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Jon Butterworth. *Most Wanted Particle: The Inside Story of the Hunt for the Higgs, the Heart of the Future of Physics.* New York: Experiment, 2016. 304 pp. \$15.95 (paper), ISBN 978-1-61519-301-1.

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The Experimenter's Redress

The US high energy physics (HEP) community could have used Jon Butterworth in the early 1990s. Congress pulled funding for the Superconducting Super Collider (SSC), the machine US high energy physicists had pushed hard as the essential next step for American physics, in the face of waning public and legislative support in 1993. The discovery of the Higgs boson sent corks popping in Geneva, Switzerland, rather than in Waxahachie, Texas, where a half-built facility lies deserted, in significant part because of that cancellation. The SSC, to be sure, could boast some enthusiastic and erudite champions, but none was endowed with the common touch Butterworth, professor of physics and head of the Department of Physics and Astronomy at University College London, brings to *Most Wanted Particle*, his first-hand account of the events leading up to the 2012 discovery of the Higgs boson at CERN (Conseil Européen pour la Recherche Nucléaire). Named for the theoretical physicist—and, since 2013, Nobel laureate—Peter Higgs, the Higgs boson is most commonly described as the particle that explains why other elementary particles have mass, and so it addresses deep questions about the workings of the universe at its very smallest scales. Its discovery, it is not too early to say, is one of the century's outstanding scientific achievements.

Butterworth is a senior experimentalist in the UK delegation to the ATLAS collaboration, one of the two major detector sites at CERN's Large Hadron Collider (LHC). He offers an insider's look at the frenzied years,

months, and then days leading up to the 2012 announcement that CERN had discovered a new, Higgs-like scalar boson. (Confidence that it was *the* Higgs predicted by the standard model of particle physics, the theory that describes all the currently known elementary particles and forces, would grow with subsequent measurements and data analysis). The book was originally published in the United Kingdom in 2014 under the title *Smashing Physics: Inside the World's Biggest Experiment*. Presuming the wordplay too British by half, the publisher, The Experiment, retitled it for a US audience and commissioned a short foreword by well-known theoretical physicist and expositor extraordinaire Lisa Randall.

Entering the US market, *Most Wanted Particle* joins a catalogue brimming with similar books. High energy physicists, cosmologists, and string theorists have taken to the popularizer's role with gusto. The archetype of this genre projects a priestly mien to deliver high-minded arguments for the profound importance of knowledge of smallest physical scales. Leon Lederman, in *The God Particle: If the Universe Is the Answer, What Is the Question?* (1993), leads off his first chapter with "In the very beginning." Steven Weinberg's *Dreams of a Final Theory* (1992) proceeds under an epigraph from John Donne. Sean Carroll suggested that his *The Big Picture: On the Origins of Life, Meaning, and the Universe Itself* (2016) should be placed alongside the Gideon Bible in the world's hotel rooms.[1] Butterworth, to his credit, avoids such indul-

gences. When he says that he does not understand why people sometimes regard particle physicists as arrogant, it is credible because he himself manifestly is not. His modesty puts readers at ease and he avoids the heavy-handedness that can give similar books the feel of a hard sell.

The book opens on Butterworth shooting pool with a reporter in a kebab shop on the outskirts of Geneva. The exposition that follows has the breezy quality of a story told over a pint in a cozy London pub and one gets the impression that this is exactly how many of Butterworth's stories might have been honed. He winds freely from discussing the details of the search for the Higgs into anecdotes about nights out in the red-light district of Hamburg and digressions about the politics of publishing in large HEP collaborations, the limits of citation counts as a measure of merit, and the importance of open access. The asides have the effect of breaking up the sometimes-challenging technical sections, making the book approachable for most audiences. And despite the fact that most of these digressions are adapted from the blog Butterworth has maintained on *The Guardian* website since late 2009, the ease with which he transitions in and out of his asides is disarming.[2]

As an experimentalist, Butterworth is more facile describing laboratory culture and procedure than theoretical concepts. As an exercise in HEP didacticism, the book succeeds up to a point. Lay readers can come away from it with a rough-and-ready understanding of the field's basic terminology and aims, but the exposition does not always build in such a way that earlier concepts make clear more complicated ones later. This is less the fault of Butterworth's writing than it is the limitations of the format for dealing with some tricky technical content. It is also just one of the book's two principle aims, the second being to convey a sense of what it is like to be an experimental high energy physicist. Butterworth runs the table on that particular rack. His avuncular, free-wheeling style proves perfectly adapted to ushering readers inside the world of a practicing high energy experimentalist and gives him the chance to expound on some of his own views on the profession.

