I

INTRODUCTION

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"*Was ist Aufklärung?*" asked Immanuel Kant in 1784, and the issue has remained hotly debated ever since.[1] Not surprisingly, therefore, if we now pose the further question "What was Enlightenment *science?*" the uncertainties are just as great – but here the controversies assume a different air.

Studies of the Enlightenment proper paint the Age of Reason in dramatic hues and reflect partisan viewpoints: some praise it as the seedbed of modern liberty, others condemn it as the poisoned spring of authoritarianism and alienation.[2] Eighteenth-century science, by contrast, has typically been portrayed in more subdued tones. To most historians it lacks the heroic quality of what came before – the martyrdom of Bruno, Galileo's titanic clash with the Vatican, the "new astronomy" and "new philosophy" of the "scientific revolution," the sublime genius of a Descartes, Newton, or Leibniz.[3] After that

[1] James Schmidt (ed.), *What Is Enlightenment? Eighteenth Century Answers and Twentieth Century Questions* (Berkeley: University of California Press, 1996).

[2] Partisans of the Enlightenment include Peter Gay, who in his *The Enlightenment: An Interpretation*, vol. II: *The Science of Freedom* (London: Weidenfeld and Nicolson, 1970), applauds the *philosophes'* championing of science: "The philosophes seized upon the new science as an irresistible force and enlisted it in their polemics, identifying themselves with sound method, progress, success, the future" (p. 128). Eric Hobsbawm has recently written, "I believe that one of the few things that stands between us and an accelerated descent into darkness is the set of values inherited from the eighteenth-century Enlightenment," *On History* (London: Weidenfeld and Nicolson, 1997), p. 265.

Suspicious of the Enlightenment have been Lester G. Crocker, *An Age of Crisis: Man and World in Eighteenth Century French Thought* (Baltimore, MD: Johns Hopkins University Press, 1959); J. L. Talmon, *The Rise of Totalitarian Democracy* (Boston: Beacon Press, 1952); and Max Horkheimer and Theodor T. Adorno, *Dialectic of Enlightenment* (New York: Herder and Herder, 1972), all of whom read fascism and totalitarianism back into Enlightenment rationality.

[3] The drama of seventeenth-century developments is, of course, registered in the term "scientific revolution." Their "revolutionary" nature was expressed by many Enlightenment commentators, notably Fontenelle, although "the scientific revolution" is a modern coinage often challenged today. See I. Bernard Cohen, *Revolution in Science* (Cambridge, MA: Harvard University Press, 1985); Cohen, "The Eighteenth-Century Origins of the Concept of Scientific Revolution," *Journal of the History of Ideas*, 37 (1976), 257–88; H. Floris Cohen, *The Scientific Revolution: A Historiographical Inquiry* (Chicago: University of Chicago Press, 1994); John Henry, *The Scientific Revolution and the Origins of Modern Science* (London: Macmillan, 1997); David C. Lindberg, "Conceptions of the Scientific

age of heroes, the eighteenth century has been chid for being dull, a trough between the peaks of the "first" and the "second" scientific revolution, a lull before the storm of the Darwin debate and the astounding breakthroughs of nineteenth-century physics. At best, dwarves were perched on giants' shoulders. "The first half of the eighteenth century was a singularly bleak period in the history of scientific thought," judged Stephen Mason; the age was marked, thought H. T. Pledge, by "an element of dullness," due in part to its "too ambitious schemes" and its "obstructive crust of elaboration and formality."[4] "The lost half century in English medicine" was William Lefanu's corresponding label for the post-1700 era, whereas another medical historian, Fielding H. Garrison, characterized the entire century as an "age of theories and systems," bedeviled by a "mania for sterile, dry-as-dust classifications of everything in nature" – one fortunately succeeded by an era that brought "The Beginnings of Organized Advancement of Science."[5]

Given such judgments, it is not surprising that muted terms such as "consolidation" have come to mind for characterizing the natural sciences in the eighteenth century. Conceding that "when Newton died [1727] the great creative phase of the scientific revolution was already finished," Rupert Hall nevertheless stressed that "its acceptance and assimilation were still incomplete": such were the bread-and-butter tasks remaining for the eighteenth century to accomplish.[6]

Casting the job of "completion" in an altogether more positive light, however, Laurence Brockliss contends in his contribution to this volume (Chapter 3) that "if the Scientific Revolution is seen as a broader cultural moment whereby the Galilean/Newtonian mathematical and phenomenological approach to the natural world became part of the mind set of the European and American elite, then that Revolution occurred *in the eighteenth century* (pre-

