True genius: the life and science of John Bardeen
Lillian Hoddeson and Vicki Daitch, Joseph Henry Press, Washington, DC, 2002, 467pp., US $27.95, ISBN 0309084083

Chapters 2–16 of this work contain a meticulously researched recreation of the life and scientific career of John Bardeen, the only person to be awarded two Nobel Prizes in physics. The book—which has taken over a decade to complete—is based on all available archival sources, as well as extensive oral interviews with family, friends, and colleagues. It captures very well the heritage, values, passions, and personality of its hero. It also provides a broad yet detailed view of his scientific creations. He is fortunate indeed to have had such fine and dedicated biographers engaged in what they describe as a labor of love.

The son of the founding Dean of the Medical School of the University of Wisconsin, Bardeen, readers learn, was born and raised in Madison. His family, childhood interests, and early schooling are sketched in enough detail to allow us to imagine him as a mathematically gifted, quiet but not inhibited fifteen year old entering the freshman class at the University of Wisconsin in 1923. It was news to me that there, while majoring in Electrical Engineering, he listened to lectures by the theoretical physicists Peter Debye, Paul Dirac, and John Van Vleck, and encountered Arnold Sommerfeld and Werner Heisenberg, which would have made him as well educated as any of his American contemporaries in the then very new Quantum Mechanics.

The authors then take us through his professional career: geophysicist in the laboratory of the Gulf Oil Company in Pittsburgh, graduate student at Princeton, Junior Fellow at Harvard, Assistant Professor in the University of Minnesota, Research Supervisor during World War II at the Naval Ordinance Laboratory in Washington, Member of Technical Staff at the Bell Laboratories in New Jersey, and Professor of Physics and Electrical Engineering at the University of Illinois. Along the way, we learn through the eyes of people who knew him well about his legendary lack of small talk, his passion for golf, his tenacity in seeking understanding of physical phenomena as well as his extraordinary gifts as a physicist, his disinterest in self-advertisement, and his basic decency. There are vignettes of family life and houses lived in, vacations and professional travels, friendships and disagreements with students and colleagues. As a portrait of the human side of a great innovator, the book is an unqualified success.

Bardeen's scientific corpus is described in considerable detail, which may be the feature of most interest to the readership of this journal. No equations are used. This will make the book less frightening to general readers, and certainly increase sales, but it requires the authors to use words precisely. By and large, they acquit themselves well.[1] The scientific work falls, roughly speaking, into five segments:

[1] In view of the fact that one of the authors (LH) is a trained theoretical physicist, the lapses are surprising. For example, the perfectly accurate description of the framework of quantum mechanics on p. 33 is marred by the parenthetical suggestion—perhaps because "momentum" was thought too technical a word—that mass is an observable governed by probabilistic rules. In the sentence on p. 127, "This

(i) the pre-1945 work, including the Ph.D. dissertation; (ii) the Bell Labs work on semi-conductors and the transistor; (iii) superconductivity, including the Bardeen, Cooper, Schrieffer theory and its consequences; (iv) electron tunneling; and (v) charge density waves.

Since my own scientific publications began in 1959, which is also when I first met Bardeen, I am reasonably familiar with topics (iii)–(v), but for the purposes of this review have looked at the other work. It is clear from his first papers in solid state physics, on the energy required to remove an electron from a simple metal, that Bardeen was an emerging star. Interestingly, two of his early papers are on nuclear physics, in part connected with a visit to Cornell in the latter half of the 1930s at the invitation of Hans Bethe. I had occasion to have lunch with Bethe (now 96, and living in Ithaca[2]) recently, and I asked him if he remembered the reason for the invitation. He said he must have been impressed by a paper he read, and that high praise from Eugene Wigner (Bardeen's Ph.D. supervisor) must also have reached him. Gentleman of few words though Bardeen was, it would have been true early that, as a quotation attributed to his student Nick Holnyak puts it, "John Bardeen knew that he was John Bardeen." The description on the jacket of *True Genius*, "John Bardeen was an unassuming man, a humble soft-spoken Midwesterner...," completely misses the supreme confidence in his own abilities that I sensed, to be sure after he had won his first Nobel, and suspect had been acquired when he was a young man.