Butterworth's discussions of how data is produced and processed in large HEP experiments are among the book's most edifying sections. The practices surrounding experimental inquiry are often flattened into two-dimensional caricatures in both news reporting and popular work written by theorists. Here, readers get a fuller account of how an experiment is proposed and vetted,

data gathered, inferences drawn and debated, and conclusions cross-referenced and checked before a paper is deemed ready for publication. Butterworth gives honest and personal testimony to the extent emotional involvement in a study can skew researchers' judgments, and describes the checks and balances that are in place to account for such potential bias. These details, more so than even the clearest explanation of theoretical concepts, give a powerful answer to the persistent question of why the lay public should place confidence in the knowledge produced in facilities like CERN.

Two notable themes develop alongside the story of the Higgs discovery, kicked along by Butterworth's periodic digressions on the state of HEP. The first is the importance of doing science in public. Butterworth has become something of a media personality in Britain, and one gets the sense from this book that his outreach flows from a genuine sense of responsibility to connect with the taxpayers who support his work. I read *Most Wanted Particle* over the weekend of the April 2017 Science March, when a series of demonstrations in support of science and its role in policymaking descended on city halls, capitol buildings, and monuments of note from Washington, DC, to Berlin. In contrast to the frequently cack-handed political messaging of the science marchers (one sign I saw this weekend read, "By denying science, you are advertising your stupidity"), Butterworth is sensitive to the tricky complexities of communicating science to non-scientists, conscious that HEP competes for attention and resources with other worthy activities, and capable of promoting his own field without denigrating others. Rather than proceeding from the presumption that a particular scientific endeavor is important and suggesting that those who do not get it are stupid or obtuse, Butterworth is more willing than most to meet the public and policymakers where they are and to state simply why *he* finds the work he does compelling. That personal touch is lacking in the more common attempts to sell HEP by appealing to the transcendent and pseudo-spiritual contributions it can make to human knowledge.

The second theme that crops up repeatedly is Butterworth's healthy skepticism of supersymmetry (SUSY) and string theory, the two most prevalent brands of what is known as "beyond the standard model" speculation. These theoretical enterprises propose menageries of new particles (at energies that always seem to be just beyond the range of the currently most powerful accelerators), extra dimensions, and an infinity of parallel universes to try to address nagging incompatibilities and aesthetic shortcomings in the standard model. SUSY and string

theory have gone far, professionally speaking, on the considerable prestige and influence HEP theory enjoys, even as they have become increasingly unmoored from experimental data, and so increasingly distant from time-honored norms of scientific practice.[3] They have also enjoyed outsized popular success. Books about string theory have been reliably solid since Brian Greene's 1999 bestseller *The Elegant Universe*, which was adapted into a NOVA series on PBS. SUSY and the multiverse took center stage in the 2013 documentary *Particle Fever*, an account of the buildup to the Higgs announcement that placed a large portion of the action at the Institute for Advanced Study in Princeton, New Jersey, a string theory hub. Butterworth is having none of it, writing, "I'm a lot more interested in trying to understand this universe than speculating about multiverses" (p. 272). Such a skeptical perspective is badly needed in the popular science literature, and Butterworth's it's-the-data-stupid pragmatism is just the vehicle for it.

If you only read one book about the Higgs hunt, read this one. Science popularization in general, and HEP popularization in particular, tends to be dominated by theorists, whose time is less consumed by the jet setting and project meetings, which this book so vividly

describes, that come with membership in an experimental collaboration of three thousand people. The more grounded perspective of the experimentalist is therefore rarely available to popular audiences, resulting in a stilted view of the current state and future aims of HEP. Butterworth's hard-headed practicality and beguiling aw-shucks humility are a welcome redress for the common vices of HEP popularization.

Notes

[1]. On Carroll's suggestion, see Michael Brooks, "It's Mind-Blowing What Our Puny Brains Can Do," *New Scientist* (April 13, 2016): <https://www.newscientist.com/article/mg23030690-200-its-mindblowing-what-our-puny-brains-can-do/>.

[2]. Jon Butterworth, *Life and Physics* (blog), *The Guardian*, <https://www.theguardian.com/science/life-and-physics>.

[3]. Nancy Cartwright and Roman Frigg, "String Theory under Scrutiny," *Physics World* 20, no. 9 (2007): 14–15. Some philosophers, however, have argued that science can and should become post-empirical. See Richard Dawid, *String Theory and the Scientific Method* (Cambridge: Cambridge University Press, 2013).

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