The Invention of Science: A New History of the Scientific Revolution

By David Wootton

Harper, 2015. Pp. xiv + 769. ISBN 978-0-06-175952-9 $35 (hbk.)

Allen Lane, Penguin Random House, 2015. Pp. 784. ISBN-10: 1846142105; ISBN-13 978-1846142109 BP30 (hdbk.)

The Invention of Science conveys in its title its most basic and striking contention. Science, as we understand it, gained its distinctive features during an epistemological shift that took place between the late 16th and 17th centuries. Speculation and inquiry concerning the natural world after this period differ qualitatively from that before it. How and why occupy the bulk of the work. Wootton also includes philosophical and historiographical arguments that may strike some readers as ancillary, but which spring from the same conviction as the rest of the text: the Scientific Revolution is the moment when the western mind opens itself to engagement with Nature on her own terms.

The book's depth of research and complexity of analysis closely accompany an overarching chronological organization. The same page may discuss Proclus's beliefs about the history of mathematics and note the Dutch introduction of Cartesian teaching into universities (p. 68); even the most sympathetic and attentive reader will be unable to predict the appearance of Wittgenstein's *Tractatus* only two paragraphs after a mention of Regiomantus's regard for Archimedes (p. 252). (These examples are drawn at random.) Nevertheless, the narrative center of gravity proceeds along a timeline roughly from Columbus's landing in the Americas to the early Industrial Revolution.

Columbus discovered a new landmass; of course other cultures had arrived there before, but his encounter was with something wholly unexpected. The concept of coming across the entirely unexpected and new had no label in 1492, except for the Portuguese 'discobrir' (p. 57). Before the Scientific Revolution, history was regarded as a series of "repetitions and vicissitudes" (p. 65; R. P. Crease, *Wall Street Journal (Online)*, 11 December 2015) also cites this). The novel and unavoidable truth of the existence of the Americas – while not an event of the Scientific Revolution proper - catalyzed the broader development of an intellectual category, which Wootton describes in Part One's Chapter 3, entitled 'Inventing Discovery'. "Discovery is not in itself a scientific idea but rather an idea that is foundational for science: we might call it a metascientific idea" (p. 103). This illustrates the first of many related conceptual innovations that together constitute the emergence of modern scientific understanding. Wootton provides similar treatments (Part Three) of the historical events that led to the reification of facts and laws, and to the creation of a competitive intellectual community united by shared expectations of experimentation and progress. This reveals our own world to us: "[i]t has now become difficult to think our way back into a world where people did not speak of facts, hypotheses and theories, where knowledge was not grounded in evidence, where nature did not have laws. The Scientific Revolution has become almost invisible simply because it has been so astonishingly successful" (p. 571).

Situated between discovery and fact – that is, in Part Two – comes mathematics. (After all, the period in question – from 1572, Brahe's observation of a nova, to 1704, Newton's

publication of his *Opticks* – is marked by developments in astronomy and physics, not chemistry, and still less biology.) In Part Two's Chapter 5, Wootton sketches diverse cultural influences that bring about and characterize the 'mathematization of the world'. Bookkeeping, not unique to the Scientific Revolution, becomes for Galileo an analogy for defending mathematical idealizations. Just as the bookkeeper rightly deals in abstractions only imperfectly realized by a business's packaged materials, so Galileo's law of fall – formulated, we learn later, in hopes of revolutionizing gunnery (p. 479) - abstractly describes the behavior of falling bodies in a way realized only imperfectly by concrete objects with wind resistance. While Giotto capably incorporated perspective in his art, its presence is not an intrinsic end, but a device of occasional artistic utility. The interpreter is bending the world to suit his purposes. Later, Brunelleschi represents the world with faithful attention to perspective. Somewhat later still, Masaccio represents even imaginary space this way. The observer is recognizing the geometrical nature of the visual world. Such changes constitute a move from a qualitative to a quantitative worldview. As later chapters discuss, this new epistemological attitude converges with the arrival of the printing press, giving rise to an intrepid and competitive scientific community.

As noted toward the close of Part Two, Protagoras's claim that 'man is the measure of all things' once held true in the sense that an ell was the length of a forearm, and the Roman mile was a thousand paces. The Scientific Revolution does not see this tendency disappear altogether - even Newton considered the heat of the blood as a fixed point – but the mathematization of the world during this period makes possible later objective measurements such as the metric system. Of course, Protagoras was asserting his relativism, but this only makes the allusion denser: the development of modern science poses a new challenge to relativism.