Revolution from Bacon to Butterfield: A Preliminary Sketch," in David C. Lindberg and Robert S. Westman (eds.), *Reappraisals of the Scientific Revolution* (Cambridge University Press, 1990), pp. 1–26; Roy Porter and Mikuláš Teich (eds.), *The Scientific Revolution in National Context* (Cambridge University Press, 1992); John A. Schuster, "The Scientific Revolution," in R. C. Olby, G. N. Cantor, J. R. R. Christie, and M. J. S. Hodge (eds.), *Companion to the History of Modern Science* (London: Routledge, 1990), pp. 217–43. From a more philosophical standpoint, the writings of T. S. Kuhn remain stimulating: *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1962). Michael Fores's "Science and the 'Neolithic Paradox,'" *History of Science*, 21 (1983), 141–63, and his "Newton on a Horse: A Critique of the Historiographies of 'Technology' and 'Modernity,'" *History of Science*, 23 (1985), 351–78, attack the "myth" of the scientific revolution; Steven Shapin's *The Scientific Revolution* (Chicago: University of Chicago Press, 1996) – a work with an exceptionally fine bibliographical essay – opens provocatively: "There was no such thing as the Scientific Revolution, and this is a book about it" (p. 1).

[4] S. F. Mason, *Main Currents in Scientific Thought* (London: Routledge, 1956), p. 223; H. T. Pledge, *Science since 1500* (London: HMSO, 1939), p. 101.

[5] Fielding H. Garrison, *An Introduction to the History of Medicine* (Philadelphia: Saunders, 1917), p. 303; W. R. LeFanu, "The Lost Half Century in English Medicine, 1700–1750," *Bulletin of the History of Medicine*, 66 (1972), 319–48. For correctives, see the essay in this volume (Chapter 20) by Thomas Broman and also W. F. Bynum, "Health, Disease and Medical Care," in G. S. Rousseau and Roy Porter (eds.), *The Ferment of Knowledge* (Cambridge University Press, 1980), pp. 211–54.

[6] A. R. Hall, *The Scientific Revolution, 1500–1800* (London: Longman, 1954), p. iii.

dominantly outside the English-speaking world after 1750)."[7] And in a similar way, Margaret Jacob has pictured the century as the era when "scientific knowledge became an integral part of Western culture" or in other words became "public knowledge."[8] "Acceptance" and "assimilation" thus may be highly apposite epithets for eighteenth-century science, especially if they are intended not to excuse drabness but to highlight transformative processes. The incorporation of science into modernity was at least as momentous as the dazzling innovative leaps of a Kepler or Harvey; it certainly presents the historian with taxing problems to explain.[9]

It is important, in any case, that talk of "assimilation" and "consolidation" should not convey the false impression that all the great breakthroughs of early modern natural science had already been achieved by 1700 and that what remained was no more than a matter of dotting i's and crossing t's – or, in Kuhnian parlance, the pursuit of normal science within well-established paradigms.[10] We should not minimize the still inchoate condition in 1700 even of those sciences intimately associated with Newton, Huygens, Leibniz, and the other pioneers of a new mathematical physics; nor, indeed, should we forget that, at the turn of the century, Leibniz still had sixteen years to live and Newton twenty-seven, or that Newton's *Opticks* had not even been published. God may have said, "*Let Newton be, and all was light,*" but the light Newton had shed by 1700 was more like the first rays of dawn than the dazzle of the noonday sun. Although Simon Schaffer has well observed that, by the nineteenth century, "it became possible to see Newtonianism as the common sense of the physical sciences,"[11] that would be an anachronistic judgment if applied to its predecessor, for although Newton has often been "celebrated as bringing the mechanical philosophy to perfection," that was

[7] Italics added. Cf. Henry, *The Scientific Revolution*, p. 96, writing in the same mode about the eighteenth century: "It is possible to conclude that the very fact that they now saw natural philosophy in this way, and even dared to hope that it might be used to establish laws for the correct ordering and running of society, is in itself indicative that a revolution in the ordering of knowledge had indeed taken place. The scientific revolution was complete."

[8] Margaret C. Jacob, *The Cultural Meaning of the Scientific Revolution* (New York: Knopf, 1988), p. 3. For "public knowledge," see Larry Stewart, *The Rise of Public Science: Rhetoric, Technology, and Natural Philosophy in Newtonian Britain, 1660–1750* (Cambridge University Press, 1992).

[9] Highly influential has been Steven Shapin's and Simon Schaffer's *Leviathan and the Air Pump* (Princeton, NJ: Princeton University Press, 1985). This book raised, and attempted via a concrete case study to resolve, the crucial question of how the new science established its truth status, a problem to which Shapin returned in *A Social History of Truth: Civility and Science in Seventeenth-Century England* (Chicago: University of Chicago Press, 1994).

