

Erwin Schrödinger and the genesis of wave mechanics.

The project has been conceived on a grand scale. The books are perhaps best described as attempts at being encyclopedias, without trying to conform to the usual format of that literary genre. An immense amount of work has been invested in them. Their scope and sweep, the wealth of detail, the amount of new material presented and the bibliographical material included in each volume all attest to the efforts involved. Valuable features of all the volumes are the extensive biographical footnotes on all people mentioned in the text. The volumes thus constitute a mini-*Dictionary of Scientific Biography* of the first few generations of quantum physicists and allow one to readily find out who was doing what, where and when.

The authors have attempted to embed the scientific developments into the wider cultural and intellectual context. Thus, for example, a great deal of information is presented on *fin-de-siècle* Vienna as a prelude to the Schrödinger volume. Many similarly informative tableaux are delineated at appropriate places: of the German university system, the Göttingen culture, the Munich seminar, the Cambridge and the Cavendish laboratories. The authors are at their best when dealing with the various contributors individually. They have painted insightful portraits of the personalities involved—Sommerfeld, Bohr, Born, Jordan, Heisenberg, Pauli, Schrödinger, among others, and a particularly fine one of Dirac. (Incidentally, it is regrettable that these fairly lavishly produced volumes contain no photographs of the principal institutions or individuals—except Schrödinger.) Furthermore, not only are the scientific contributions of these individuals presented in rich detail, but they are also illuminated by accounts of the sources upon which they are based and of the intellectual tradition on which they draw. Thus, in their discussion of the novel features of Dirac's q number representation of observables the authors discuss his contacts at Cambridge with the mathematician Henry F. Baker and the influence of Baker's *Principles of Geometry* on Dirac. Similarly, Mehra and Rechenberg stress the importance of Hermann Weyl's gauge theory in Schrödinger's researches during the early 1920s, and particularly for his formulation of wave mechanics. Their account of Weyl's earlier work sheds light on Schrödinger's motivation in introducing complex numbers into his wave mechanics.

All the material is presented in its full mathematical detail. Often, the

reader may be overwhelmed by the details and will fail to see the forest for all the trees. This problem is aggravated by the fact that the authors have been less than successful in their integration of physics, physicists and context. However, whatever the shortcomings of these volumes—and there are many—there is no question that they constitute valuable resources for anyone interested in the history of quantum mechanics. They will surely be the point of entry for anyone wishing to obtain information on the technical aspects of the subject. But there are caveats that the reader should keep in mind. The authors often rely heavily on interviews and on recollections many years after the fact—and memories can be treacherous. The discussions give very little emphasis on experimental practice. There are also important omissions of the secondary literature. For example, Sin-Itiro Tomonaga's insightful two-volume account of the genesis of quantum mechanics is not mentioned, nor are other important contributions by historians of the physical sciences. More generally, the authors fail to fully acknowledge their indebtedness to the many historians who have tilled these pastures before them and have given structure and meaning to the story. For example, a footnote in the volume on Schrödinger informs the reader that V. V. Raman and Paul Forman have also drawn attention to the role played by Schrödinger's notes on *Tensoranalytische Mechanik* in his subsequent discovery of wave mechanics. However, the pathbreaking research into Schrödinger's genesis of wave mechanics was done—before Mehra and Rechenbach's work—by Forman, by Paul Hanle and by Linda Wessels, among others. Although these authors receive references (usually only in brief footnotes), the importance of their work is not conveyed. Similar criticism can be made in many other places.

What is missing in the presentation thus far is how the pieces fit together. Thus readers would have to reconstruct for themselves an assessment of the impact of general relativity on the development of wave mechanics in the period 1920–1927. Similarly, although the relevance of the Hilbert–Minkowski mathematical physics tradition and the importance of the Courant–Hilbert volumes are detailed when discussing various individuals—such as Born, Jordan, Schrödinger and Cornelius Lanczos—no general discussion is given. It is such integrations that would transform these informative volumes into genuine histories.

In his preface to volume 1 Mehra notes that several accounts dealing

with parts of the history of quantum mechanics already existed in print. "Our aim, however, goes much beyond such works. We want to give the full story of all significant problems and their interplay in leading to the discovery and completion of quantum mechanics and to discuss the role and contributions of individual quantum physicists properly and adequately." Therein, perhaps, lies the greatest flaw in the enterprise, since the story is greater than the sum of such parts.

The authors seem to believe that it is possible to give *the* full story and *the* definitive interpretation of the events we call the quantum mechanical revolution, events which so deeply transformed so many different disciplines and whose impact on our culture has yet to be assessed. Alexander von Humboldt in a letter to the young Charles Darwin in 1839 commented that "works are of value only if they give rise to better ones." By having chosen to write in a way that closes the discourse the authors have diminished their accomplishments and the value of these volumes. By not giving greater emphasis to the diversity and the richness of other interpretations, they not only have impoverished their own presentation but have lessened the magnitude of the intellectual upheaval they are attempting to recount.

The Anthropic Cosmological Principle

John D. Barrow and Frank J. Tipler
706 pp. Oxford U. P., New York, 1986.
ISBN 0-19-851949-4. \$29.95

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While the principle in question has several forms, which come under the general rubric of the "anthropic principle," the main distinction appears to be between what I would call a necessary and a sufficient version. The necessary version says in effect that the observed structure and properties of the universe must be consistent with our existence. The sufficient version says that these properties require our existence or at least require the existence of some kind of intelligent observers.