To explain the Scientific Revolution as a turn toward a progressive interrogation of nature, as Wootton does, implies an anti-relativistic position. Wootton gives Brahe's 1572 observation of a nova as the start of the Scientific Revolution, instead of the more familiar date (which Kuhn preferred) of Copernican's 1543 publication of the theory of heliocentrism. Brahe's observation had a more immediate impact upon astronomy, but the significance runs deeper. Like Columbus, Brahe came across a novel phenomenon not anticipated by or explicable by reference to accepted theories. By contrast, for all his deviation from the astronomy of the day, Copernicus, like his Aristotelian contemporaries, offered a model of celestial organization. Copernicus contributed an advanced cartography, but the nova counts as a discovery. The news catalyzed the astronomical community to attempt and publish measurements of the nova's parallax, and "[b]y 1588 astronomy had become concerned with the organization of the heavens in three dimensions, not just in two." (p. 199) Many thematic elements converge here: discovery, the printing press, competitive experimental community, and mathematization. Moreover, they do not just converge; they converge on something; they have found fertile territory. "This story is a fine example of…path dependency[:…] astronomers embarked on a path that could only lead…to decisive evidence" contrary to Aristotelian astronomy. (p. 194) The invention of science was not a fated event that would have played out no matter the circumstances, but the particular conditions (of discovery, printing, etc.) that Wootton identifies mark and generate advances. Because this characterization admits genuine advancement, it commits to some form of realism.

Wootton renders these philosophical commitments transparent: "This book has therefore been deliberately written in opposition to certain conventions [Wootton directly identifies these as relativism and postmodernism] which have become established in 'these postmodern days'."

(p. 554) Whether one agrees that Wootton's targets are among "today's most influential historians of science" (Lewens, *The Spectator*, 16 January 2016) or thinks Wootton "is still engaged in debates that most historians of science have left behind" (Fara, *Literary Review*, October 2015; Breen (*The Chronicle of Higher Education*, 10 January 2016) dismissively refers to "these forays into academic squabbling"), such explication discourages further relativism in the field, and establishes the book's position unambiguously for future readers, whatever historiographical trends come to pass. Throughout, and especially in the Conclusion chapters, the author distances himself from the position that "science is not a cross-cultural form of knowledge but a local consensus, specific to a particular community" (p. 528). He locates a source of such relativism in the history of science literature's tendency to endorse a relativistic interpretation of Wittgenstein, and provides a detailed alternative reading (pp. 577-80). Wootton also argues for a moderate interpretation of the Duhem-Quine thesis "in which evidence and culture each have a part to play in the construction of scientific beliefs" (p. 516). Cultural factors did enable the adoption of Newtonian theory in England and stifle it in France, but those factors belong "first and foremost, [to] the culture of science itself" (ibid.). Too great an emphasis on underdetermination can mischaracterize pivotal scientific moments: "once their existence [i.e. of the phases of Venus] was acknowledged, the conclusion that Venus orbited the Sun was inescapable" (p. 515).

This looks dangerously like begging the question: perhaps the apparent inescapability of the heliocentric orbit of Venus comes from a failure of imagination, and the suggestion of path-dependency is ad hoc. But Wootton's articulation of his case includes a cautious situation with respect to realism. He raises Putnam's 'no-miracles' argument (that science could only achieve the success it has, barring miracles, if it 'gets at the truth') expressly in order to critique it, citing Laudan's observation that scientific theories with predictive application have often come to be regarded as false (p. 568). Making a complementary argument, Wootton claims "explaining science in terms of common sense is simply to go round in a circle" (529). Rather, "we must acknowledge the dangers of arguing from universal standards of human rationality" in our account of the history of science. (p. 537) The charge of scientism does not fit Wootton's position. He willingly accepts that the intellectual tools distinctive of modern science "are contingent, fallible, imperfect; yet they make possible reliable and robust knowledge" (p. 565). Since the Scientific Revolution, particular scientific claims on knowledge have "changed beyond all recognition", but the Scientific Revolution's "conceptual framework has proved remarkably stable" (p. 570). For this reason, Wootton, unlike Kuhn, writes of the one Scientific Revolution, not multiple revolutions within science (p. 18). When understood this way, there is nothing 'curious' about "Wootton's insistence that the tracks for modern science were laid down in the 17th century" (contra Daston, *theguardian.com*, 28 November 2015) because, in Wootton's words, "it seems virtually certain that future scientists will still be talking about facts and theories, experiments and hypotheses" (p. 570).

