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The Quantum Labyrinth: How Richard Feynman and John Wheeler Revolutionized Time and Reality. , Paul Halpern, Basic Books, 2017, $30.00

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Given how comprehensive the book is, I was rather surprised that chapter 21, whose subject is the possibility of life on other planets, omitted the Drake equation and did not discuss the Fermi paradox. My only other quibble is with the black-and-white photographs of key scientists that are interspersed throughout the book. I can see that this was likely an attempt to humanize scientific research in cosmology, but the photographs mostly serve as a stark reminder of the peculiar demographics of our field. In my opinion, it would have been best to stick to pictures of the incredible instruments that have enabled cosmology's amazing discoveries. Speaking of imagery, some of the schematic figures are fantastic. Figure 16.6 explaining true and false vacuum is a gem.

To conclude, *Cosmology for the Curious* offers an excellent tour of the key ideas in cosmology. It also crisply delineates our empirically determined understanding from more speculative areas of current research. I am currently using it in my introductory cosmology class.

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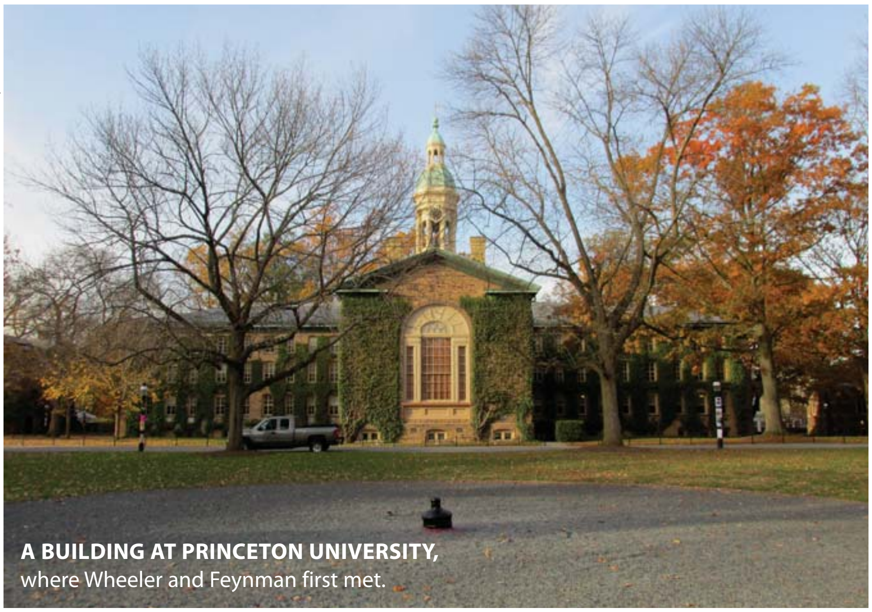

A BUILDING AT PRINCETON UNIVERSITY, where Wheeler and Feynman first met.

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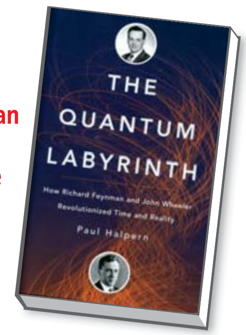

In the fall of 1939, Richard Feynman and John Archibald Wheeler, two of the most formidable physicists of the 20th century, began an extraordinarily fruitful collaboration. Their lifelong friendship resulted not only in groundbreaking work on electrodynamics but also in personal growth—Feynman learned how to think like a physicist and Wheeler became a gifted and proficient mentor—that influenced the course of physics over their lives.

In *The Quantum Labyrinth: How Richard Feynman and John Wheeler Revolutionized Time and Reality*, physicist and science writer Paul Halpern offers an accessible narrative that describes the Wheeler–Feynman relationship and its impact on US physics in the 20th century. That achievement is no small feat, since prose lacks the precision of mathematics. Indeed, Halpern's skillful use of analogy reminds me of two celebrated lecture series given by his subjects: the Physics for Poets course that Wheeler taught at Princeton University in the early 1970s and the Character of Physical Law lectures that Feynman gave at Cornell University in 1964.