[10] T. S. Kuhn, *The Structure of Scientific Revolutions*. On the geographico-cultural diffusion of science, see, for instance, Henry Guerlac, *Newton on the Continent* (Ithaca, NY: Cornell University Press, 1981); Guerlac, "Where the Statue Stood, Divergent Loyalties to Newton in the Eighteenth Century," in Earl R. Wasserman (ed.), *Aspects of the Eighteenth Century* (Baltimore, MD: Johns Hopkins University Press, 1965), pp. 317–34; A. Rupert Hall, "Newton in France: A New View," *History of Science*, 13 (1975), 233–50.

[11] Simon Schaffer, "Newtonianism," in Olby et al. (eds.), *Companion to the History of Modern Science*, pp. 610–26, especially p. 611. For comment on the Pope quotation, see Steven Shapin, "Social Uses of Science," in Rousseau and Porter (eds.), *The Ferment of Knowledge*, pp. 93–142, especially p. 95.

hardly so, insists Steven Shapin.[12] The Lucasian Professor bequeathed as many problems as solutions, and, as Curtis Wilson's discussion of astronomy and cosmology (Chapter 14 in this volume) demonstrates, eighteenth-century astro-physicists were still making striking innovations – observational, computational, and theoretical.[13]

Even more remarkable, perhaps, and often interlinked, were contemporary developments in mathematics. To many European practitioners, Newton's methods appeared radically wanting. While British mathematicians were treading water, hampered by the clumsy Newtonian "fluxion" procedures, the Bernoullis, Maupertuis, Euler, Clairaut, d'Alembert, Lagrange, Laplace, and other Continental mathematicians, many of whom were closely linked with the Berlin, St. Petersburg, and Paris academies, made brilliant advances. Innovative techniques in analysis spurred the application of mathematics to many problems, including the motion of rigid bodies, vibration, hydromechanics, and tension; and conservation laws were developed that theorized the cosmos in terms alien to the cosmology of divine intervention championed by Newton, pointing toward Laplace's nebular hypothesis. Surveying the vis viva controversy and the strides made by rational mechanics, John Henry has recently confirmed that "eighteenth century developments in mathematics perhaps owe more to the achievements of Leibniz and the Bernoulli brothers, than to Newton, whose dominion over British mathematicians seems to have led to a noticeable decline."[14]

Moreover, the headway made by eighteenth-century mathematics was far from confined to the internal and technical achievements that form the core of Craig Fraser's contribution to this volume (Chapter 13). In the *Preliminary Discourse* to the *Encyclopédie,* Jean d'Alembert proclaimed mathematics to be the basis of all physical science:

> The use of mathematical knowledge is no less considerable in the examination of the terrestrial bodies that surround us [than it is in astronomy]. All the properties we observe in these bodies have relationships among themselves that are more or less accessible to us. The knowledge or the discovery of these relationships is almost always the only object that we are permitted to attain, and consequently the only one that we ought to propose for ourselves.[15]

Corroborating Margaret Jacob's claim that in the eighteenth century "scientific knowledge became an integral part of Western culture," historians have stressed the permeation of the "*esprit géometrique*" (or "calculating spirit")

[12] Shapin, *The Scientific Revolution,* p. 157.
[13] See also J. D. North, *The Fontana History of Astronomy and Cosmology* (London: Fontana, 1994).
[14] Henry, *The Scientific Revolution,* p. 94.
[15] Quoted in Thomas L. Hankins, *Science and the Enlightenment* (Cambridge University Press, 1985), pp. 46–7.

into everyday life, from life insurance to gambling and other situations in which the determination of probabilities became pressing.[16]

Nor was that all. As signaled many years ago by Herbert Butterfield's notoriously question-begging chapter heading, "The Postponed Scientific Revolution in Chemistry," one field that proved exceptionally innovative – in new experimental practices, practical discoveries, and theoretical reconceptualization – was chemistry. In his article in this volume (Chapter 16), Jan Golinski underscores the significance of the dramatic recognition that the atmosphere was not a uniform physical state but a mix of separate gases with distinct chemical properties. In that light he reassesses Butterfield's claim that Lavoisierian chemistry constituted the concluding chapter of the seventeenth-century "scientific revolution."[17]

