



## **Jimena Canales, *Bedeveled: a shadow history of demons in science*, Princeton: Princeton University Press, 2020**

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For Jimena Canales, a contradiction lies at the heart of science: the more scientists try to understand the world by “reducing it to its material essentials, the more they end up relying on imaginary creatures” (p. 316), namely ‘scientific demons’. To understand and dispel this contradiction, Canales takes her reader through four centuries of scientific developments, roughly from Descartes until today. I would like to emphasize some of the perspectives taken by Canales to tell such a story. First, Canales’ historical analysis of science systematically refers to, and is enriched by, cultural factors, such as literature and technology. Second, she shows that the history of science could be told not just through what is discovered, but also through what remains concealed, the limits of science. These limits for Canales are to be found in the births and lives of ‘scientific demons’, and in how scientists—as well as philosophers, historians, sociologists, science fiction writers, and many others—engaged with them, mainly by means of thought experiments. Indeed, many scientific thought experiments refer to fantastic demons, beings, ghosts, or intelligences endowed with certain faculties. And even though the philosophical literature on scientific thought experiments has been growing exponentially since the early 1990’s and has generated a huge debate, little attention has been given to the function of such demons, their nature, their evolution, and how they interacted with each other.

In *Bedeveled*, Canales provides a detailed study of demons as a scientific “term of art” (p. 304). She shows that demons are taken seriously in science; they are not just heuristic additions. On the contrary, Canales defends that their “status within nature is akin to that of many other tools of thought [...] such as concepts, numbers, classes, and categories”. However, and in contrast to these other tools of thought, which are “formal or abstract”, these demons, Canales claims, are

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“colorful and concrete. They have names, proclivities, and personalities” (p. 301). While few arguments are explicitly provided to defend and clarify such a claim, her book offers a thorough historical analysis of demons and their role in scientific and technological change and progress. These include famous examples, such as Descartes’ trickster demon that could manipulate our senses, Laplace’s demon that could manipulate huge amounts of data, and Maxwell’s demon that could manipulate molecules by directing them, as well as lesser-known and more recent demons from biology, quantum mechanics, computer science, and economics. Throughout the chapters, these different demons are linked together and explored by scientists from different disciplines. For instance, Laplace’s and Maxwell’s demons are presented first in their original contexts, Newtonian mechanics and thermodynamics respectively, in chapters 2 and 3. Later they are reconsidered in the context of quantum mechanics (chapter 6), biology and the origin of life (chapter 9), and even in (global) economics (chapter 10).

As mentioned above, Canales’ historical analysis of science systematically refers to and is enriched by cultural factors such as literature and technology. For instance, through the influence of literary fiction writers on Descartes’ thinking, we understand better his philosophy and why he was weary of the dangers of reading novels. In particular, the reader learns that Descartes’s mind–body dualism, as well as the demon that led to it, arose in relation to Cervantes’ *Don Quixote*. The influence that this novel exerted was made possible by the technological advances during Descartes’ era, such as the printing press and early theatre, which blurred the boundary between reality and spectacle—just like Descartes’s demon. Without printing technologies, novels such as *Don Quixote* would not have circulated. This particular novel seems to have concerned Descartes greatly; it showed him how “easily an unreal world had supplanted the hero’s sense of reality” (p. 18). Indeed, Canales tells us that “Descartes warned against the dangers of reading novels such as those that fascinated Quixote and a growing public”. He thought that “[i]f Don Quixote was knocked out of his rocker by reading too many chivalric stories, other readers could suffer similar fate by following his steps” (p. 18). More generally, the connection of science to technology is a theme that runs throughout this book. Canales explores some roads that took us from established scientific theories and technologies to demons, and from those to new scientific theorizing and new advances in technology. The cycle starts again, generating new demons, which cohabit and interact with previous ones and—together with real experiments—generate new knowledge and technological advances along the way.