In the story of the invention of the transistor, the action is followed day by day, conveying very well the drama of the co-discovery with Walter Brattain, the tensions with William Shockley, and emerging dissatisfactions with Bell Labs management. I found this fascinating and informative reading, and must confess with embarrassment that I had forgotten, if I ever knew, about the patented first working device, the "bipolar" transistor, and how difficult it was to get it to work. Materials research has made the conceptually simpler ideas of semiconductor physics which underlay Shockley's thinking realizable today in a way that they were not fifty years ago. The book is a useful reminder of how easily a practicing physicist not involved in the details can overlook the not always straightforward history of discovery.

Bardeen's work on the theory of superconductivity after his move to the University of Illinois is also described with a close and accurate attention to the order of events, as recorded in his notes and in the recollections of his collaborators, especially his then postdoc Leon Cooper and student Robert Schrieffer. This dramatic story could hardly be better told. I was glad to see an extended mention of his review in the 1956 *Handbuch der Physik*, which precedes the famous and

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(*footnote continued*)
implied that at the surface of the semiconductor the electron wavefunction (a measurement of the probability of finding an electron there)...," someone has changed "measure" to "measurement," again no doubt with the best of intentions. These errors, as well as some obvious typos—misspelling of Bardeen's daughter's name on the dedicatory page, Wagner for Wigner on p. 198, an "or" requiring deletion in the second complete sentence on p. 317—are presumably due for correction in another printing.

[2] He will be 97 when this review appears.

definitive Bardeen, Cooper, Schrieffer (BCS) theory, and is a summary of his determined and thorough study of the existing experimental and theoretical information.[3] The landmark BCS publication was a truly collaborative effort, with seminal contributions by Cooper and Schrieffer. (However, from the opening sentence of the paper, all of which should be required reading for every physicist, "The main facts which a theory of superconductivity must explain are (1)..., and (5)...," one recognizes the authoritative voice of the senior author.) The narrative recounts the frustrations and joy of working it all out, as well as the magical end-game, when experiments on the attenuation of high frequency sound and the relaxation of nuclear spins verified subtle predictions of the paper.[4] The important consequences for other branches of physics of the ideas that flowed from BCS—e.g., broken symmetry and the associated collective modes—are correctly emphasized.[5]

Bardeen's research after these heroic periods, each of which led to a Nobel prize, is covered in an equally graphic way. His role as resident sage in Urbana becomes progressively more important. I have a (minor) complaint about this part of the book, which is that the view of the physics department at the University of Illinois (one of the best) is parochial. As an illustration, Tony Leggett, would, I am sure, be the first to be embarrassed by the statement that he "explained theoretically" the nature of superfluid Helium 3, which is not to say that his understanding of the meaning of the nuclear magnetic resonance signal does not deserve a Nobel prize.[6] Further, the remark attributed to David Lazarus that no one he knows has remained as productive in his later years as Bardeen ignores the obvious cases of Hans Bethe, P.W. Anderson, and others I could think of.

My encounters with Bardeen, perhaps a dozen, took place during the last third of his life. I never found him easy to understand. Our first two or three serious exchanges were about the Josephson effect. (Some recollections of my contribution

[3] In a lecture, "Reflections, Reminiscences, and Ramblings on the Theme: Memory and Creativity," (available at http://www.physics.cornell.edu/profpages/Ambegaokar.htm by clicking on Scan of original printed article) I describe the effect that reading this paper had on me in 1959. "Bardeen was my hero. Not only because I had studied the BCS theory but also because as a graduate student I had been asked to give a few seminars on the background to the subject, and for that purpose had read a long review article written by him just before the new theory appeared. That review made it clear that he had followed with great care and tenacity all the clues that experimental research had been revealing. His own reasoning was very hard to follow, and some of it, in hindsight, clearly wrong. But it was wrong in a deep way: his wrong arguments had the seeds of how matters did in fact work out when the pieces were put together correctly."

