framework for analyzing alternative interpretations that seek to solve this problem without running afoul of "no-go" theorems due to John Bell and the mathematicians Simon Kochen and Ernst Specker, among others. Excluded from this framework are both dynamical collapse theories, in the tradition of Gian Carlo Ghirardi, Alberto Rimini and Tullio Weber, and Hugh Everett's interpretation and its modern variants.

Bub dismisses the former as being a competitor to quantum mechanics rather than an interpretation of that theory, and he presents what he takes to be conclusive objections to the latter. What remains is a class of "no-collapse" accounts, including Bohm's hidden-variable interpretation and Bohr's complementarity interpretation. Although Bub's framework offers a novel way of making sense of Bohr's views, he focuses mainly on realist interpretations: "What we ought to aim for is a description that preserves as much as possible of Einstein's realist intuitions, subject to the constraints of the 'no-go' hidden variable theorems, which limit the applicability of those intuitions in a quantum world in various ways. The uniqueness theorem of chapter 4 characterizes the broad features of such a description" (page 238).

Bub calls this uniqueness theorem (of Bub and Rob Clifton) "the heart of the book." He intends it to show how many determinate properties a quantum system can consistently be taken to have or lack, where the quantum state generates a probability distribution over these determinate properties. Each determinate property state turns out to be defined by both the quantum state and some preferred observable R.

Taking R to correspond to the identity operator, we recover a principle that has come to be known as the eigenvalue–eigenstate link: An observable has a definite value if and only if the quantum state is an eigenvector of the corresponding operator with that eigenvalue. But since it was this link that generated the measurement problem for the standard interpretation, Bub thinks we should instead choose R to be something else, and thereby facilitate an account of the measurement process in terms of the dynamics of property states.

Taking R as position in configuration space, we get Bohm's deterministic hidden-variable interpretation. Bub does not reject this choice because of its well-known nonlocality, since no

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