JEMS 12 (2023), 1: 9–31
https://doi.org/10.5840/jems20231211

Introduction: Science Beyond the Enlightenment

Michael Bycroft
History Department, University of Warwick,
Faculty of Arts Building, University Road, Coventry,
United Kingdom, CV4 7EQ
m.bycroft@warwick.ac.uk

Abstract: The eighteenth century has long been a problem for historians of science. The century suffers from an apparent lack of towering individuals and unifying theories, as Geoffrey Cantor observed in an essay published in 1982. Much good work has been done in the forty years since then, most of it aimed at locating science in the Enlightenment. But the Enlightenment is just one of several themes that can help to make sense of eighteenth-century science as a whole. The other themes may be summarised as Classification, the First Scientific Revolution, the Second Scientific Revolution, Discipline Formation, and Natural Philosophy. The articles in this special issue are relevant to all six themes, as a summary of those articles will show. This essay ends with suggestions for future research on eighteenth-century science. The upshot is that we need to go beyond the Enlightenment by considering the five other themes discussed here and by considering events in general history other than the Enlightenment.

Keywords: science, Enlightenment, Geoffrey Cantor, the Scientific Revolution, the Second Scientific Revolution, Age of Revolutions, General Crisis, disciplines, natural philosophy

"It is difficult to find any master thesis for the eighteenth century."[1] So wrote the historian of science Geoffrey Cantor in a penetrating essay published in 1982. Cantor explained that the eighteenth century was a "grey area on

[1] Geoffrey Cantor, "Essay Review: The Eighteenth Century Problem: *The Ferment of Knowledge: Studies in the Historiography of Eighteenth Century Science*," *History of Science* 20 (1982), pp. 44-63, on p. 59.

the historical chart," one that "seems devoid of both giants and key ideas." The seventeenth century had its Galileos and Newtons, the nineteenth century its general theories of life and the universe; the eighteenth century seemed to have neither. The century was poorly served by textbooks, with no introductory survey of its own and little exposure in general works on the history of science. Undergraduate teaching on the period was equally patchy: "small spoonfuls of electricity, chemistry, heat theory and the theory of generation stirred in with a pinch of institutional history topped with a healthy helping of science and the French Revolution."[2] The problem was not the lack of research on the period—there was plenty of that in scholarly journals—but the lack of a cogent synthesis. Hence the title of Cantor's essay: "the eighteenth century problem."

It may appear that the problem has been solved. Cantor's essay was itself a sign that, as he put it, "attitudes towards the eighteenth century have begun to change."[3] The essay was a review of *The Ferment of Knowledge: Studies in the Historiography of Eighteenth Century Science*, a collection published in 1980 to address the lack of "strong interpretation" of the century, to quote the editors of the volume, G. S. Rousseau and Roy Porter.[4] Since then, strong interpretations of the period have appeared every decade or so. *The Quantifying Spirit in the 18th Century*, edited by Tore Frängsmyr, John Heilbron, and Robin Rider, came out in 1990.[5] There was a burst of activity around 2000, with the publication of no fewer than four edited collections and one encyclopaedia on eighteenth-century science.[6] A decade later, in 2011, Jan Golinski surveyed the latest work on the topic.[7] Recent essay collections on particular themes (travel, material culture, disciplines, connoisseurship) show

[2] Ibid.

[3] Ibid.

[4] G. S. Rousseau and Roy Porter, "Introduction," in G. S. Rousseau and Roy Porter (eds.), *The Ferment of Knowledge: Studies in the Historiography of Eighteenth Century Science*, Cambridge: Cambridge University Press, 1980, pp. 1-7, on p. 3.

[5] Tore Frängsmyr, John Heilbron, and Robin Rider (eds.), *The Quantifying Spirit in the 18th Century*, Berkeley, CA: University of California Press, 1990.

[6] William Clark, Jan Golinski, and Simon Schaffer (eds.), *The Sciences in Enlightened Europe*, Chicago, IL: Chicago University Press, 1999. Kostas Gavroglu (ed.), *The Sciences in the European Periphery During the Enlightenment*, Springer: Dordrecht, 1999. Roy Porter (ed.), *The Cambridge History of Science, vol. 4: Eighteenth Century Science*, Cambridge: Cambridge University Press, 2003. William E. Burns, *Science in the Enlightenment: An Encyclopedia*, Santa Barbara: ABC-CLIO, 2003. Lorraine Daston and Gianna Pomata (eds.), *The Faces of Nature in Enlightenment Europe*, Berlin: BWV-Berliner Wissenschafts-Verlag, 2003.

[7] Jan Golinski, "Science *in* the Enlightenment, Revisited," *History of Science* 49 (2011), pp. 217-31. Cf. idem, "Science *in* the Enlightenment," *History of Science* 24 (1986), pp. 411-24.

the fertility of the field.[8] General histories of science have flowed from the presses in the meantime, thereby providing the "big picture" and "generalist's vision" that the field seemed to lack around the turn of the millennium.[9] And the new generation of big pictures has more room for the eighteenth century than older ones.[10] "The eighteenth century ... has moved toward the center from the periphery of the history of science," as Anita Guerrini put it in 2016.[11] This is not because "giants" and "key ideas" have been found but because giants and ideas are no longer the main organising principles in these histories. Institutions, geopolitics, and ways of knowing have taken the place of towering individuals and unifying theories. In short, much good work has been done.

Why then this special issue? Partly because good work continues to be done. This work is in need of synthesis and juxtaposition, in the present decade as in early ones. In addition, there are some significant ways in which eighteenth-century science remains a problem. Cantor's essay has been sidelined in subsequent discussions of eighteenth-century science.[12] As a result, some of his specific points have been overlooked. One is the lack of a specialised textbook. In 2023, as in 1982, there is no up-to-date synthetic monograph on

[8] Luisa Calè and Adriana Craciun (eds.), *The Disorder of Things*, special issue of *Eighteenth-Century Studies* 45, no. 1 (2011). Adriana Craciun and Simon Schaffer (eds.), *The Material Cultures of Enlightenment Arts and Sciences*, London: Palgrave Macmillan, 2016. Adriana Craciun and Mary Terrall (eds.), *Curious Encounters: Voyaging, Collecting, and Making Knowledge in the Long Eighteenth Century*, Toronto: University of Toronto Press, 2019. Michael Bycroft and Alexander Wragge-Morley (eds.), *Science and Connoisseurship in the European Enlightenment*, special issue of *History of Science* 60, no. 4 (2022).

[9] James A. Secord, "Introduction," *British Journal of the History of Science* 26, no. 4 (1993), pp. 387-9. Robert Kohler, "A Generalist's Vision," *Isis* 96, no. 2 (2005), pp. 224-9.

[10] Here are some examples. James McClellan and Harold Dorn, *Science and Technology in World History*, 3rd edn., Baltimore, MA: Johns Hopkins University Press, 2015 [1999]. John Pickstone, *Ways of Knowing: A New History of Science, Technology and Medicine*, Manchester: Manchester University Press, 2000. Peter Bowler and Iwan Rhys Morus, *Making Modern Science: A Historical Survey*, Chicago, IL: University of Chicago Press, 2005. Peter Dear, *The Intelligibility of Nature: How Science Makes Sense of the World*, Chicago, IL: Chicago University Press, 2006. Patricia Fara, *Science: A Four Thousand Year History*, Oxford: Oxford University Press, 2009. Stephen Gaukroger, *The Collapse of Mechanism and the Rise of Sensibility: Science and the Shaping of Modernity, 1680-1760*, Oxford: Oxford University Press, 2011. David Knight, *Voyaging in Strange Seas: the Great Revolution in Science*, London: Yale University Press, 2014. James Poskett, *Horizons: A Global History of Science*, London: Penguin, 2022.

[11] Anita Guerrini, "The Material Turn in the History of Life Science," *Literature Compass* 13, no. 7 (2016), pp. 469-80, on p. 470.

