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BOOK REVIEW

A difficult subject leavened with human interest

Jim Baggott: The quantum story: A history in 40 moments: New York: Oxford University Press, 2011, xix+469pp, $29.95 HB

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As we approach the November 2012 semicentennial of the death of Niels Bohr, this engrossing history of the development of Bohr's legacy, the quantum theory, is especially timely and welcome. In his preface, Baggott reveals that he had initially hoped "to write a 'biography' of quantum theory based on the biographies of the physicists who forged it and refined it" (xv). While *The Quantum Story* is not exactly that book, it does provide a glimpse into the lives of many who number in what Baggott calls (in reference to American physicist Murray Gell-Mann in Chapter 21) "the long and illustrious line of prodigious intellects that came to be applied to problems in quantum physics in the twentieth century" (206), including not only well-known figures but also some who lack instant name recognition. (The second category includes not only runners-up to fame, such as American physicist Ralph de Laer Kronig, who bitterly resented the dismissal of his theory of self-rotation and felt he had been kept from becoming the "discoverer" of electron spin, but also, sadly, Nobel laureates, such as Gerardus 't Hooft, who shared the 1999 physics award, and Tony Leggett, who shared the 2003 prize.)

The one caution to readers who are not well-versed in the language of physics is that some sections are very technical indeed. I thought of Baggott's own tendency to obscure his forest for the trees when I read his description in Chapter 19 of audience reaction to Julian Schwinger's 5-h-long presentation on relativistic quantum electrodynamics at a small, National Academy-sponsored conference in March 1948: "Eyes glazed over and minds became numb as Schwinger derived one mathematical result after another. It was only when Schwinger tried to make connections with the underlying physics that the audience came to life and asked questions" (182). Nonetheless, readers less comfortable with equations and technical terminology and more interested in the human aspects of the development

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of science will find much to feast on throughout this book, including vivid descriptions like the one just quoted.

Small wonder, in any case, that mere mortals are likely to struggle with the ideas surveyed so masterfully in this book. As Baggott makes clear in some of the amusing stories he includes, even the great physicists of the day did not always know what to make of emerging work in the field. For example, Paul Langevin, finding it difficult to evaluate the doctoral work of his student Louis de Broglie, turned in desperation to Einstein for help, while Ralph Fowler, personally "unimpressed" by a proof copy of Heisenberg's quantum mechanics, passed it on to his student, 23-year-old Paul Dirac, who "realized precisely what Heisenberg had done". Decades later, at a small 1948 conference on relativistic quantum electrodynamics, the participants seem to have been at a loss to understand the mathematics of either Julian Schwinger or Richard Feynman. Feynman reminisced years later, "Bohr thought that I didn't know the uncertainty principle and was actually not doing quantum mechanics right either. He didn't understand at all what I was saying". (Bohr, of course, had once been the young man who was able to see more deeply than his seniors. Baggott does not make this point, but in an interview with Thomas Kuhn shortly before Bohr's death in November 1962, Bohr reflected on why he had been able to figure out how Ernest Rutherford's model of the atom might really work: "I do not think that [Rutherford] really knew too much about the quantum. I think I knew much more, you see…. In the former years I had been very interested in the quantum".)

A theme running through Baggott's narrative is that the struggle to understand quantum physics is partly a struggle to find the right language, be it verbal or visual. In describing the development of relativistic QED, Baggott includes Freeman Dyson's explicit reference to the role language played: "Hans [Bethe] was using the old cookbook quantum mechanics that Dick [Feynman] couldn't understand. They were getting the same answers whenever they calculated the same problems. And Dick could calculate a whole lot of things that Hans couldn't. It was obvious to me that Dick's theory must be fundamentally right. I decided that my main job… must be to understand Dick and explain his ideas in a language that the rest of the world could understand". Two decades later, Feynman once again proves the superior explicator of data suggesting experimental proof for the existence of quarks. In presenting his own data from the Stanford Linear Accelerator, James Bjorken "had expressed them in the esoteric language of current algebra," while Feynman described "the events in a far simpler, yet richer, more visual way". Language also comes up in the discussion of Sheldon Glashow's work on electroweak interactions. According to Baggott, by the time of the late summer 1960 high-energy physics conference in Rochester, New York, "Glashow had thus far articulated the theory in Schwinger's impenetrable style, and Gell-Mann now offered a translation in a language that more physicists would understand." (In an April 2011 talk postdating the publication of this book, I heard Nobel laureate Steven Weinberg develop the theme of language in recounting a humorous exchange between himself and Murray Gell-Mann about some new words that had recently been coined to account for the massive partners required by supersymmetry—including squarks, selectrons, photinos, winos, and zinos; Gell-Mann spoke of them not as language but as