These advances in science and technology are portrayed as quests to make actual what was once just a figment of a scientist’s imagination, a clever way to illustrate or to defeat some scientific theory. Canales’ analysis is partly driven by questions such as: how does the imagination become, or leads to, something actual? If the science of today is the technology of tomorrow, then “what comes before both?” (p. 13). Her answer is that scientists’ imagination, particularly in the form of demons, precedes both. Demons are not only born from established scientific theories and existing technologies, but they also direct future research programs and shape future technologies. Demons are found “at the cutting edge of science and technology” (p. 305).

For instance, Laplace's 'law-abiding demon' referred to an imaginary intelligence (later dubbed a demon) that knew the deterministic laws of motion and initial state of every particle in the world. Such an intelligence could, Laplace argued, predict the future states of the physical world and retrodict its past states with arbitrary precision. Canales nicely retraces the influence that Laplace's demon exerted in the development of many technologies, in particular computers, starting with Babbage and Lovelace in the nineteenth century (see chapter 3).

Another example is Maxwell's 'law breaker demon' that could manipulate a massless door in such a way that it could separate fast from slow molecules inside a vessel at uniform temperature. If successful, Maxwell's demon could create a temperature difference without expenditure of work, in contradiction to the second law of thermodynamics. This temperature difference could then be used to run a heat engine, for instance. Although Maxwell's demon has already received a great deal of historical, scientific, and philosophical attention, the reader still discovers many things about its life in several chapters of the book. For instance, Canales explains how it became the inspiration for building more efficient refrigerators by Einstein and Szilard in the 1930's, who submitted 37 patent applications to this end and sold some to industrials such as Electrolux, before they both immigrated to the United States following the rise of Nazi Germany. In thinking about the theoretical as well as the practical aspects of Maxwell's demon and the (im)possibility of building a perpetual motion machine, new technologies were conceived and produced. Today we are still in the process of reducing dissipation and maximizing the efficiency of our engines, especially our computers. Interestingly, the thermodynamics of computation as a theoretical field arose from attempts to exorcise Maxwell's demon, at least in the form that Szilard gave it in 1929.

Finally, with regards to the quantum 'law bender demons', Canales tells the story that goes from Compton's lesser-known quantum demon, and many others, to the building of the atomic bomb (chapter 6). These demons, like most others discussed in the book, are analysed and linked to the technologies they were born from as well as to the technologies they made possible.

Canales suggests that the narrative she presents in her book has crucial ethical implications. When a technology becomes actual, it is usually too late to regulate its use; we only have a few levers at our disposal. Unfortunately, many of the examples she discusses in her book justify her fears, from the atomic bomb to the recent rise of social media with its spread of fake news. If ethical responsibility starts with our imagination, then an argument could be made that we should be morally accountable for damages done by imagined, not yet actual technology. The author's point, I take it, is that by taking scientific demons seriously we might be able to imagine what our future technology could look like.

In her conclusion and postscript, Canales tackles some issues in general philosophy of science. Her discussion is understandably brief, though a bit outdated. She briefly contrasts Reichenbach and the logical positivists to Meinong and Vaihinger's fictionalism, and refers to Kuhn, Feyerabend, and Popper. Regrettably, the last three to four decades of research in the philosophy of scientific thought experiments and imagination are simply ignored. In addition, her analyses are sometimes misleading. For example, Kuhn is wrongly portrayed as a philosopher who "simply

defenestrated” thought experiments and “without giving them a chance” claimed that thought experiments “can teach nothing about the world” (p. 319). Maybe Canales only meant to refer to Kuhn’s treatment of thought experiments that refer to demons, which could be argued for, but surely Kuhn did not defenestrate *all* thought experiments. On the contrary, the contemporary literature on the subject almost always refers to Kuhn’s paper on thought experiments (Kuhn, Thomas, 1964, ‘A function for thought experiments’, reprinted in *The Essential Tension*, 1977, Chicago: University of Chicago Press, pp. 240–265) as a starting point. That said, one cannot say it all in one book.

Overall, philosophers of science interested in thought experiments, the role of imagination and fiction in science, scientific change, understanding, explanation, and the role of idealisations and abstractions in science—to name just few topics—will find in *Bedeviled* a welcome, in-depth historical investigation of the many functions that demons have played and continue to play in science and technology.

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