Preface

Olival Freire's *The quantum dissidents – Rebuilding the foundations of quantum mechanics 1950-1990* is a compelling, important book. It is also a remarkable book. At one level it is a richly documented history of how the foundations of quantum mechanics were formulated and variously interpreted from 1925 until the 1990s. Special emphasis is given to the developments from the 1950s on, and two threads are initially followed that eventually combine. The first has as its point of departure, the interpretation of the mathematical formalism of quantum mechanics that David Bohm and Hugh Everett formulated in the early 1950s. Bohm's was a deterministic interpretation in contrast to the conventional probabilistic one, and Everett's became known as a "many world" formulation of quantum mechanics. Their interpretations differed radically from those by the founding fathers, in particular the ones formulated by Werner Heisenberg, by Wolfgang Pauli, and by Niels Bohr, that became amalgamated and loosely referred to as the Copenhagen interpretation. Freire begins the second thread with Eugene Wigner's post-World War II critical analysis of John von Neumann's formulation of the measurement process as framed in his *Mathematische Grundlagen der Quantenmechanik* in 1932. The two threads became intertwined as foundational issues assumed greater legitimacy in the late 1950s. A new phase opened in the early 1960s when John Bell showed how to quantitatively address the quantum weirdness exhibited by entanglement and non-locality, and John Clauser and Abner Shimony indicated how to translate these insights into executable experiments. Alain Aspect's definitive experiments in the early 1980s confirmed the validity of quantum mechanics and corroborated what John Archibald Wheeler had said regarding delayed choice experiments, namely that "no phenomenon is a phenomenon until it is an observed phenomenon." Research on the foundations of quantum mechanics became highly regarded by the community after Aspect's experiments. The subsequent refinements of these experiments made them critically relevant to computer science and helped establish the field of quantum information, one of whose aims is to revolutionize computing, and another is to make the transmission of information absolutely secure and thereby revolutionizing cryptography. All these developments are beautifully expounded by Freire.

If *The quantum dissidents* contained only its detailed, internalist, presentation of the history of how the foundations of quantum mechanics became differently interpreted, this would already be a most impressive accomplishment by virtue of the command and synthesis of the huge amount of materials Freire had gathered and made use of: personal interviews, the American Physical Society's Center for the History of Physics' as well as other interviews, biographies, documents from numerous archives, correspondences, published articles and books, unpublished notes and papers, annotations to papers, ... And equally impressive is the fact that Freire explains all the physics he presents in a readily accessible, accurate, clear, succinct fashion. For example, we learn what the measurement problem is, how it became a foundational issue, and why by virtue of the extreme fineness of the level structure of a ***macroscopic*** body when described quantum mechanically, its interactions with its surrounding can never be neglected and that it can never be considered a closed system. This is the basis of the decoherence mechanism that Dieter Zeh, Wojciech Zurek, and others have introduced in order to explain how definitive pointer readings come about in the quantum mechanical description of the measurement process. Today, by virtue of these advances a complete quantum mechanical description of the measurement process is almost at hand.

But Freire wanted his presentation to be more than *a longue durée* internalist narration of the history of the changes in the conceptualization of the foundations of quantum mechanics brought about by the investigations of various theorists who dissented from the orthodox view. He wanted to understand why *investigating* foundational questions regarding quantum mechanics was actively discouraged until the 1960s. And in addition to answers to questions such as: "What were the factors that led these "dissenters" to choose issues from the foundations of quantum mechanics as research themes? What issues did each one of them come to grips with? What were the favorable factors, and what were the obstacles to their activities? And to what extent did they succeed in their endeavor?" Freire wanted to know in what ways the political and cultural contexts made the change possible, and in what ways these contexts—as well as ideology and metaphysics—were reflected in the interpretations given.

Considering the founding fathers of quantum mechanics—Heisenberg, Dirac, Pauli, Schrödinger, Bohr—as being "off-scale" was part of a creation myth and contributed to the belief that all foundational problems had been answered by the Copenhagen interpretation. Similarly, von Neumann, whose axiomatization of quantum mechanics made rigorous mathematical statements regarding the formalism possible, was deemed off-scale among the then off-scale mathematicians. His proof of the impossibility of introducing hidden variables was assumed flawless and went unchallenged until Bell—who was trying to understand the consistency of Bohm's deterministic interpretation of quantum mechanics with a particle's position and momentum considered hidden variables—discovered an invalid assumption in von Neumann's "proof." Interestingly, the mistake had been detected in the mid-1930s by Grete Hermann, but because she was primarily a mathematician interested in philosophical problems and perhaps because she was a woman, her finding went unnoticed by the physics community. In any case, physicists during

the 1930s were fully occupied successfully extending the boundaries of the applicability of quantum mechanics to solid state and nuclear physics, and exploring its validity at ever smaller distances.