[12] Cantor's essay is not mentioned in Golinski, "Science *in* the Enlightenment"; nor in William Clark, Jan Golinski and Simon Schaffer, "Introduction," in their *The Sciences in Enlightened Europe*, Chicago, IL: Chicago University Press, 1999, pp. 3-40; nor in Roy Porter, "Introduction," in Porter, *Eighteenth Century Science*, pp. 1-20. It is mentioned briefly in Golinski, "Science *in* the Enlightenment, Revisited," p. 217.

eighteenth-century science. There is no successor to Thomas Hankins' *Science and Enlightenment*, first published in 1985 and now showing its age. The edited collections and reference works on the century are more comprehensive than Hankins' book but less cohesive. The new big pictures enrich Hankins' account in some respects but impoverish it in others, usually by omitting some of the intellectual developments that Hankins covered so thoroughly.[13] Textbooks aside, Cantor identified a particular problem with the eighteenth century that has been inadequately addressed since then, namely the identity and trajectory of natural philosophy. In addition, the irenic spirit of Cantor's review is worth reviving. Cantor was writing in the midst of heated debates between "internalists" and "externalists"—roughly speaking, between intellectual historians of science and social historians of science.[14] Yet he gave a sympathetic summary of the various interpretations of eighteenth-century science, noted the tensions between those interpretations, and tried to harmonise them. The number of interpretations has only increased in the forty years since then. The tensions between them, and the benefits of harmonisation, have grown accordingly.

I therefore begin this introductory essay with a survey of current interpretations of eighteenth-century science. I then outline the articles in this special issue with the survey in mind, before ending with some suggestions for future solutions to the eighteenth-century problem. The upshot is that the Enlightenment, often proposed as a solution to eighteenth-century science, is also part of the problem.

Six Master Theses

What are the master theses about eighteenth-century science that have some currency in the 2020s? The obvious one, the one that has been developed most explicitly and extensively since 1982, is the Enlightenment. This was the ostensible theme of Hankins' 1985 textbook. As Jan Golinski pointed out at the time, the book had less to say about the Enlightenment than the title would suggest. In his review of the book, pointedly titled "Science *in* the Enlightenment," Golinski made the case for locating eighteenth-century science more squarely in the social and cultural context of the period.[15] This proposal was not immediately followed up. As late as 1998, Thomas Broman lamented that

[13] For example, one would not guess from Fara, *Science*, that rational mechanics was a major eighteenth-century research programme; nor from Poskett, *Horizons*, that there was a chemical revolution in the same century. Cf. Hankins, *Science and Enlightenment*, chaps. 2 and 4.

[14] See Rousseau and Porter, "Introduction," pp. 1-2; Cantor, "Eighteenth Century Problem," pp. 56-7.

[15] Golinski, "Science *in* the Enlightenment."

"those of us who write about this period have done little to formulate a new vision of how it fits into the larger narrative of history of science."[16] Broman himself spelled out a "new vision," arguing that the eighteenth century was the key period for the rise of natural science as a public authority.[17] The public place of science was also the theme of *The Sciences in Enlightened Europe*, a collection published in 1999 and edited by William Clark, Jan Golinski, and Simon Schaffer. Noting the lack of a unified account of eighteenth-century science, the editors made the unity of the Enlightenment their topic. They aimed to show "how concrete forces of unification were operating in conjunction with those of local differentiation," where the "concrete forces" in question included states, instruments, the public sphere, and local resistance to all three.[18] Golinski expanded on these themes in a 2011 essay, arguing that "a focus on the Enlightenment at the peripheries can enhance our sense of the dynamics of the movement as a whole."[19] Meanwhile, the fourth volume of the *Cambridge History of Science*, dedicated to the eighteenth century, appeared in 2003. Understandably enough for a collectively written work of reference, there was no master thesis in this volume. But the Enlightenment was front and centre in the editor's introduction, which opened with a variant of Immanuel Kant's famous question: "What is Enlightenment *science*?"[20]

The Enlightenment also looms large in the new generation of general histories of science. Already in 1999, James McClellan and Harold Dorn included a section called "Science and the Enlightenment" in their *Science and Technology in World History*.[21] Ten years later, Patricia Fara gave ample room to the eighteenth century in her four-thousand-year history of science. In six succinct chapters, Fara pursued the now-familiar idea that science became a public force in the Age of Reason: "for anyone interested in appreciating how science has become so powerful, then this is the all-important period."[22] More recently, David Knight and James Poskett have organised their eighteenth-century material around the notion of the Enlightenment.[23] And the Enlightenment makes

[16] Thomas Broman, "The Habermasian Public Sphere and 'Science in the Enlightenment,'" *History of Science* 37 (1998), pp. 124-49, on p. 123. Cf. Peter Dear's contemporaneous remark about the eighteenth century as the "Dark Continent of the history of science": Peter Dear, "The Mathematical Principles of Natural Philosophy: Toward a Heuristic Narrative for the Scientific Revolution," *Configurations* 6, no. 2 (1998), pp. 172-92, on p. 191.

[17] Broman, "Habermasian Public Sphere."

[18] Clark et al, "Introduction," p. 20.

[19] Golinski, "Science in the Enlightenment, Revisited," p. 226.

[20] Porter, "Introduction," p. 1.

[21] McClellan and Dorn, *Science and Technology in World History*, pp. 292-5.

[22] Fara, *Science*, p. 173.

[23] Knight, *Voyaging in Strange Seas*, "Chap 12: Enlightenment: Leisure, Electricity, and Chemistry." Poskett, *Horizons*, "Part II: Empire and Enlightenment, c. 1650 to 1800."

several cameo appearances in Peter Bowler and Iwen Rhys Morus' textbook on the history of modern science.[24] These books cover many aspects of eighteenth-century science—coffee houses, natural theology, the Lunar Society, the transatlantic slave trade, and much else—but the Enlightenment is the hook on which it all hangs.

This is not the only option, however. There are other master theses about eighteenth-century science that are only loosely related to the Enlightenment. Several historians have argued that classification was the signature of the century. "The eighteenth century was the great age of classification," wrote John Pickstone, before illustrating this with reference to plants, animals, minerals, diseases, crafts, and commodities.[25] Peter Dear has made a similar case more recently, adding stars, fossils and chemical substances to the list of things reduced to classes in the period.[26] This is an echo of Michel Foucault's "classical episteme," an epoch in the history of knowledge that was exemplified by Carl Linnaeus' classification of plants and that stretched from Descartes to Kant and from law to linguistics.[27] Charles Gillispie, writing a few years before Foucault, also saw classification as an eighteenth-century pursuit, in chemistry as well as in botany and mineralogy. Gillispie disliked classification ("the mind reeled in boredom along ordered rows of trivia") but he saw its importance.[28] The broad agreement on this thesis is an argument in its favour. If historians as varied as Pickstone, Gillispie and Foucault have endorsed the thesis, there must be something in it.

The same goes for the view that the eighteenth century ushered in the "second scientific revolution." The name is sometimes used for the whole of nineteenth-century science, or for the transition from classical to modern physics in the early twentieth century.[29] I use the phrase here to refer to the decades on either side of 1800, from about 1770 to about 1830. There is wide agreement, even among historians who agree on little else, that something dramatic happened in this period with regards to science. Already in 1987, R. Steven Turner noted the wide consensus about this event, which he called

[24] Bowler and Morus, *Making Modern Science*, pp. 66, 108, 135, 194, 417.

[25] Pickstone, *Ways of Knowing*, pp. 30, 67-73, 75.

[26] Dear, *Intelligibility of Nature*, chap. 2.

[27] Michel Foucault, *Les mots et les choses: une archéologie des sciences humaines*, Paris: Gallimard, 1966, chap. 5.

[28] Charles C. Gillispie, *The Edge of Objectivity: An Essay in the History of Scientific Ideas*, new paperback edn., Princeton, NJ: Princeton University Press, 2017 [1960], p. 260, cf. 170-1, 217, 249, 292.

