LETTERS

Rebutting remarks on Feynman and Wheeler

I must take issue with some of the assertions in Terry Christensen's review "Entertaining biography lacks rigorous history" (PHYSICS TODAY, April 2018, page 56) of my book *The Quantum Labyrinth: How Richard Feynman and John Wheeler Revolutionized Time and Reality*. Contrary to the headline, the history in the book is well documented and based on extensive archival research, examinations of conference proceedings, numerous phone and email interviews with those who knew the two physicists, and so forth.

Christensen asserts that I credit Feynman and Wheeler for other physicists' accomplishments. Although I point out their considerable achievements, I devote much of the book to describing the work of other thinkers, including Freeman Dyson, Bryce DeWitt and Cécile DeWitt-Morette, Charles Misner, and Kip Thorne.

"Halpern does not offer any supporting evidence," writes Christensen, for my claim that Wheeler was glad that Feynman was his student. Yet I include direct quotes from Wheeler to that effect—for example, on page 7, "Through some wonderful freak of fate I ended up with him assigned to me."

"Halpern's narrative," says Christensen, "downplays some key aspects of the Feynman–Wheeler story. One is the sheer improbability of their relationship." However, I wrote, "When admitted to Princeton, Feynman had originally been assigned as Wigner's teaching assistant. At the last minute, Feynman was switched to assisting Wheeler instead."

Christensen says that I do not "take stock of the difficulties inherent" in producing a significant paper during wartime. But I do. I emphasize that issue, including on page 92 a key quote from Wheeler in a March 1942 letter he wrote to Feynman: "I would advise you very strongly to write up what you have in these remaining few weeks before you get into the situation in which I now find myself, where there is absolutely no time to work on our theory of action at a distance."

At another point Christensen says of me, "He . . . fails to point out Feynman's aversion to working with graduate students; his celebrated Physics X course was open to undergraduates only." Yet that depiction is based more on folklore than on fact. Actually, Feynman mentored numerous graduate students—Laurie Brown, Albert Hibbs, and others—but urged them to work independently, a style many other theorists have chosen. Julian Schwinger, for example, spent very little time with his many PhD students. There are many pedagogical reasons why Feynman would dissuade graduate students from taking Physics X, a freshman course for nonmajors; for one thing, their extensive knowledge would intimidate novices.

Christensen states that I gloss over "Wheeler's reluctance to support either Feynman or Hugh Everett III when his own mentor, Niels Bohr, expressed disapproval of their work." Perhaps he missed where I had written, on page 147, "Wheeler took careful notes but, as far as history records, did not defend Feynman. Wheeler always treated Bohr, his dear mentor and role model, with the utmost deference and respect," and on page 192 that Wheeler "met with Bohr and Petersen to try to convince them of the merits of Everett's hypothesis."

In short, *The Quantum Labyrinth* is historically rigorous, extensively researched, and accurate.

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Editors' note: The headline for the review was written by a staff member, not by the reviewer.

▶ **Christensen replies:** Regarding John Wheeler's "freak of fate" quote, there is other evidence to consider. I refer Paul Halpern to a series of Wheeler interviews conducted by Ken Ford.[1] At one point, Ford asked Wheeler to name his best graduate students. Wheeler listed five names, none of them Richard Feynman. As a follow-up, Ford asked specifically about Feynman. Wheeler recalled Feynman's fun-loving personality.

My concern about adequate credit to

other physicists is that the overselling of the Wheeler–Feynman contribution trivialized the contributions of others who were not part of Wheeler's intellectual lineage—Steven Weinberg, for example. The physicists Halpern named in his response were former Wheeler students, collaborators with Wheeler, or collaborators with former Wheeler students.

Halpern's contention that Feynman had "numerous" graduate students is surprising. Feynman's aversion to supervising PhD students is well documented and, indeed, was articulated by Feynman himself.[2] Moreover, in 2001 I attempted to determine the number of PhD students Feynman had supervised. Personal communications with David Goodstein, Kip Thorne, and Feynman's long-term secretary, Helen Tuck, were not terribly fruitful. In the end, only five names surfaced, and not all could be verified.

Goodstein's own research suggests that in the mid to late 20th century, a professor at a major research university would, on average, supervise 15 PhD students.[3] Julian Schwinger is reported to have supervised 13; Wheeler, among the most prolific of mentors, supervised 52. At most, it seems that Feynman supervised 7.

There is more to say, but space here is limited. In sum, I stand by my review.

References

1. J. A. Wheeler, interviews with K. Ford, 1994–95, www.aip.org/history-programs/niels-bohr-library/oral-histories/5908-10.
2. R. P. Feynman, interview with C. Weiner, 1966, www.aip.org/history-programs/niels-bohr-library/oral-histories/5020-4; J. Gleick, *Genius: The Life and Science of Richard Feynman*, Vintage Books (1992), pp. 12 and 278.
3. D. L. Goodstein, *Am. Scholar* **62**, 215 (1993).

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Cartilage lubrication and load pressure

Sabrina Jahn and Jacob Klein, authors of "Lubrication of articular cartilage" (PHYSICS TODAY, April 2018, page 48), write that "the fluid between the surfaces reduced the friction and supported much of the load via its own pressure." That is, load on a joint pressurizes the fluid in the pores of the cartilages, providing self-pressurized hydrostatic lubrication. Loaded cartilage slowly loses pore fluid, but with each step the flexing and unloading of the joint and the bad fit of the cartilages to each other expose the surface of each to free fluid that it cannot resorb. That, in turn, allows the cartilage to resorb fluid. I called this cycle "weeping lubrication" because cartilage weeps fluid when squeezed.

Experiments by Gerard Ateshian show that cartilage fully charged with pore fluid carries almost all its load by hydrostatic pressure.[1] In the study discussed in reference 9 of Jahn and Klein's article,[2] a woman with an instrumented prosthetic hip rose from her chair, but little of the 20 MPa loading that Jahn and Klein mention would have been carried by high-spot to high-spot solid contact.

Because of support by hydrostatic pressure, joints carry high loads without overloading the boundary lubrication that synovial fluid provides, which, experiments show, fails at more than modest solid–solid loading.[3]

I offer some advice for experimenters: When loaded cartilage eventually loses all pore pressure, the entire load transfers to the boundary-lubricated high spots and reveals their friction coefficient. For that to happen quickly, the sample must be very thin and on a very permeable mount.

References

1. G. A. Ateshian, *J. Biomech.* **42**, 1163 (2009).
2. W. A. Hodge et al., *Proc. Natl. Acad. Sci. USA* **83**, 2879 (1986).
3. C. W. McCutchen, *Wear* **5**, 1 (1962); C. W. McCutchen, in *The Joints and Synovial Fluid*, vol. 1, L. Sokoloff, ed., Academic Press (1978), p. 437; T. A. Schmidt et al., *Arthritis Rheum.* **56**, 882 (2007).

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