Meanwhile, new specialties were taking shape, so that by the turn of the nineteenth century, as is shown here by Rhoda Rappaport (Chapter 18) and Shirley Roe (Chapter 17), terms such as "geology" and "biology" had been minted and were soon to become standard labels for emergent disciplinary domains. Aspects of the physical sciences amenable to experimental inquiry – notably magnetism, electricity, optics, fluid mechanics, pneumatics, the study of fire, heat, and other subtle or imponderable fluids, meteorology, strength of materials, hydrostatics and hygrometry, to list only the most prominent – took striking steps forward: as Rod Home emphasizes (Chapter 15), understanding of magnetism and electricity changed radically between 1700 and 1800. It ceased to be plausible to view physics, in the traditional, Aristotelian manner, primarily as a branch of philosophy: by 1800 true physics meant experimental physics.[18]

Even in well-plowed fields of inquiry such as natural history, remarkable changes can be seen. It was at this time, for instance, that plant sexuality was first fully established as the foundation for botanical thinking within the new and enduring taxonomic system developed by Linnaeus. The first evolutionary theories were advanced, associated (obliquely) with Buffon and (explicitly)

[16] For the calculating spirit and its applications in the realms of probability, see Gerd Gigerenzer, Zeno Swijtink, Theodore Porter, Lorraine Daston, John Beatty, and Lorenz Krüger, *The Empire of Chance* (Cambridge University Press, 1989); Ian Hacking, *The Emergence of Probability* (Cambridge University Press, 1975); Hacking, *The Taming of Chance* (Cambridge University Press, 1990); Lorraine Daston, *Classical Probability in the Enlightenment* (Princeton, NJ: Princeton University Press, 1988); Daston, "The Domestication of Risk: Mathematical Probability and Insurance 1650–1830," in Lorenz Krüger, Lorraine Daston, and M. Heidelberger (eds.), *The Probabilistic Revolution* (Ann Arbor: University of Michigan Press, 1987), pp. 237–60; Tore Frängsmyr, J. L. Heilbron, and Robin E. Rider (eds.), *The Quantifying Spirit in the 18th Century* (Berkeley: University of California Press, 1990).

[17] Herbert Butterfield, *The Origins of Modern Science, 1300–1800* (London: Bell, 1949). On that "postponed revolution," see William H. Brock, *The Fontana History of Chemistry* (London: Fontana, 1992), p. 86: "Lavoisier's synthesis of constitutional ideas and experiment appears as impressive as the work of Newton in physics the century before." For a different notion of "revolutionary" chemistry, see Archibald Clow and Nan L. Clow, *The Chemical Revolution: A Contribution to Social Technology* (London: Batchworth Press, 1952).

[18] For a recent study see, for instance, Patricia Fara, *Sympathetic Attractions: Magnetic Practices, Beliefs and Symbolism in Eighteenth-Century England* (Princeton, NJ: Princeton University Press, 1996).

with Erasmus Darwin and Lamarck.[19] It is not crudely Whiggish or merely celebratory of the so-called "forerunners of [Charles] Darwin"[20] to insist that theorists of life were finding that the static, hierarchical, and Christian Chain of Being no longer possessed explanatory power and that the living needed to be conceptualized within a more dynamic framework and an extended timescale. In short, wherever one looks, there was, during the eighteenth century, no stalling in scientific theory or practice, no shortage of what (depending on which philosophies or sociologies of science we adopt) we can call the "discovery," "invention," or "construction" of new knowledge.[21]

It would be wrong, however, to imply that eighteenth-century science deserves study solely for, and in respect of, its conceptual innovativeness. And this point leads us back to the notion of "consolidation." Gradually, unevenly, but, perhaps, inexorably, the production of knowledge about Nature and the casting of discourse in natural terms were playing increasingly prominent roles in culture, ideology, and society at large. Natural philosophers and historians were claiming their place in the sun alongside churchmen and humanists. Gentlemen of science – and, as Londa Schiebinger documents in this volume (Chapter 8), a handful of ladies, too – were winning admittance into the Republic of Letters and were changing its complexion in the process.[22] Furthermore, as Robert Fox (Chapter 5) and Rob Iliffe (Chapter 26) substantiate, governments were increasingly employing experts as administrators, explorers, civil and military engineers, propagandists, and managers of natural resources. Science was held to provide the knowledge base necessary for "enlightened absolutism," above all through statistics (*Statistik:* state information) and political arithmetic; scientific experts would be brokers in the Baconian marriage of knowledge and power. Looking back, historians might variously interpret such developments as progressive or, on the other hand, as acts of social policing; but, either way, natural knowledge acquired an enhanced public prominence during the last years of the *ancien régime,* mediating values and visions. Despite their radically disparate philosophical allegiances, the deeply pious Joseph Priestley and the *philosophe* Condorcet were both looking, during the French Revolutionary era, to a future society transformed by scientific discoveries and scientific rationality – one marked not merely by material improvements but by the perfectibility of humankind in a new heaven on Earth.[23]

[19] Jacques Roger, "The Living World," in Rousseau and Porter (eds.), *The Ferment of Knowledge,* pp. 255–84; Maureen McNeil, *Under the Banner of Science: Erasmus Darwin and His Age* (Manchester: Manchester University Press, 1987).