[4] The description of the physics of nuclear magnetic relaxation on p. 214 is incorrect. The reason for the *more* rapid relaxation, in comparison to the normal state, just below the transition temperature has to do with the "coherence factor"—the constructive interference of two quantum mechanical amplitudes. This subtle error illustrates the difficulty of writing accurately in words about physics.

[5] The explanation of "broken symmetry" on p. 198 leaves something to be desired. The comparison should be between the stable equilibrium of wine residue at the bottom of a vertically supported amphora and the neutral equilibrium of residue at an arbitrary position around the perimeter of the base of a vertical modern wine bottle. The highest point of the base of a modern wine bottle corresponds to unstable equilibrium and is an improbable place for residue to collect.

[6] Added note: This sentence was written in April 2003, 5 months before the Nobel Committee concurred in the opinion.

to this subject are contained in the lecture cited in footnote 3.) I have a two page hand-written letter from him dated February 3, 1963, explaining very politely but firmly why the effect is an artifact of an incorrect calculation. He had explained his argument orally to me a little earlier at the January meeting of the American Physical Society, bolstering it with a drawing—a circle for the Fermi sea and dots representing quasi-particles. Some months later, at the Washington meeting of the APS, he drew the same picture while explaining why Josephson was right after all. I have no recollection of understanding the second argument any more than I did the first, even though the book emphasizes that he was especially good at tailoring his arguments to the level of understanding of his audience. In spite of this experience, it is a source of regret to me that I had no further occasion to cross scientific paths with him, and I always felt proud that he did not seem to consider me a dead loss. After a seminar visit to the University of Illinois in the late 1960s, he took me to lunch, told me that I had scooped him on the calculation I had just reported (on ultrasound attenuation in "strong-coupling" superconductors) and then surprised me by talking somewhat animatedly about the rich black volcanic soil of the region. We had other conversations, including a longish one about kinetic effects in superconductors, in our swim suits on the shore of Lake Winnipesaukee during a Gordon conference I arranged in 1977. (Neither his membership in a college swim team, which I did not know about before reading the book, nor mine came up.) I also remember, while driving him to our house for dinner after a Cornell seminar, mentioning that I had a job offer, to which he said after a really quite short pause that Cornell probably attracted better graduate students, a clinching argument. I tell these stories to illustrate that though he was, to put it mildly, the opposite of garrulous, he was by no means tongue-tied. Our last conversation was about his passionate late interest, in quantum effects in charge density wave transport, where his intuition seems to have failed him again. He was outspokenly uncomplimentary about theories suggesting that the phenomena could be understood without the explicit use of quantum mechanics.

Chapters 1 and 17 have not yet been mentioned in this review. These are titled, "The question of Genius," and "True Genius and how to cultivate it." There are two theses here: (i) that Bardeen is less known to the public than other great scientists because he was a silent and unassuming man; and (ii) that his work habits and techniques can be analyzed and taught. There are elements of truth to both these claims, but their development is less successful than the rest of the book. It is hard to believe that many pages of critical analysis are worth the conclusion, "Talent appears to be based on both genetics and training." To the assertion that Bardeen was fundamentally different from other Nobel Prize winners, I can only say that there are some every year, and that those I know come in all shapes and sizes. Let me end with a true story.[7] During a conference in Gothenburg, five physicists attempted to enter a taxi; one was told by the driver that he would have to get out. As we drove

[7] Q: Could someone tell me if I am inventing or quoting the remark, "If you want to find out about people do not ask a sociologist, ask a taxi driver?".

off, with me as it happened in the front seat, I told the driver that the man he had ejected had won a Nobel Prize, to which the laconic reply was, "There are many".

Vinay Ambegaokar
Cornell University,
514A Clark Hall, Ithaca, NY 14853, USA
Email address: va14@cornell.edu

doi:10.1016/j.shpsb.2003.10.001