[29] The whole nineteenth century in Stephen Brush, *The History of Modern Science: a Guide to the Second Scientific Revolution, 1800-1950*, Ames: Iowa State University Press, 1988. Classical to modern physics at Gillispie, *Edge of Objectivity*, p. 494.

"the great transition."[30] Andrew Cunningham and Perry Williams called it "the invention of science" in an article published in 1993.[31] In the same year—indeed the same journal issue—John Pickstone located the "analytical way of knowing" in this period.[32] John Heilbron has since called this "the transition to modern science" and "the quantifying spirit."[33] David Knight, following Thomas Kuhn, calls it "the second scientific revolution."[34] Whatever we call it, it is not going to go away. The Age of Revolutions is too well-established as a category in general history to be brushed aside by historians of science.[35] The mathematization of heat and electricity, the advent of clinical medicine, and the emergence of a truly historical geology are equally important; all have been located in the decades around 1800. Any solution to the eighteenth-century problem needs to take the second scientific revolution into account.

And if we take the second scientific revolution seriously, why not the first? There is a long tradition of locating the origins of modern science in the seventeenth century.[36] Historians of science are understandably wary of this tradition, with its single-minded focus on a few famous sons of north-western Europe. Historians of eighteenth-century science have chafed against the idea that their century was a mere extension of the previous one. But the first

[30] R. Steven Turner, "The Great Transition and the Social Patterns of German Science," *Minerva* 25, nos. 1-2 (1987), pp. 56-76.

[31] Andrew Cunningham and Perry Williams, "De-Centring the 'Big Picture': 'The Origins of Modern Science' and the Modern Origins of Science," *The British Journal for the History of Science* 26, no. 4 (1993), pp. 407-32, esp. 409-10.

[32] John Pickstone, "Ways of Knowing: Towards a Historical Sociology of Science, Technology and Medicine," *British Journal for the History of Science* 26, no. 4 (1993), pp. 433-58.

[33] John Heilbron, "History of Science," in John Heilbron (ed.), *The Oxford Companion to the History of Modern Science*, Oxford: Oxford University Press, 2003.

[34] Knight, *Voyaging on Strange Seas*, pp. 277-8, 282-8. The original source of the phrase seems to be Thomas Kuhn, "The Function of Measurement in Modern Physical Science," *Isis* 52, no. 2 (1961), pp. 161-193, on p. 188. For details, see I. Bernard Cohen, *Revolutions in Science*, Harvard, MA: Harvard University Press, 1985, pp. 92, 95-6, 97-101. A recent discussion is Johan Heilbron, "Auguste Comte and the Second Scientific Revolution," in Andrew Wernick (ed.), *The Anthem Companion to Auguste Comte*, London: Anthem Press, 2017, pp. 23-42, on pp. 34-8.

[35] The classic account is Eric Hobsbawm, *The Age of Revolution, 1789-1848*, London: Weidenfeld and Nicholson, 1962. Broader and more recent accounts are David Armitage and Sanjay Subrahmanyam (eds.), *The Age of Revolutions in Global Context, c. 1760–1840*, Houndmills: Palgrave Macmillan, 2010; John Darwin, *After Tamerlane: The Rise and Fall of Global Empires, 1400-1200*, London: Penguin, 2008, chap. 4 ("The Eurasian Revolution"); Sujit Sivasundarum, *Waves Across the South: a New History of Revolution and Empire* Chicago, IL: University of Chicago Press, 2021.

[36] For the history of this idea, see James A. Secord, "Inventing the Scientific Revolution," *Isis* 114, no. 1 (2023), pp. 50-76, and references therein.

scientific revolution cannot be dismissed so easily. It still has vigorous advocates.[37] Common sense would suggest that science after 1700 owed something to science before 1700. Moreover, early scholarship on the scientific revolution had much to say about the nature of this transition.[38] In 1949, Herbert Butterfield explained the adoption of the new science by the French *philosophes* in terms of a new social class that valued both novelty and the life of the mind.[39] A few years later, Rupert Hall dedicated a chapter to each of chemistry, physics, and natural history in his history of the scientific revolution, thereby putting eighteenth-century developments in a longer perspective.[40] Charles C. Gillispie made a neat distinction between "rationalist" and "romantic" readings of eighteenth-century science.[41] There are echoes of these books in more recent surveys. David Knight ends his account of the "great revolution in science" in 1770, not 1700. James Poskett treats eighteenth-century astronomy as an elaboration of a theory of gravity published in 1687.[42] Peter Bowler and Iwan Rhys Morus organise their textbook in much the same way as Gillispie did in 1960. They begin with a "scientific revolution" in physics and astronomy before working their way, chapter by chapter, through key episodes in other scientific disciplines. On this scheme, eighteenth-century science produced a "chemical revolution" but little else.[43] The idea of the scientific revolution is forever growing new limbs after having them cut off, like the polyps studied by the Swiss naturalist Abraham Tremblay in the 1730s and 1740s. We may still wish to think of eighteenth-century science as a response to the intellectual turbulence of the previous century.

We therefore have at least four master theses that may be summarised as Enlightenment, Classification, Second Scientific Revolution, and First Scientific Revolution. There are yet two more theses worth considering. One was clearly stated by Thomas Hankins in *Science and Enlightenment*. "The creation of the new scientific disciplines was probably the most important contribution of the Enlightenment [i.e. the eighteenth century] to the modernization of science."[44]

[37] Floris H. Cohen, *How Modern Science Came Into the World: Four Civilizations, One 17th-Century Breakthrough*, Amsterdam: Amsterdam University Press, 2010. David Wootton, *The Invention of Science: A New History of the Scientific Revolution*, London: Penguin, 2015.

[38] The following is a more positive view of the books by Butterfield, Hall and Gillispie than the view at Clark et al, "Introduction," pp. 13-15.

[39] Herbert Butterfield, *The Origins of Modern Science, 1300-1800*, 2nd edn., London: G. Bell and Sons, 1957 [1949], chap. 9, esp. pp. 167-70.

[40] Rupert Hall, *The Scientific Revolution, 1500-1800: The Formation of the Modern Scientific Attitude*, London: Longmans, 1962 [1954], chaps. 10, 11, 12.

[41] Gillispie, *Edge of Objectivity*, chap. 5.

[42] Poskett, *Horizons*, chap. 3.

[43] Bowler and Morus, *Making Modern Science*, Part 1.

[44] Hankins, *Science and Enlightenment*, p. 11, cf. vii. See the back cover of the 1999 edition.

This thesis has dropped out of discussions of the eighteenth-century problem, despite appearing in the preface and introduction of Hankins' book, and even on the back cover of at least one edition.[45] Commentators have focused on what Hankins did not do (situate science in the Enlightenment) at the expense of what he did do (trace the formation of disciplines). It is true that Hankins was not always explicit about this thesis in the body of the book, but the thesis is there nonetheless. Hankins took each discipline in turn and explained how some of its key ingredients were confected in the eighteenth century. Experimental physics had a distinctive subject matter by 1720 and became quantitative from about 1780.[46] The moral sciences began to ape the natural sciences from about 1750.[47] Natural history and physiology converged, from 1740 onwards, on the idea that living things must be studied differently from non-living ones.[48] The "revolution in physics and chemistry" that Antoine-Laurent Lavoisier envisaged was in fact the creation of chemistry as a discipline distinct from natural philosophy, as opposed to a revolution within a pre-existing discipline of chemistry.[49] One can quibble about the details of this story, but as an overall framework for eighteenth-century science it is as good as any.