Understood this way, Wootton's case also survives the charge of Whiggishness (the tendency of some historical accounts to present events as inevitably proceeding toward a goal, a charge levelled at Wootton by Breen, *The Chronicle of Higher Education*, 10 January 2016). Chapter 16 distinguishes retrospective history from Whiggish history: retrospective history is unavoidable (how else could historians even select worthy topics?) and indispensable (careful hindsight allows us to examine causal relations). Throughout, Wootton presents the invention of science as dependent upon historically contingent events; his moderate realism only implies that

the durability of the Scientific Revolution's epistemological innovations largely results from their production of genuine advancements. Wootton (p. 541) cites Kuhn: "Scientific development is like Darwinian evolution, a process driven from behind rather than pulled toward some fixed goal toward which it grows ever closer" (Kuhn, *The Trouble with the Historical Philosophy of Science*, Department of the History of Science, Harvard University, 1992, p. 14). Precisely this attitude motivates Wootton's historiographical approach.

The light Wootton shines on the origins and nature of modern science casts some shade. This is understandable, since the innovations of the Scientific Revolution depended upon a process of often explicit rejection of Aristotelian astronomy and physics, then espoused by natural philosophers. At points, though, the narrative obscures too much. For example, Wootton writes: "the new science was about one thing more than anything else, and that is the triumph of experience over philosophy" (p. 567). This puts the point too crudely: it was a triumph of a new attitude that accepted experience as a source of new knowledge, over a medieval form of Aristotelian natural philosophy that compelled interpretation of experience as conforming to received knowledge. Overall, this is the case that Wootton is making, but too often the language can be construed as denigrating philosophy in general. In some cases, the tension is apparent. In the same paragraph (p. 209), Wootton (fairly) describes the revolt of mathematicians against the philosophy taught in universities, contrasting it with the metaphysics that arises in the time of Galileo, Descartes, and Newton. The hasty reader might not notice that metaphysics is a branch of philosophy and that Descartes was a philosopher. Wootton tends to use the labels of 'philosophy' and 'philosopher' to apply only to an increasingly outmoded way of thought. Elsewhere, Wootton writes of scientists "freeing themselves from the philosophers' preoccupation with truth" as knowledge of substance, following this immediately with "Locke and Newton insisted that we could have no knowledge of substance" (p. 397). Again, Locke was a philosopher, and this position concerning knowledge and substance is a philosophical one. Hobbes, Descartes, and Locke all feature regularly in the account; sometimes their positions reflect the modern scientific worldview, and sometimes they stand at odds with it, but the same holds true even for Newton. While these distinctions often get lost as Wootton makes his case, this does not reflect some deeper disciplinary bias, as Wootton announces early: "Magic was replaced by science, myth by fact, the philosophy and science of ancient Greece by something that is still recognizably our philosophy and science…" (p. 11).

This expression of the thesis courts a related but different controversy. Even if Wootton is not denigrating philosophy, is he underestimating the role of ancient or medieval thinkers in the invention of science? Daston (*theguardian.com*, 28 November 2015) criticizes how "Wootton is committed to making the scientific revolution…discontinuous with all that came before…." Wootton at least acknowledges that others argue for continuity (p. 18). He also cites Regiomantus's claim that Aristotle "would not be able to make sense" of what medieval universities taught in his name, avoiding a problematic conflation (p. 187). For the most part, though, Wootton prefers to engage the issue not by raising and responding explicitly to claims of continuity, but by emphasizing the positive case for epistemological change. This approach may leave room for debate, although it may prove a debate over emphasis. After all, near the close of an appendix section dedicated to this question, Wootton writes: "It is no part of my argument to dispute the claim that we only have the sciences we have because Aristotle and the medieval philosophers opened up certain lines of inquiry" (p. 575).

The range on display here is exhilarating almost regardless of the reader's particular interests. In service of the point that concepts can exist without words (a scrupulous qualification, given the prominence Wootton assigns to the rise of words such as 'discovery' and 'fact'), Wootton describes the implicit taxonomy of clouds that predated the usage of 'cirrus', 'nimbus' and so on, quoting Robert Hooke (London, 1705): "'What is the reason of the various Figure of the Clouds, undulated, hairy, crisped, coyled, confus'd, and the like?'" (p. 47). Clearing up a matter of academic credit, he notes that MacIntyre mistakenly criticizes Kuhn for not admitting his debt to Polanyi; Kuhn acknowledges Polanyi in all editions of *The Structure of Scientific Revolutions* (Chicago, 1962/1970/1996). Perhaps we can forgive MacIntyre, though, as "the acknowledgement is overlooked in the index to the third and later editions" (585). We should be nonetheless grateful that Wootton goes to such lengths in explaining *The Invention of Science.*

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