As in Halpern's previous book, *Einstein's Dice and Schrödinger's Cat: How Two Great Minds Battled Quantum Randomness to Create a Unified Theory of Physics* (2015), *The Quantum Labyrinth* discusses the interaction of two remarkable intellectuals. A key difference in the stories is that the relationship between Erwin Schrödinger and Albert Einstein collapsed under the pressure of professional competition, whereas Wheeler and Feynman remained close friends until the latter's death.

There are, however, problematic passages in *The Quantum Labyrinth*. One issue is Halpern's tendency to overstate the importance of Feynman and Wheeler. For instance, Halpern writes, "Arguably, much of the visionary work in theoretical physics in the late-twentieth and twenty-first centuries derives from their [Feynman and Wheeler's] bold discourse, including the basis of the Standard Model of particle physics and all manner of astrophysical concepts, such as the properties of black holes and wormholes."

Unfortunately, that assertion risks trivializing the important contributions of physicists who were not part of Wheeler's intellectual lineage. Steven Weinberg and Murray Gell-Mann immediately come to mind in the context of the standard model. Similarly, Halpern's claim ignores the contributions that George Gamow and Stephen Hawking, among others, made to our understanding of astrophysics and cosmology. Halpern states, "Ultimately they [Wheeler and Feynman] reshaped the concept of time itself, allowing for alternative realities and backward journeys." Although Wheeler played a significant role in that work, much of the credit for expanding our knowledge of the topic should go to Igor Novikov and to former Wheeler student and recent Nobelist Kip Thorne.

There are also places where Halpern speculates on what Wheeler, Feynman, and some of their colleagues were thinking at particular times, and presents his speculation as fact. For example, Halpern writes that during Feynman's Princeton years, Wheeler "counted his blessings for the good fortune of having such an extraordinarily original thinker as a student." Although it may well be the case that Wheeler was pleased to have Feynman as his student, Halpern does not offer any supporting evidence for that claim.

Additionally, Halpern's narrative downplays some key aspects of the Feynman–Wheeler story. One is the sheer improbability of their relationship. Feynman, who had been an undergraduate at MIT, planned to pursue his graduate work there until the department chair insisted he broaden his horizons by applying elsewhere. The Princeton administration had to be convinced that he wasn't "too Jewish." Then Feynman, who had expected to work with the distinguished physicist Eugene Wigner, was taken aback to find that Wheeler, his assigned dissertation adviser, was only 28 years old—a mere seven years older than Feynman himself.

Halpern briefly mentions that during World War II the two men produced a significant paper on the absorption of radiation, but he does not take stock of the difficulties inherent in such a project. Both Wheeler and Feynman had taxing wartime workloads, and their geographical separation—Feynman was by then at Los Alamos—severely limited the opportunities for interaction. The completion of their paper was, in itself, a testament to the perseverance required to do good science.

Halpern also has a tendency to turn a blind eye to the personal failings of both Feynman and Wheeler. For example, he extols Feynman's talent at lecturing but fails to point out Feynman's aversion to working with graduate students; his celebrated Physics X course was open to undergraduates only. Similarly, Halpern lauds Wheeler's enthusiasm for mentoring but glosses over Wheeler's reluctance to support either Feynman or Hugh Everett III when his own mentor, Niels Bohr, expressed disapproval of their work.

Nonetheless, Halpern's book offers some insights into the development of 20th-century physics. The discussions of classical electromagnetic fields and of Paul Dirac's early work on quantum electrodynamics are two good examples. Although Halpern's explanation of Wheeler's "delayed-choice" thought experiment requires careful reading, the effort is worth it; the implications in a cosmological frame of reference are fascinating.

In the final analysis, readers will be well served to consider the intended audience of this book. Halpern has delivered a popular narrative that is designed to enlighten and perhaps entertain laypeople with a casual interest in science. So long as scholarly readers do not expect rigorous history, they will find this book a pleasant diversion.

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