A final thesis concerns the fate of natural philosophy. This is not so much a thesis as a puzzle. There is widespread agreement that natural philosophy is part of the solution to the eighteenth-century problem, but there is no consensus on how the solution goes. In this respect, not much has changed since Cantor's review of *Ferment of Knowledge*. That collection seemed to do away with the idea that eighteenth-century natural philosophy was an elaboration of Isaac Newton's theory of matter, offering in its place a range of conflicting views about the identity and trajectory of natural philosophy. For some contributors, natural philosophy was continuous with modern science; for others it was anything but modern science. For some it was bound up with metaphysical systems; for others it was the enemy of systems. Some played up the link to universities, others the link to theology and public spectacle.[50] The decades since then have produced an equally wide and perplexing range of options. Cunningham and Williams, in the 1993 article mentioned above, argued that natural philosophy was fundamentally about God and that it was superseded

[45] Hankins' book is mentioned, but not his thesis, at Golinski, "Science *in* the Enlightenment," p. 411; Broman, "Habermasian Public Sphere," p. 123; Clark et al, "Introduction," pp. 7, 9; Porter, "Introduction," p. 16; Golinski, "Science *in* the Enlightenment, Revisited," p. 217.

[46] Hankins, *Science and Enlightenment*, pp. 46-50, 70-1.

[47] Ibid, pp. 159-61.

[48] Ibid, chap. 5.

[49] Ibid, pp. 81, 112.

[50] Cantor, "Eighteenth Century Problem," pp. 58-61.

by modern scientific disciplines around 1800 and not before.[51] A few years earlier, John Schuster and Graeme Watchirs published an account of experimental natural philosophy which stressed "the crystallization and demarcation of regional domains of experimental work and discourse" in the eighteenth century.[52] More recently, and independently, Steven Gaukroger has written of the "collapse" of the mechanical philosophy in first half of the eighteenth century and its replacement by "a loose grouping of disciplines with different subject matters and different methods."[53] Other historians have studied natural philosophy through the lens of natural history, sometimes stressing the interdependence of these two traditions in the eighteenth century and sometimes their independence.[54] A *longue durée* history of natural philosophy, by Edward Grant, jumps straight from the seventeenth century to the nineteenth.[55] Some good surveys of eighteenth-century science simply ignore the question of natural philosophy.[56] Natural philosophy is oddly separate from the Enlightenment in the secondary literature, with authors focusing on one or the other, rarely both.[57] Natural philosophy may be a sixth master thesis of eighteenth-century science, but it is a thesis in need of explication.

Six Articles

The articles that follow attack the eighteenth-century problem in different ways. Domenico Bertoloni Meli starts with Hankins' 1985 book, writing that

[51] Cunningham and Williams, "De-Centring the 'Big Picture,'" pp. 421-2.

[52] John Schuster and Graeme Watchirs, "Natural Philosophy, Experiment and Discourse in the 18th Century: Beyond the Kuhn/Bachelard Problematic," in Homer Eugene le Grand (ed.), *Experimental Inquiries: Historical, Philosophical, and Social Studies of Experimentation in Science*, Dordrecht: Kluwer, 1990, pp. 215-38, on p. 223.

[53] Gaukroger, *Collapse of Mechanism*, p. 7.

[54] Independence at Pickstone, "Ways of Knowing," p. 439; Simon Schaffer, "Natural Philosophy and Public Spectacle in the Eighteenth Century," *History of Science* 21, no. 1 (1983), pp. 1-43, on pp. 22-3. Interdependence at Peter Anstey, "Bacon, Experimental Philosophy and French Enlightenment Natural History," in Raphaële Garrod and Paul Smith (eds.), *Natural History in Early Modern France: The Poetics of an Epistemic Genre*, Leiden: Brill, 2018, pp. 205–240; Mary Terrall, *Catching Nature in the Act: Réaumur and the Practice of Natural History in the Eighteenth Century*, Chicago, IL: Chicago University Press, 2014.

[55] Edward Grant, *A History of Natural Philosophy: From the Ancient World to the Nineteenth Century*, Cambridge: Cambridge University Press, 2007, chap. 10.

[56] There is little or no explicit discussion of natural philosophy as a category of knowledge in Fara, *Science*; Poskett, *Horizons*; Golinski, "Science *in* the Enlightenment"; Clark et al, "Introduction"; Golinski, "Science *in* the Enlightenment, Revisited."

[57] See the previous note. Conversely, there is little explicit discussion of the Enlightenment in Porter and Rousseau, *Ferment of Knowledge*; or Cantor, "Eighteenth Century Problem." An exception is Gaukroger, *Collapse of Mechanism*, which links the collapse of the mechanical philosophy to the Enlightenment.

it is "the most succinct and comprehensive textbook on the subject."[58] The book certainly had blind spots, from the Leibniz/Clarke correspondence to the history of museums to gender and empire. But Bertoloni Meli finds a recurring theme in the book: the tendency of eighteenth-century naturalists to see their work as descriptive rather than explanatory, as an effort to reduce the phenomena to rule rather than to identify their causes. Bertoloni Meli builds on this idea by noting the role of Isaac Newton's work as a model for eighteenth-century phenomenalism. Indeed, one can argue that Newton belongs more fully to the eighteenth century than the seventeenth. Once we see this, Bertoloni Meli argues, we can also see that systematization was a common theme of a wide range of eighteenth-century practices, from the *Encyclopédie* of Diderot and d'Alembert to the tables of numerical values that were so common in the century's studies of comets, diseases, cannon balls, and much else.

Emma Spary, like Bertoloni Meli, looks for clues to the character of eighteenth-century science in the decades around 1700. Historians have long associated the experimental philosophy that emerged in seventeenth-century England with phenomena that could not be easily explained in mechanistic terms and were therefore attributed to "occult" properties.[59] Spary extends this idea in a surprising new direction. Based on a study of 125 private libraries in France, published between 1660 and 1730, Spary shows that occult phenomena continued to circulate well into the eighteenth century in the form of books of secrets. These books were read by a wide audience that went far beyond elite institutions such as the Parisian Académie Royale des Sciences. Books of secrets are easy to dismiss as naïve or superstitious, a throwback to an unenlightened age, but their discussions of divining rods and sympathetic communication went hand-in-hand with the latest discoveries in natural philosophy. Books of secrets were "critical to continued scholarly interest in natural phenomena which did not lend themselves to reductionist mechanistic interpretation."[60] Occult phenomena were not ejected from these books after 1700; they were reinterpreted as contributions to useful public knowledge.

Brendan Dooley, too, focuses on the early decades of the eighteenth century. He excavates the mental world of Antonio Vallisneri, a physician at the University of Padua and co-founder of the important *Giornale de' letterati d'Italia*. This was an uneasy time in Italian intellectual life, with a Galilean tradition of

[58] This issue, p. 33.

[59] A classic paper in this tradition is John Henry, "Occult Qualities and the Experimental Philosophy: Active Principles in pre-Newtonian Matter Theory," *History of Science* 24 (1986), pp. 335-381. For a comprehensive treatment, see Xiaona Wang, *Handling 'Occult Qualities' in the Scientific Revolution: Disciplines and New Approaches to Natural Philosophy, from John Dee to Isaac Newton*, Leiden: Brill, 2023, chap. 4.

[60] This issue, p. 87.

observation and experiment co-existing with bouts of paranoia about unorthodox opinions. Dooley documents the "honest dissimulation" that was needed to pursue the latest findings in natural philosophy without falling foul of church and state. For Vallisneri, the key distinctions were between the knowable and the unknowable and between public and private writings. He avoided the more controversial implications of his ideas by professing ignorance about the deep causes of the phenomena he observed: "I only attempt to fly in proportion to the measure of my short, clay-covered wings."[61] He was more candid in private letters to friends, where he asserted (for example) that the earth was far older than generally thought. As Dooley puts it, the details of Vallisneri's career illustrate the "contrasts and paradoxes" of the early Italian Enlightenment.