Although there are earlier references to these principles, their modern

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incarnation is due mainly to the work of Brandon Carter and Robert Dicke, and this book, written by two well-known cosmologists, is an attempt to summarize both their history and the evidence in support of them. The erudition displayed here is simply awesome, and it is difficult indeed to imagine a topic that touches, however tangentially, on these principles that has been omitted. That said, I found that too many of the discussions lacked sufficient detail to allow the general reader, or even the specialist, to follow the argument—too much has to be taken on faith. While, for example, the chapter on cosmology abounds with formulas, very few are actually derived and many of the order-of-magnitude arguments left me unconvinced. One longs for the deductive approach one finds for example in Steven Weinberg's *Gravitation and Cosmology*. In fairness to the authors I should say that they do cite references in support of each of their assertions. But without access to a large scientific library the reader will have difficulty tracking them down (some have not been published in standard journals). And I fear that most of the references will be beyond comprehension except to specialists. Finally, I found the presentation relentless. There was no space, no doubts. The reader is simply overwhelmed in the end, but not necessarily convinced.

One of the main objections to the necessary version of the anthropic principle is that it does not satisfy Karl Popper's requirement of falsifiability. To refute this claim the authors offer the Carter inequality, which connects the number of improbable steps in the evolution of the species *Homo sapiens* and the length of time the Earth will remain a habitable planet. I could not follow the derivation given in the book. But worse, the estimates of the number of improbable steps range from about 10, which gives an upper limit of 4.5×10^8 years for the length of time the biosphere can continue into the future, to more than 110 000, giving an upper limit of 4.1×10^4 years for this time. Strangely, this latter estimate is based on a probabilistic calculation of the odds of assembling a single gene that does not take into account the enormous reduction in these odds when one includes the solar energy input into the system where this assemblage presumably took place. In any case it is not a prediction that most of us will be able to check. Furthermore, no mechanism for the demise of the biosphere is suggested by the derivation, so the lengthy discussion of such mechanisms that follows it seems irrelevant.

Finally I must say a few words about

the sufficient version of the anthropic principle. One of the major goals of this book apparently is to impress the reader with the improbable fine tuning of the laws of nature that is necessary for our existence. We are told, for example, that "if the relative strengths of the nuclear and electromagnetic forces were to be slightly different then carbon atoms could not exist in nature and human physicists could not have evolved." And indeed, one cannot help but be impressed with the large number of such fine tunings that seem to be required for our existence. But does this mean that they are sufficient for this existence? One cannot help but conclude that the main purpose of this book is to argue for such a teleological interpretation as the only way to understand this fine tuning. This is a fascinating question but in my opinion not—despite the authors' claims to the contrary—part of the discourse of contemporary science.

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Physics of Dense Matter

Y. C. Leung

268 pp. World Scientific, Singapore
(Teaneck, N. J.), 1985.
ISBN 9971-978-10-5. \$47.00

Supernova 1987a is a timely reminder of the rich and fascinating physics of dense matter and its role in supernovae and neutron stars. Few problems have such fundamental appeal and involve such a rich blend of nuclear physics, particle physics, astrophysics and condensed matter physics.

One essential ingredient for understanding supernovae and neutron stars is the equation of state of equilibrated matter. Y. C. Leung has written a clear, pedagogical introduction to our present understanding of the equation of state of condensed matter from terrestrial densities to beyond the densities found within nuclei. Leung assumes no prior or specialized background and his thorough and detailed treatment is easily accessible to an advanced undergraduate student or beginning graduate student with a knowledge of quantum mechanics. Particularly valuable is his treatment of the regime up to nuclear density, for which the relevant approximations have been tested quantitatively in experiments on atomic nuclei. In no other place, to my knowledge, can a student find collected so conveniently all the relevant ingredients of many-body physics, atomic physics and nuclear physics: the Thomas-Fermi, Hartree-Fock and thermal Hartree-Fock approximations; a review of nuclear interactions; and the independent-pair

and variational treatments of nuclear matter. From these ingredients, Leung provides a quantitative description of how matter progresses from the low-density state, consisting of isolated nuclei; through the region of subnuclear densities, in which the high Fermi energy of electrons results in increasingly neutron-rich nuclei and eventually forces neutrons out of nuclei; and to the emergence of a uniform quantum liquid at nuclear density. The last section of the book treats the more controversial region above the density of nuclear matter, providing a brief survey of meson-nucleon field theory, pion condensation and quark matter. In contrast to earlier sections, the treatment of these topics is not self-contained, and serves only as an introduction. Numerical tables of the calculated equation of state are provided in an appendix, a thoughtful convenience for those who wish to use the equation of state in astrophysical calculations.

If the book has any fault, it is that treating so rich a topic in 268 pages necessarily leaves much unsaid. Conspicuously absent is discussion of superfluidity and the associated pinning of vortices to nuclei in the neutron drip regime, which are important for understanding pulsar glitches. There is no discussion of strange matter nor of the possibility that it is in fact the true ground state of matter. The few experimental facts that constrain the equation of state—such as the compression modulus obtained from giant monopole resonances, and the limits placed by the measured masses of neutron stars—are not mentioned. These omissions are consistent with the fact that the most recent references cited are from 1982. Clearly, Leung has chosen to focus his book on older aspects of dense matter physics that are reasonably well understood. For readers who seek a clear, readable presentation of this physics, and are not put off by photoreproduction of a typewritten manuscript in the era of computer-driven laser printers, this book is an excellent reference.

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Applied Classical Electrodynamics

Frederic A. Hopf and George I. A. Stegeman

Volume 1: Linear Optics
262 pp. Wiley, New York, 1985.
ISBN 0-471-82788-6. \$29.95

Volume 2: Nonlinear Optics
182 pp. Wiley, New York, 1986.
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