After World War II, the plethora of new precision instruments that became off-shelf equipment in the laboratory, the success of the renormalization program in quantum electrodynamics, masers, lasers, transistors, and PDP computers opened up new worlds in "table-top" physics. And ever more powerful accelerators did the same in high energy physics. In the United States, the one country whose home grounds had not been devastated by the war, worrying about the foundations of quantum mechanics—when the latter had been responsible for successfully designing an atomic bomb during the war—seemed misguided given all the concrete problems that were being successfully addressed using the conventional interpretation of quantum mechanics to get measurable numbers out. Furthermore, philosophizing had always been looked at askance in the United States and positivistic pragmatism flourished there after it was introduced by Charles Sanders Pierce and William James in the last third of the nineteenth century.

But two new factors altered the postwar political and social contexts of the physics community in the United States. One was the Cold War and the concomitant McCarthyism; the other was the large increase of its physics community—from some 3,000 before the war to over 8,000 after the war— the number of theorists among them and the new status accorded to them. Freire sensitively conveys the consequences of the Cold War and of McCarthyism in his narration of how and why David Bohm formulated his particular interpretation of quantum mechanics. Likewise, the paternalism that bound the physics community and the power it had vested in Bohr and his apostle, Leon Rosenfeld, are clearly described when Freire tells the story of Hugh Everett and of the reception of his "relative state" formulation of quantum mechanics. Similarly, the crucial importance of the political and cultural contexts is convincingly rendered when Freire analyzes the ways the civil rights movement, the Vietnam war, and the student upheavals transformed what had been deemed good physics and helped bring center stage foundational issues in quantum mechanics in the early 1970s.

One of the outstanding features of the book is its weaving together of professional, cultural, and political contexts with the personal and individual. We thus get short, incisive biographies of the principal actors, their family background, the institutions they were educated in, their mentors and thesis advisors, the universities they became associated with, the resources they could draw on, the encouragement and support they received from colleagues at their home institution, and from the wider physics community. And these presentations are supplemented by sociological insights gleaned from various sources: Pierre Bourdieu on habitus and various forms of capital, the strong program of the sociology of scientific knowledge, Timothy Lenoir, David Kaiser,... In the final chapter of the book, Freire makes use of prosopography to characterize the two dozen or so courageous physicists who were primarily responsible for effecting the dramatic changes in the conceptualization of quantum mechanics, the ones he calls the "quantum dissidents." They belonged to different generations, but they all had integrity, were self-confident,

and they all shared the belief "that issues in foundations of quantum mechanics were worthy enough to be pursued as part of a professional career in physics, and that denying this was a dogmatic attitude. This was the main feature of their dissidence, as most physicists at the time disagreed with this." One other feature stands out as a result of Freire's analysis. The decisive changes came about by virtue of what a few in that group had done: Bell, Shimony, Clauser, Aspect. The changes were engendered by the actions of ***individuals*** making use of the resources of the collectivity they were part of. The seminal paper of John Bell, John Clauser, Abner Shimony, Michael Horne, and Richard Holt seems to be the exception. But it turns out to have resulted from pooling together into one paper the conclusions Bell, Clauser, and Shimony had reached independently. They did so in order to maximize its impact.

Commendations similar to the above can be made regarding Freire's discussion of philosophical issues. One of the central concerns of the book is explaining how come the same mathematical structure can support so many different physical interpretations. When explaining why this is so, Freire introduces the reader to the Quine-Duhem thesis regarding the under-determination of theories, to concerns with realism, to the equivalence of various mathematical formulations, to what constitutes deterministic or probabilistic explanations, to when are explanations causal, and much else. And Freire always does so simply, concisely and without ostentation.

I would characterize the book as exemplifying what the successful synthesis of the history, sociology, and philosophy of science can accomplish. I can give *The quantum dissidents – Rebuilding the foundations of quantum mechanics 1950-1990* no higher compliment than to say that anyone aspiring to become a physicist would become a better one by reading it.

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