Anita Guerrini's paper is about natural history collecting, one of the blind spots in Hankins' 1982 textbook. Scholarship on this topic has expanded enormously since then, but blind spots remain. Human skeletons, when discussed at all in histories of the period, are usually used to illustrate the emergence of a biological conception of race at the very end of the century. And indeed, the measurement of skull angles was important in the attempts by Petrus Cramer and Johann Friedrich Blumenbach to slot human beings into distinct races in the 1790s. Guerrini shows that these developments were part of a longer history that sat squarely in the eighteenth century. All human bones, not just skulls, were collected by leading naturalists such as Hans Sloane, William and John Hunter, and Joseph Banks. And they were collected as relics, curiosities, *memento mori*, and pedagogical aids, not usually as markers of national or racial identity. The eighteenth century was therefore a distinct period in the history of collecting, between the introduction of human bones into collections in the latter part of the seventeenth century and the use of skulls for racial classification a century later. The topic raises the wider question of the place of power and politics in eighteenth-century science. "The eighteenth century remains a problem," Guerrini writes[62]—not because we have overlooked the century but because we have overlooked its mixed legacy in the present.

Instruments are another topic that, like collecting, has grown in significance since the 1980s. Richard Sorrenson synthesises much work in this area to show that the improvement of instruments was a major theme of eighteenth-century science. This was the period in which the use of instruments "became the overwhelming norm in natural and experimental philosophy."[63] Sorrenson develops the idea of instrumental improvement as both an analysts' category and an actors' one, using the gazometer, reflecting telescope, and

[61] This issue, p. 69.
[62] This issue, p. 134.
[63] This issue, p. 171.

theodolite as examples. These examples illustrate different routes to improvement: combining pre-existing instruments; increasing the power of an existing instrument; and increasing its accuracy. The examples also show that the notion of "improvement" was used at the time to understand the evolution of instruments, just as it was used for trade, agriculture, and character. Sorrenson's broader point is that the eighteenth century was a period of gradual rather than revolutionary change in the sciences. The improvement of instruments, rather than the invention of entirely new ones, was the order of the day.

Adrian Wilson, like Sorrenson, aims to do justice to the intellectual achievements of eighteenth-century science. Also like Sorrenson, Wilson proposes a broad solution to the eighteenth-century problem that is backed up by three detailed examples. The solution is to locate the eighteenth century in a larger narrative about the origins of science. The larger narrative usually includes what I have called the first and second scientific revolutions. Wilson recognises these two transformations and argues that an equally significant transformation, which he calls "The Great Instauration," occurred in the eighteenth century. The name is a nod to Francis Bacon and an assertion that eighteenth-century science was as much a realisation of Bacon's vision as it was of Newton's. It was institutionally solid, geographically broad, and socially diverse; it was driven forward by precision, instruments, and accidental discovery. These points are illustrated by astronomy, electricity, and chemistry. Wilson's treatment of these examples shows how much remained to be done in 1700 and how much of it was done by 1800. Indeed, much of it was done in the middle decades of the century, from about 1720 to 1780, a period that is usually seen as an especially barren one for science.

Taken together, these articles show that there is more than one eighteenth-century problem. There is the problem of recognising the intellectual significance of the century's science; of grappling with its material legacy; of expanding its social scope; and of coming to terms with its paradoxes and hesitations. In solving these problems, the authors engage in different ways with the six master theses mentioned earlier. If an overall trend emerges, it is that of creative recombination. Each article brings together two or more of the received theses in a new way. Spary and Dooley are both concerned with the "threshold of the Enlightenment," to borrow from Dooley's title. Both articles show that the public sphere of the eighteenth century reshaped elements of European intellectual culture that are usually associated with the first scientific revolution, such as Cartesian mechanical philosophy and Boylean experimental philosophy. Other articles combine elements of the first and second scientific revolutions, Bertoloni Meli under the heading of "systematization" and Wilson under the heading of "the Great Instauration." Guerrini's article on human skeletons may be read as a study in classification, the Enlightenment, *and* the

quantifying spirit. Finally, Sorrenson brings together a defining feature of the Enlightenment (improvement) and a defining feature of the second scientific revolution (precise instruments). The eighteenth-century problem is multiple, but this multiplicity may be part of the solution.

Six Desiderata

Of course, these articles do not add up to a single new master thesis about eighteenth-century science. Nor do they make up for the lack of a synthetic monograph on the period. The successor to Hankins' *Science and Enlightenment* is yet to be written, as Bertoloni Meli observes in his article. Hankins' book, published in 1985, was itself a successor to a work by Abraham Wolf published 46 years previously.[64] At this rate, a successor to Hankins' book ought to appear in 2031 or thereabouts. I conclude this essay with some desiderata for such a book, the overriding theme being the emancipation of eighteenth-century science from the Enlightenment.

This does not mean ignoring the Enlightenment but putting the Enlightenment in its place. The Enlightenment is just one of least six master theses about eighteenth-century science. One desideratum is to identify some of the tensions between these theses and to attempt to ease them. One such tension concerns discipline formation, a process that is sometimes associated with the fragmentation of natural philosophy early in the century and sometimes with the second scientific revolution at the end of the century. Another concerns the dominant way of knowing in the period. Classification is a perennial favourite, but Hankins tells us that "mathematics set the style for the science of the Enlightenment."[65] Fara tells us that electricity was an exemplary public science in the period, yet the most spectacular electrical experiments were not quantitative, and nor were they classificatory in any obvious way.[66] This points to a third tension: the classification thesis suggests that eighteenth-century science was attracted to orderly phenomena, whereas the Enlightenment thesis draws attention to strange and anomalous phenomena that captivated the wider public.[67] Carl Linnaeus was counting stamens at the same time as Jean-Antoine Nollet

[64] Abraham Wolf, *A History of Science, Technology and Philosophy in the Eighteenth Century*, New York: Macmillan, 1939. Hankins, *Science and Enlightenment*, p. vii.

[65] Hankins, *Science and Enlightenment*, p. 16.

[66] Fara, *Science*, p. 195.

[67] This tension is discussed (resolved?) at Simon Schaffer, "Natural Philosophy," in Rousseau and Porter, *Ferment of Knowledge*, pp. 55-92, on pp. 84-6; Schaffer, "Natural Philosophy and Public Spectacle," pp. 22-3; Nicholas Jardine, "Inner History; or, How to End Enlightenment," in Clark et al, *Sciences in Enlightened Europe*, pp. 477-94, on pp. 483-4.

was electrifying monks—is there a master thesis that accounts for both? The same example illustrates a final dilemma, between global and Eurocentric histories. Eurocentric surveys of eighteenth-century science have plenty of room for chemistry and experimental physics, yet these fields are virtually absent in global surveys of the same period, which focus on natural history, medicine, cartography, and astronomy.[68] It is an open question how these paradoxes will be resolved, but the first step is to see that the Enlightenment is only one piece of the eighteenth-century puzzle.

Another piece of the puzzle is the wider historiography of the eighteenth century, which has been neglected by historians of science. This may seem like a strange statement given that the whole thrust of the historiography of science in the last half-century has been to place science in historical context—to set it "in a large cultural perspective," as Rousseau and Porter put it in 1980.[69] But the fact remains that the eighteenth-century problem has been discussed in almost complete absence of any reference to the standard works on the general history of the eighteenth century. M. S. Anderson's *Europe in the Eighteenth Century, 1713-1783* went through three editions between 1961 and 1987 but has not been mentioned once in discussions of the overall shape of eighteenth-century science.[70] There is a whole industry of textbooks on eighteenth-century Europe that has not been tapped in this discussion[71]; global and world histories are equally underused.[72] The fiscal-military state, the industrious revolution, the

[68] See Poskett, *Horizons*, chaps. 3 and 4. There is a similar range of disciplines in studies of eighteenth-century science in specific regions outside Europe and colonial North America. Examples are: Kapil Raj, *Relocating Modern Science: Circulation and the Construction of Knowledge in South Asia and Europe, 1650-1900*, Basingstoke: Palgrave Macmillan, 2007, chaps. 1 and 2; Benjamin Elman, *On Their Own Terms: Science in China, 1550-1900*, Harvard, MA: Harvard University Press, 2009, chaps. 4, 5, 6, 7; Harun Küçük, *Science Without Leisure: Practical Naturalism in Istanbul, 1660-1732*, Pittsburgh, PN: University of Pittsburgh Press, 2019; and Federico Marcon, *The Knowledge of Nature and the Nature of Knowledge in Early Modern Japan*, Chicago, IL: University of Chicago Press, 2015, parts III and IV.

