personally aware of the deeper facts but, in good faith, simply believed what was convincingly presented to them.

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The Quantum Theory of Fields, Vol. II: Modern Applications

Steven Weinberg
Cambridge U. P., New York, 1996. 500 pp. $47.95 hc
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The quantum theory of fields is the central tool in the study of physics at small distances and high energies. This theory also has important applications to many other areas of physics, including condensed matter physics, atomic physics, nuclear physics, astrophysics and cosmology. Continued development of quantum field theory will certainly be important for further progress in all of these areas. Supersymmetric field theories and superstring theories, which are outgrowths of quantum field theory that have achieved an independent status, may play an important role in some of these areas, but as yet, there is no definitive empirical support for these latter developments.

In volume I of this two-volume work, titled *Foundations* (See the review in PHYSICS TODAY, November 1995, page 78), Steven Weinberg, a Nobelist in physics for his contributions to the electroweak theory that partially unifies electromagnetism and weak interactions, gave a definitive account of the foundations of quantum field theory. In that volume, Weinberg emphasized the unique role that quantum field theory plays as the formalism that accommodates the requirements of both quantum mechanics and the special theory of relativity. He focused not only on how quantum field theory operates but also on why it has to be the way it is. Weinberg treated quantum electrodynamics, an Abelian or $U(1)$ gauge theory, in this first volume.

Weinberg devotes his second volume, *Modern Applications*, to non-Abelian gauge theories and their applications to the two central theories that make up the standard model of elementary particle physics: quantum chromodynamics, the theory of the strong interactions, an unbroken $SU(3)$ gauge theory; and the electroweak theory—a spontaneously broken $SU(2)\times U(1)$ gauge theory. He does not include supersymmetry or string theory, which would require another volume. The second volume can be read independently of the first, provided the reader has both the background and the maturity to absorb the presentation, which is comprehensive and general.

Weinberg discusses the quantization of gauge theories starting with the work of Bryce S. DeWitt and of Ludwig D. Faddeev and Viktor N. Popov, going on to the BRST (Batalin–Rouet–Stora–Tyutin) method and further to the Batalin–Vilkovisky technique and the associated antifield and antibracket formalism. To find a discussion of these latter topics elsewhere, one must consult books dedicated to gauge quantization, such as *Quantization of Gauge Systems* by Marc Henneaux and Claudio Teitelboim (Princeton U. P., 1992). After the first three chapters on gauge theory and its renormalization using external field methods, Weinberg reveals a panoply of techniques employed to apply field theory to the standard model, including renormalization group methods, spontaneously broken global and gauge theories, effective field theories, operator product expansions and topologically nontrivial field configurations. Weinberg has made seminal contributions to many of these areas; the uniformity of presentation reflects his mastery of every aspect of the subject.

As a text for a first course on field theory applied to the standard model, *An Introduction to Quantum Field Theory*, by Michael E. Peskin and Daniel V. Schroeder, (See the review in PHYSICS TODAY, August 1995, page 69), takes a more elementary, less general approach and requires a less steep learning curve for the neophyte. Weinberg's *Modern Applications* goes to the boundaries of our present understanding of field theory. It is unmatched by any other book on quantum field theory for its depth, generality and definitive character, and it will be an essential reference for serious students and researchers in elementary particle physics.

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Time's Arrow and Archimedes' Point

Huw Price
Oxford U.P., New York, 1996.
306 pp. $25.00 hc
ISBN 0-19-510095-6

Huw Price, a reader in philosophy at the University of Sydney in Australia, has written a book addressed to physicists, philosophers and general readers concerned with the perception and treatment of time in the formulation of fundamental physical theory. He claims, quite correctly, that "philosophers as well as physicists often fail to pay adequate attention to the [asymmetric] temporal character of the viewpoint which we humans have on the world." To overcome this human bias and achieve temporal correctness, Price advocates the "Archimedean view of reality . . . the view from *nowhen*" (recalling Archimedes's boast that he could lift the whole Earth, given a fixed point outside of it and a long enough lever).

The first main theme of the book is that "the asymmetries of thermodynamics and radiation appear to depend on the fact that the universe had a particular character early in its history: Its matter was very evenly distributed, which is a very ordered [low entropy] condition for a system in which gravity is the dominant force." Price then argues that, while this initial condition explains the observed macroscopic asymmetry, which includes our own biological and psychological makeup—the past feels very different to us from the future—it does not imply an additional microscopic asymmetry that physicists often mistakenly assume. This he calls μInnocence: "Interacting [microscopic] systems are uncorrelated before they interact." This leads to "a deep and almost unrecognized conflict in contemporary physics. If we are to retain *T* Symmetry, we should abandon μInnocence." Furthermore, "quantum mechanics seems to offer empirical confirmation that μInnocence fails. The failure of μInnocence seems to open the way for a kind of backward causation."

A detailed discussion of quantum mechanics is in the last part of the book. After describing the usual paradoxes, Price comes down strongly in favor of what he calls "the common future hypothesis," which is a denial of μInnocence, or independence, to objects that have an interaction in the future. "Compared to all other major approaches, its advantage seems to be that it does not conflict with special relativity"—that is, it does not require the "crude" nonlocality that follows from Bell's theorem when backward causation is excluded, because "the point at which [systems] become coupled . . . lies well within the light cone of their later [interactions]." In fact, Price advocates a local hidden-variable theory made compatible with quantum mechanics and special relativity through backward causation.

On the whole, Price does well in pointing out how the macroscopic asymmetries in our world are explained by the low-entropy initial state of our universe. This idea is, of course, not original to Price. It goes back at least to Ludwig Boltzmann, and it was presented succinctly and elegantly by Richard Feynman: "It is necessary to add to the physical laws the hypothesis that in the past the universe was more ordered, in the technical sense, than it is today . . . to make an understanding of the irreversibility (*The Character of Physical Law*, MIT P., 1967)." Price does not quote Feynman but follows closely the recent, very clear formulation of this idea in terms of the Big Bang model described by Roger Penrose in *The Emperor's New Mind* (Oxford U. P., 1989), where Penrose equates "initial state" with the smooth energy density state prevalent soon after the Big Bang.

To be able to make deductions from this smooth initial macrostate of the universe, one has to add, implicitly or explicitly, that the initial microstate was typical with respect to some (at least vaguely defined) weight or measure on the different microstates compatible with the initial macrostate, for example, "uniform" weight to all quantum states. Accepting this reasonable minimalist assumption, one should then be able to decide, at least in principle, what correlations are to be expected in particular situations; no additional independent assumptions about μInnocence would then be necessary or possible. Of course, this might still require adopting, as practical working hypotheses, certain rules of thumb about correlations and causations, not only in our daily lives but also in our scientific work. This, and not some hidden "mistake," seems to me the justification of the working assumption of the lack or irrelevance of certain correlations to which Price so strongly objects.

Price's failure to deal with this makes his argument about the merits of backward causation as a viable explanation of our world unconvincing. What he suggests is not clearly wrong, and it certainly should not be dismissed out of hand. But Price doesn't seem to appreciate the difference between having a general idea, which one can discuss at lunch, and actually providing a consistent physical theory, or even the outlines of one, which implements, in the form of equations, this backward causation. Lacking such a theory, he should have put forward his ideas much more tentatively. Whether a theory of this kind could really be made viable is another matter.

Still, despite many shortcomings and much arrogance, the book is worthy of attention. Price presents a good account of the conceptual problems present in our current view of the world, a world where results of measurements, as given by instrument