slanguage, with Weinberg responding that what they were discussing was not exactly language but rather *languino.*)

Not unrelated to the question of language is the issue of the relationship between quantum theory and philosophy, which is dear to Baggott's heart. Indeed, he asserts that modern quantum theory actually *is* philosophy. In describing his earlier book *Beyond Measure: Modern Physics, Philosophy, and the Meaning of Quantum Theory* (2003), Baggott has said, "It is virtually impossible to dig beneath the surface of quantum theory without being confronted by innumerable philosophical conundrums. The theory itself forces you to take more than a passing interest in its philosophical foundations and the implications for our ability to comprehend the nature of reality". Among the interesting points *The Quantum Story* raises in this context is Bohr's "anti-realist" philosophy that not only "denied that quantum theory has anything meaningful to say about an underlying physical reality that exists independently of our measuring devices" but also "denied the possibility that further development of the theory could take us closer to some as yet unrevealed truth". Baggott also asserts that whatever Bohr's definition of the crucial concept of complementarity was, its introduction "represented a marked break with the past. For the first time in its history, science was confronting what Bohr believed to be a profound limitation on our ability to acquire scientific knowledge. Classical physics had no such limitation".

I was particularly taken by Baggott's suggestion toward the end of the book that challenging realism—defined as "the assumption that particles have the properties we assign to them even when we don't look"—does not, by contrast, represent a break with the past. This challenge is the same one found underlying the well-known problem about whether a tree falling in the forest actually makes a sound if there is no one there to hear it. In the book's epilogue, Baggott states definitively that while science "is not philosophy," scientific pursuits like superstring theory, which lack "recourse to experiment," propel science into the arena of the "speculative and metaphysical".

Before concluding my review of this very fine book, let me quickly mention some minor editorial lapses that intrude upon what is otherwise an elegantly written text. Among the few jarring proofreading glitches, the most significant include the misspelling of Karl Schwarzschild's name both in the text and the index, inconsistent spelling of Albert Michelson's name, the use of "dice" as a singular noun, and the omission from the index of Gerardus 't Hooft, who appears more than once in the narrative.

More significantly, from a twenty-first century perspective, Baggott's failure to include women scientists strikes me as a troubling gap in the book's otherwise amazingly comprehensive coverage of a difficult field. Baggott riffs on the CERN community's cocktail party analogy to describe the Higgs mechanism, referring to the gravitation of guests not toward the original version's Prime Minister Margaret Thatcher but rather toward a female "noted celebrity physicist (no doubt a Nobel Laureate)". Nonetheless, although the photograph of double Nobel Laureate Marie Curie appears in the book, Baggott says nothing at all about her work, though it could be argued that her inauguration of the science of radioactivity provided the key to quantum theory's radical reworking of our understanding of matter and

energy; Curie's name does not even appear in the index. Baggott has precious little to say about the work of the few women scientists he does mention, including Lise Meitner, Emmy Noether, and Madame Wu, though he wastes space on some scientists' sexual partners and on the wives of a few others. While Baggott makes a brief nod in the direction of British theorist Fay Dowker, there are many other women theorists whose work he might have mentioned, including Lisa Randall at Harvard and Eva Silverstein at Stanford. This failure notwithstanding, I heartily recommend that readers of *Metascience* commemorate the forthcoming 50th anniversary of Niels Bohr's death by spending time with Baggott's challenging but rewarding *The Quantum Story.*