[69] Rousseau and Porter, "Introduction," p. 5, cf. 1-2.

[70] Matthew S. Anderson, *Europe in the Eighteenth Century, 1713-1783*, 3rd edn., New York, NY: 1987 [1961].

[71] Here are some examples. Isser Coloch and Gregory S. Brown, *Eighteenth-Century Europe: Tradition and Progress, 1715-1789*, 2nd edn., London: Norton, 2012 [1982]. William Doyle, *The Old European Order, 1660-1800*, 2nd edn., Oxford: Oxford University Press, 1992 [1987]. Timothy Blanning (ed.), *The Eighteenth Century*, Oxford: Oxford University Press, 2000. Robin W. Winks and Thomas E. Kaiser, *Europe from the Old Regime to the Age of Revolution*, Oxford: Oxford University Press, 2004. Timothy Blanning, *The Pursuit of Glory: Europe 1648-1815*, London: Penguin, 2007.

[72] Darwin, *After Tamerlane*, chaps. 3 and 4. Charles H. Parker, *Global Interactions in the Early Modern Age, 1400-1800*, Cambridge: Cambridge University Press, 2010. James Belich, *The World the Plague Made: the Black Death and the Rise of Europe*, Princeton, NJ: Princeton University Press, 2022, chaps. 15 and 16.

second hundred years' war, the emulation of Asian manufactures in Europe—these are as much a part of the eighteenth century as are the *philosophes* or the public sphere.[73] They have all been broached by historians of science, but usually in specific studies rather than in broad surveys. The broad surveys engage above all with the historiography of the Enlightenment. This engagement has been fruitful, and continues to be so, but it ought to be extended to other branches of eighteenth-century historiography. Poskett's global history of science shows the power of this approach. The two chapters on the eighteenth century may have "Enlightenment" in the title, but they are organised around the transatlantic slave trade and the expansion of the French, British and Russian empires. The result is a sweeping narrative that is nevertheless specific to the eighteenth century.

Engagement with the wider historiography may help to meet another desideratum, that of being more precise about the chronology of the eighteenth century. Cantor opened his review of *Ferment of Knowledge* by noting that centuries are "unnatural units" that nevertheless "furnish useful labels which considerably influence our conceptualization of history and the categories we employ."[74] Cantor was relaxed about the dates we choose for the nominal eighteenth century; later commentators have followed suit. But the dates do matter. According to John Heilbron, writing as editor of the *Oxford Companion to the History of Modern Science*, the key periods were 1640-1750, 1720-1770, and 1770-1830; elsewhere Heilbron stresses the period 1660-1700.[75] Each of these periods showed "simultaneous and significant changes in institutional and intellectual factors," whereas the period 1700 to 1799 did not. On this showing, the eighteenth-century problem is an artefact of our fondness for round numbers.

We can be more precise about places as well as about dates. There has been much useful reflection about the geographical pattern of past science—about the pros and cons of analytical categories such as diffusion, accumulation, circulation, exchange, empires, networks, peripheries, and so on.[76] But

[73] Jan de Vries, *The Industrious Revolution: Consumer Behavior and the Household Economy, 1650 to the Present*, Cambridge: Cambridge University Press, 2008. Felicia Gottman, Hanna Hodacs and Chris Nierstrasz (eds.), *Goods from the East, 1600-1800: Trading Eurasia*, Palgrave Macmillan: Basingstoke, 2015. Aaron Graham and Patrick Walsh (eds.), *The British Fiscal-Military Sates, 1660-c. 1783*, London: Routledge, 2016. John Shovlin. *Trading with the Enemy: Britain, France, and the 18th-Century Quest for a Peaceful World Order*, New Haven, CT: Yale University Press, 2021.

[74] Cantor, "Eighteenth Century Problem," p. 44.

[75] Heilbron, "History of Science." John Heilbron, "Coming to Terms with the Scientific Revolution," *European Review* 15, no. 4 (2007), pp. 473-489.

[76] See Golinski, "Science *in* the Enlightenment, Revisited," for a survey of this trend as applied to eighteenth-century science.

whichever category we choose, it will not tell us much about the specifics of the eighteenth century. It will not tell us whether the Enlightenment began in the Dutch Republic, as Jonathan Israel has argued. It will not argue for or against James Belich's thesis that European empires were threadbare in 1800.[77] It will tell us little about the received geopolitical narrative for the period, nor whether this narrative can be extended to science. To find out, we need to engage with the whole historiography of the eighteenth century—not just with the Enlightenment and not just with social theorists such as Jürgen Habermas, Michel Foucault and Bruno Latour.

More engagement with general history may help those of us who work on the eighteenth century to overcome our wariness of the first and second scientific revolutions. Europeanists have identified a General Crisis in the middle decades of the seventeenth century and an Age of Revolutions around 1800, with the eighteenth century strung between them.[78] This pattern seems to be wider than Europe, since both the General Crisis and the Age of Revolutions have featured in global histories that cover much of the world.[79] The period between the crises and the revolutions has been called the Age of Equilibrium—a period in which powerful forces cancelled each other out rather than compounding each other.[80] This has not marginalised the study of the eighteenth century in general histories. On the contrary, it makes the century the "hinge between the old world and the new," to quote one textbook on the period.[81] In sum, general historians have found a way to narrate this period without nullifying it. Historians of science ought to be able to do the same.

In doing so we would benefit from more recombinations of existing grand narratives. As the papers in this special issue show, there are surprising synergies between the various narratives as well as persistent tensions. One further synergy that deserves more attention is between the formation of the public sphere and the formation of scientific disciplines. These are usually seen as sequential developments rather than parallel ones, with an ill-disciplined

[77] Jonathan Israel, *Radical Enlightenment: Philosophy and the Making of Modernity, 1650-1750*, Oxford: Oxford University Press, 2001. Belich, *The World the Plague Made*, chap. 15.

[78] The classic studies are Hobsbawm, *Age of Revolution*; and Geoffrey Parker and Lesley M. Smith, *The General Crisis of the Seventeenth Century*, London: Routledge and Kegan Paul, 1978. The ages of crisis and revolution framed William Doyle's influential textbook: Doyle, *Old European Order*, p. 1, chaps. 14-15.

[79] Geoffrey Parker, *Global Crisis: War, Climate Change and Catastrophe in the Seventeenth Century*, London: Yale University Press, 2014.

[80] Darwin, *After Tamerlane*, chap. 3.

[81] Timothy Blanning, "Introduction: the Beneficiaries and Casualties of Expansion," in Blanning, *The Eighteenth Century*, pp. 1-10, on p. 1.

natural philosophy being replaced by specialised journals and societies in the decades around 1800. But there is scattered evidence for an alternative view. The public sphere was a catalyst, perhaps not of disciplines in the twentieth-century sense, but at least of the segmentation of natural knowledge. In the history of physics, instrument-driven public lectures had narrowed the field of experimental natural philosophy by 1750, as John Heilbron has shown.[82] Crystallography began as a solution to the problem of cataloguing private mineral collections, as Hélène Metzger once noted.[83] The Republic of Letters, a community of passionate amateurs, encouraged a certain degree of specialisation: "to be an enlightened student of nature (including human nature) implied an intense preoccupation with some domain of phenomena," in Lorraine Daston's words.[84] Separately, Thomas Broman has argued that professional expertise emerged from the eighteenth-century public sphere and that it still depends on an idealized conception of the public.[85] Enlightenment and discipline-formation have more in common than meet the eye. Similar synergies can perhaps be found elsewhere. Is the formation of disciplines, as described by Hankins, simply another way of looking at the fragmentation of natural philosophy, as described both by Gaukroger, and by Schuster and Watchirs? Did classification evolve in the same way as quantification, with some phenomena classified early and others later?[86] Can the chemical revolution be understood in terms of the emulation of East Asian manufactured goods, thereby bringing chemistry into the fold of the global history of eighteenth-century science?[87] New narratives are easier to generate when we have a clear view of the range of narratives currently in play.

