Speakable and Unspeakable in Quantum Mechanics. J. S. Bell. 212 pp. Cambridge U.P., New York, 1987. Price: $14.95 (paper) ISBN 0-521-36869-3. (Reviewed by Michael A. Horne and Anton Zeilinger.)

This book collects all of John Bell's papers on conceptual and philosophical problems of quantum mechanics: twenty-two papers written over the past 25 years. The first two papers in the collection are the famous pair from the mid-1960s that revolutionized the discussion of the foundations of quantum mechanics. In the first paper, Bell shows that the statistical nature of quantum mechanics does not necessarily prohibit the existence of states with definite values for observable properties, pointing out the flaws in earlier proofs by John von Neumann and others. In the second, he continues the analysis of two-particle systems begun by Albert Einstein, Boris Podolsky, and Nathan Rosen in the 1930s, who argued convincingly that definite properties exist. Bell proves, however, that the existence of definite properties implies instantaneous influence at a distance if quantum mechanics is valid. It is in this paper that he presents the now-famous Bell inequalities. The impact of this work may be judged from the title of a recent AJP Resource Letter and Reprint Book, *Foundations of Quantum Mechanics Since the Bell Inequalities.*[1]

The rest of the collection reveals that, for Bell, quantum mechanics presents basic problems. The paper bearing the title of the book succinctly presents two of them. One problem is this: "how exactly is the world to be divided into speakable apparatus...that we can talk about...and unspeakable quantum systems that we cannot talk about?" Discussions of this fundamental ambiguity occur throughout the book. The second problem with quantum theory is "the apparently essential conflict between any sharp formulation and fundamental relativity." This conflict was revealed by his own work in the 1960s and was, as he points out, previously exhibited in the nonlocal de Broglie–Bohm theory. He feels that "it may be that a real synthesis of quantum and relativity theories requires not just technical developments but radical conceptual renewal." Another problem is the well-known one Schrödinger had with his cat. The wavefunction admits the superposition of the possibilities "cat alive" and "cat dead," while upon observation she is always found to be either dead or alive. This, to Bell, raises the question, "Are there quantum jumps?"—the title of the last paper in the collection—and he concludes "either the wave function, as given by the Schrödinger equation, is not everything, or it is not right." The first possibility is developed, for example, in the de Broglie–Bohm theory, while the second one would require modification of the Schrödinger equation.

While some papers in the collection require a basic familiarity with the formalism, others, like the title paper, are accessible to everyone. Large parts of other papers are also accessible to the nonphysicist, for example, "Six possible worlds of quantum mechanics" and "Bertlmann's socks and the nature of reality." This last paper, in itself, justifies the purchase of the book for a philosopher. The philosopher who is unaware of, or unimpressed by, the EPR correlations, should, after reading this one paper, be terminally puzzled. This should also hold for the physicist who, despite "having suffered a course on quantum mechanics," is also unimpressed.

We should emphasize, as does Bell, that some of the problems of quantum mechanics he discusses are not of practical importance. For example, the split between the speakable apparatus and unspeakable system, "although ambiguous in principle, is sufficiently unambiguous for practical purposes: put sufficiently much into the quantum system that the inclusion of more would not significantly alter practical predictions." Also, experimental physicists can continue to use quantum mechanics to predict their measurement results without referring to books on quantum measurement theory. But the problems are of great conceptual significance, arising only if we want to understand. Bell does not discuss what we think is one of the greatest problems of this kind: that is, to understand "why quantum mechanics?" Shouldn't a theory as fundamentally important as quantum mechanics follow from something deeper? We suggest that the fundamental elements of quantum mechanics may follow from a careful analysis of what it means to observe, to collect data, and to order them in such a way that physical laws can be constructed.

This book is lovely and thoughtful, and it should be read by everyone interested in fundamental questions of nature.

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[1] L. E. Ballentine, "Resource letter IQM-2: Foundations of quantum mechanics since the Bell inequalities," Am. J. Phys. **55**, 785–792 (1987).

The How and the Why: An Essay on the Origins and Development of Physical Theory. David Park. 459 pp. Princeton U. P., Princeton, 1988. Price: $35.00 ISBN 0-691-08492-0. (Reviewed by James T. Cushing.)

This is a marvelous, technically competent, literate, engagingly written book that every student (whether a science major or not) in a science course—and their instructors—should have to read. This is especially so since "grand sweep" introductory physics texts for nonscience students, such as Cooper's *An Introduction to the Meaning and Structure of Physics*[1] and Brancazio's *The Nature of Physics*[2] are either little used now or actually out of print. It is an intellectual history of the concept of science as we know it today. The book is steeped in scholarship, but never heavy or burdensome with it. It is a wonderful synthesis of philosophy and science (which, after all, began as one). If students were familiar with this or similar books, then Bloom's *The Closing of the American Mind*[3] would be unable to make its case. But, alas, they are not! The story Park has to tell is not a new one (although he does carry the tale up to the latest developments in theoretical physics), but it is done exceptionally well. And, besides, such a good story is always a joy to reread, even for those already familiar with its main points (in greater or less detail). It would serve little purpose for me to recapitulate the details here, since the pleasure is in reading Park's version. So, let me