[82] John Heilbron, *Elements of Early Modern Physics*, Berkeley, CA: University of California Press, 1982, pp. 5-9.

[83] Hélène Metzger, *La genèse de la science des cristaux*, Paris: Albert Blanchard, 1969 [1918], p. 66.

[84] Lorraine Daston, "The Ethos of Enlightenment," in Clark et al, *Sciences in Enlightened Europe*, pp. 495-504, on p. 500.

[85] Broman, "The Habermasian Public Sphere," pp. 140-2.

[86] This pattern was identified in the history of quantification in Thomas Kuhn, "Mathematical Versus Experimental Traditions in the Development of Physical Science," *Journal of Interdisciplinary History* 7, no. 1 (1976), pp. 1-31. The pattern is partially extended to classification in Frängsmyr et al, *The Quantifying Spirit*; and McClellan and Dorn, *Science and Technology in World History*, pp. 321-7, esp. 323.

[87] Some starting points along these lines are: Cyril S. Smith, "Porcelain and Plutonism," in Cecil J. Schneer (ed.), *Toward a History of Geology*, Cambridge: MIT Press, 1969, pp. 316–38; Michael Bycroft, "What Difference does a Translation Make? The *Traité des vernis* (1723) in the Career of Charles Dufay," in Sietske Fransen, Niall Hodson, and Karl A. E. Enenkel (eds.), *Translating Early Modern Science*, Leiden: Brill, 2017, pp. 66-90; and Elman, *On Their Own Terms*, pp. 208-9, 212-16.

Rupert Hall once remarked on the "dual character" of eighteenth-century science, conservative and radical in equal measure.[88] Jan Golinski made a similar point in his recent characterisation of the Enlightenment: "the challenge for historians today is to keep both sides of the picture before our eyes simultaneously."[89] The point generalises. The challenge is to keep *all* sides in view, not just tradition and innovation but also the other master theses discussed here. A truly enlightened account of eighteenth-century science will go well beyond the Enlightenment.

Acknowledgments
This article benefited greatly from conversations with, and comments from, Adrian Wilson. I would also like to thank the authors of the articles in this special issue for their timely comments and corrections. An audience at the Centre for the History of Philosophy of Science at Leeds University gave helpful comments on a related paper.

Works Cited

Matthew S. Anderson, *Europe in the Eighteenth Century, 1713-1783*, 3rd edn., New York, NY: 1987 [1961].
Peter Anstey, "Bacon, Experimental Philosophy and French Enlightenment Natural History," in Raphaële Garrod and Paul Smith (eds.), *Natural History in Early Modern France: The Poetics of an Epistemic Genre*, Leiden: Brill, 2018, pp. 205–240.
David Armitage and Sanjay Subrahmanyam (eds.), *The Age of Revolutions in Global Context, c. 1760–1840*, Houndmills: Palgrave Macmillan, 2010.
James Belich, *The World the Plague Made: the Black Death and the Rise of Europe*, Princeton, NJ: Princeton University Press, 2022.
Timothy Blanning (ed.), *The Eighteenth Century*, Oxford: Oxford University Press, 2000.
Timothy Blanning, "Introduction: the Beneficiaries and Casualties of Expansion," in Blanning, *The Eighteenth Century*, pp. 1-10.
Timothy Blanning, *The Pursuit of Glory: Europe 1648-1815*, London: Penguin, 2007.
Peter Bowler and Iwan Rhys Morus, *Making Modern Science: A Historical Survey*, Chicago, IL: University of Chicago Press, 2005.
Thomas Broman, "The Habermasian Public Sphere and 'Science in the Enlightenment,'" *History of Science* 37 (1998), pp. 124-49.
Stephen Brush, *The History of Modern Science: a Guide to the Second Scientific Revolution, 1800-1950*, Ames: Iowa State University Press, 1988.
William E. Burns, *Science in the Enlightenment: An Encyclopedia*, Santa Barbara: ABC-CLIO, 2003.

[88] Hall, *Scientific Revolution*, p. 342.
[89] Golinski, "Science *in* the Enlightenment, Revisited," p. 227.

Herbert Butterfield, *The Origins of Modern Science, 1300-1800*, 2nd edn., London: G. Bell and Sons, 1957 [1949].

Michael Bycroft, "What Difference does a Translation Make? The *Traité des vernis* (1723) in the Career of Charles Dufay," in Sietske Fransen, Niall Hodson, and Karl A. E. Enenkel (eds.), *Translating Early Modern Science*, Leiden: Brill, 2017, pp. 66-90.

Michael Bycroft and Alexander Wragge-Morley (eds.), *Science and Connoisseurship in the European Enlightenment*, special issue of *History of Science* 60, no. 4 (2022).

Luisa Calè and Adriana Craciun (eds.), *The Disorder of Things*, special issue of *Eighteenth-Century Studies* 45, no. 1 (2011).

Geoffrey Cantor, "Essay Review: The Eighteenth Century Problem: *The Ferment of Knowledge: Studies in the Historiography of Eighteenth Century Science*," *History of Science* 20 (1982), pp. 44-63.

William Clark, Jan Golinski, and Simon Schaffer (eds.), *The Sciences in Enlightened Europe*, Chicago, IL: Chicago University Press, 1999.

Floris H. Cohen, *How Modern Science Came Into the World: Four Civilizations, One 17th-Century Breakthrough*, Amsterdam: Amsterdam University Press, 2010.

I. Bernard Cohen, *Revolutions in Science*, Harvard, MA: Harvard University Press, 1985.

Isser Coloch and Gregory S. Brown, *Eighteenth-Century Europe: Tradition and Progress, 1715-1789*, 2nd edn., London: Norton, 2012 [1982].

Adriana Craciun and Simon Schaffer (eds.), *The Material Cultures of Enlightenment Arts and Sciences*, London: Palgrave Macmillan, 2016.

Adriana Craciun and Mary Terrall (eds.), *Curious Encounters: Voyaging, Collecting, and Making Knowledge in the Long Eighteenth Century*, Toronto: University of Toronto Press, 2019.

Andrew Cunningham and Perry Williams, "De-Centring the 'Big Picture': 'The Origins of Modern Science' and the Modern Origins of Science," *The British Journal for the History of Science* 26, no. 4 (1993), pp. 407-32.

John Darwin, *After Tamerlane: The Rise and Fall of Global Empires, 1400-1200*, London: Penguin, 2008.

Lorraine Daston, "The Ethos of Enlightenment," in Clark et al, *Sciences in Enlightened Europe*, pp. 495-504.

Lorraine Daston and Gianna Pomata (eds.), *The Faces of Nature in Enlightenment Europe*, Berlin: BWV-Berliner Wissenschafts-Verlag, 2003.

Peter Dear, "The Mathematical Principles of Natural Philosophy: Toward a Heuristic Narrative for the Scientific Revolution," *Configurations* 6, no. 2 (1998), pp. 172-92.

Peter Dear, *The Intelligibility of Nature: How Science Makes Sense of the World*, Chicago, IL: Chicago University Press, 2006.

William Doyle, *The Old European Order, 1660-1800*, 2nd edn., Oxford: Oxford University Press, 1992 [1987].

Benjamin Elman, *On Their Own Terms: Science in China, 1550-1900*, Harvard, MA: Harvard University Press, 2009.

Patricia Fara, *Science: A Four Thousand Year History*, Oxford: Oxford University Press, 2009.

Michel Foucault, *Les mots et les choses: une archéologie des sciences humaines*, Paris: Gallimard, 1966.

Tore Frängsmyr, John Heilbron, and Robin Rider (eds.), *The Quantifying Spirit in the 18th Century*, Berkeley, CA: University of California Press, 1990.

Stephen Gaukroger, *The Collapse of Mechanism and the Rise of Sensibility: Science and the Shaping of Modernity, 1680-1760*, Oxford: Oxford University Press, 2011.

Kostas Gavroglu (ed.), *The Sciences in the European Periphery During the Enlightenment*, Springer: Dordrecht, 1999.

Charles C. Gillispie, *The Edge of Objectivity: An Essay in the History of Scientific Ideas*, new paperback edn., Princeton, NJ: Princeton University Press, 2017 [1960].

Jan Golinski, "Science *in* the Enlightenment," *History of Science* 24 (1986), pp. 411-24.

Jan Golinski, "Science *in* the Enlightenment, Revisited," *History of Science* 49 (2011), pp. 217-31.

Felicia Gottman, Hanna Hodacs and Chris Nierstrasz (eds.), *Goods from the East, 1600-1800: Trading Eurasia*, Palgrave Macmillan: Basingstoke, 2015.

Aaron Graham and Patrick Walsh (eds.), *The British Fiscal-Military Sates, 1660-c. 1783*, London: Routledge, 2016.

Edward Grant, *A History of Natural Philosophy: From the Ancient World to the Nineteenth Century*, Cambridge: Cambridge University Press, 2007.

Anita Guerrini, "The Material Turn in the History of Life Science," *Literature Compass* 13, no. 7 (2016), pp. 469-80.

Rupert Hall, *The Scientific Revolution, 1500-1800: The Formation of the Modern Scientific Attitude*, London: Longmans, 1962 [1954].

Johan Heilbron, "Auguste Comte and the Second Scientific Revolution," in Andrew Wernick (ed.), *The Anthem Companion to Auguste Comte*, London: Anthem Press, 2017, pp. 23-42.

John Heilbron, *Elements of Early Modern Physics*, Berkeley, CA: University of California Press, 1982.

John Heilbron, "History of Science," in John Heilbron (eds.), *The Oxford Companion to the History of Modern Science*, Oxford: Oxford University Press, 2003.

John Heilbron, "Coming to Terms with the Scientific Revolution," *European Review* 15, no. 4 (2007), pp. 473-489.

John Henry, "Occult Qualities and the Experimental Philosophy: Active Principles in pre-Newtonian Matter Theory," *History of Science* 24 (1986), pp. 335-381.

Eric Hobsbawm, *The Age of Revolution, 1789-1848*, London: Weidenfeld and Nicholson, 1962.

Jonathan Israel, *Radical Enlightenment: Philosophy and the Making of Modernity, 1650-1750*, Oxford: Oxford University Press, 2001.

Nicholas Jardine, "Inner History; or, How to End Enlightenment," in Clark et al, *Sciences in Enlightened Europe*, pp. 477-94.

David Knight, *Voyaging in Strange Seas: the Great Revolution in Science*, London: Yale University Press, 2014.

Robert Kohler, "A Generalist's Vision," *Isis* 96, no. 2 (2005), pp. 224-9.

Harun Küçük, *Science Without Leisure: Practical Naturalism in Istanbul, 1660-1732*, Pittsburgh, PN: University of Pittsburgh Press, 2019.

Thomas Kuhn, "The Function of Measurement in Modern Physical Science," *Isis* 52, no. 2 (1961), pp. 161-193.

Thomas Kuhn, "Mathematical Versus Experimental Traditions in the Development of Physical Science," *Journal of Interdisciplinary History* 7, no. 1 (1976), pp. 1-31.
Federico Marcon, *The Knowledge of Nature and the Nature of Knowledge in Early Modern Japan*, Chicago, IL: University of Chicago Press, 2015.
James McClellan and Harold Dorn, *Science and Technology in World History*, 3rd edn., Baltimore, MA: Johns Hopkins University Press, 2015 [1999].
Hélène Metzger, *La genèse de la science des cristaux*, Paris: Albert Blanchard, 1969 [1918].
Charles H. Parker, *Global Interactions in the Early Modern Age, 1400-1800*, Cambridge: Cambridge University Press, 2010.
Geoffrey Parker and Lesley M. Smith, *The General Crisis of the Seventeenth Century*, London: Routledge and Kegan Paul, 1978.
Geoffrey Parker, *Global Crisis: War, Climate Change and Catastrophe in the Seventeenth Century*, London: Yale University Press, 2014.
John Pickstone, "Ways of Knowing: Towards a Historical Sociology of Science, Technology and Medicine," *British Journal for the History of Science* 26, no. 4 (1993), pp. 433-58.
John Pickstone, *Ways of Knowing: A New History of Science, Technology and Medicine*, Manchester: Manchester University Press, 2000.
Roy Porter (ed.), *The Cambridge History of Science, vol. 4: Eighteenth Century Science*, Cambridge: Cambridge University Press, 2003.
Roy Porter, "Introduction," in Porter, *Eighteenth Century Science*, pp. 1-20.
James Poskett, *Horizons: A Global History of Science*, London: Penguin, 2022.
Kapil Raj, *Relocating Modern Science: Circulation and the Construction of Knowledge in South Asia and Europe, 1650-1900*, Basingstoke: Palgrave Macmillan, 2007.
G. S. Rousseau and Roy Porter (eds.), *The Ferment of Knowledge: Studies in the Historiography of Eighteenth Century Science*, Cambridge: Cambridge University Press, 1980.
G. S. Rousseau and Roy Porter, "Introduction," in Rousseau and Porter, *Ferment of Knowledge*, pp. 1-7.
Simon Schaffer, "Natural Philosophy and Public Spectacle in the Eighteenth Century," *History of Science* 21, no. 1 (1983), pp. 1-43.
John Schuster and Graeme Watchirs, "Natural Philosophy, Experiment and Discourse in the 18th Century: Beyond the Kuhn/Bachelard Problematic," in Homer Eugene Le Grand (ed.), *Experimental Inquiries: Historical, Philosophical, and Social Studies of Experimentation in Science*, Dordrecht: Kluwer, 1990, pp. 215-38.
James A. Secord, "Introduction," *British Journal of the History of Science* 26, no. 4 (1993), pp. 387-9.
James A. Secord, "Inventing the Scientific Revolution," *Isis* 114, no. 1 (2023), pp. 50-76.
John Shovlin. *Trading with the Enemy: Britain, France, and the 18th-Century Quest for a Peaceful World Order*, New Haven, CT: Yale University Press, 2021.
Sujit Sivasundarum, *Waves Across the South: a New History of Revolution and Empire* Chicago, IL: University of Chicago Press, 2021.
Cyril S. Smith, "Porcelain and Plutonism," in Cecil J. Schneer (ed.), *Toward a History of Geology*, Cambridge: MIT Press, 1969.
Mary Terrall, *Catching Nature in the Act: Réaumur and the Practice of Natural History in the Eighteenth century*, Chicago, IL: Chicago University Press, 2014.

R. Steven Turner, "The Great Transition and the Social Patterns of German Science," *Minerva* 25, nos. 1-2 (1987), pp. 56-76.

Jan de Vries, *The Industrious Revolution: Consumer Behavior and the Household Economy, 1650 to the Present*, Cambridge: Cambridge University Press, 2008.

Xiaona Wang, *Handling 'Occult Qualities' in the Scientific Revolution: Disciplines and New Approaches to Natural Philosophy, from John Dee to Isaac Newton*, Leiden: Brill, 2023.

Robin W. Winks and Thomas E. Kaiser, *Europe from the Old Regime to the Age of Revolution*, Oxford: Oxford University Press, 2004.

Abraham Wolf, *A History of Science, Technology and Philosophy in the Eighteenth Century*, New York: Macmillan, 1939.

David Wootton, *The Invention of Science: A New History of the Scientific Revolution*, London: Penguin, 2015.