[20] Bentley Glass, Owsei Temkin, and William L. Straus (eds.), *Forerunners of Darwin, 1745–1859* (Baltimore, MD: Johns Hopkins University Press, 1968).

[21] For debates about scientific "knowledge," see Helge Kragh, *An Introduction to the Historiography of Science* (Cambridge University Press, 1987).

[22] Anne Goldgar, *Impolite Learning: Conduct and Community in the Republic of Letters 1680–1750* (New Haven, CT: Yale University Press, 1995).

[23] For state-employed experts, see Ken Alder, *Engineering the Revolution: Arms and Enlightenment in*

Some measure of science's growing authority is evident, as G. S. Rousseau observes in his discussion of literary responses (Chapter 33), in the vehemence of the Romantic revolt against it. The antiscience satires of the Augustan era – poking fun at virtuosi who peered down telescopes and mistook flies for elephants on the moon – give the impression that, around 1700, humanists still hardly discerned a scientific "threat." Indeed, many men of letters – not least, as we have already seen, Alexander Pope – were notably fulsome about scientific advances:

> Newton, pure Intelligence, whom God
> To Mortals lent, to trace his boundless Works
> From laws sublimely simple

sang James Thomson. Humanists were prominent in the dissemination of the sublime truths of the new science. In 1686, for instance, Bernard de Fontenelle produced his famous dialog *On The Plurality of Worlds* – the first work in France that made science both intelligible and entertaining to the general reading public. The man of letters thus conferred his blessing upon natural science, preparing the way, so to speak, for the cultural displacement of Christianity.

In stark contrast, there was something quite new in the venom of William Blake, directed in the late eighteenth century at the infernal trinity of Bacon, Locke, and Newton, as also in Charles Lamb's notorious toast to Newton's health "and confusion to mathematics," or, in its subtler manner, Goethe's formulation of an alternative to the mechanistic reductionism he deplored in Newtonianism. Mechanical science, judged Romantic critics, was turning into a veritable Frankenstein's monster.[24]

Perhaps the most telling index of this eighteenth-century "consolidation" of science is its embodiment in permanent institutional form. In earlier generations, natural knowledge had possessed few stable specialist platforms, and none unique unto itself. Most adepts had had to carve out a personal niche, be it at court, in the Church, or in academe; a few, such as Tycho Brahe, had been able to draw on private wealth, while others, such as Paracelsus, had lived

France, 1763–1815 (Princeton, NJ: Princeton University Press, 1997). For utilitarianism and progress see David Spadafora, *The Idea of Progress in Eighteenth Century Britain* (New Haven, CT: Yale University Press, 1990); Sidney Pollard, *The Idea of Progress: History and Society* (London: Watts, 1968); Keith Michael Baker, *Condorcet: From Natural Philosophy to Social Mathematics* (Chicago: University of Chicago Press, 1975).

[24] See the essay by Rousseau in this volume (Chapter 33) and also Gillian Beer, "Science and Literature," in Olby et al. (eds.), *Companion to the History of Modern Science*, pp. 783–98; Andrew Cunningham and Nicholas Jardine (eds.), *Romanticism and the Sciences* (Cambridge University Press, 1990); Marjorie Hope Nicolson, *Newton Demands the Muse: Newton's "Opticks" and the Eighteenth-Century Poets* (Princeton, NJ: Princeton University Press, 1946); Nicolson, *Science and Imagination* (Ithaca, NY: Cornell University Press, 1956); Joseph M. Levine, *The Battle of the Books: History and Literature in the Augustan Age* (Ithaca, NY: Cornell University Press, 1992). Thomson is quoted in Colin Russell, *Science and Social Change in Britain and Europe, 1700–1900* (New York: St. Martin's Press, 1983), p. 16.

hand-to-mouth. Although some educational foundations, as Brockliss here demonstrates, had given a modicum of encouragement to scientific and medical studies, the natural sciences could never become dominant in the traditional university system, whose rationale lay in training the clergy, a goal later supplemented by the aim of educating gentlemen or civil servants. In any case, by the 1700s universities were generally stagnating, although, of course, thanks to the Humboldtian reforms, they were to enjoy a surprising nineteenth-century resurrection.[25]

The precariousness of traditional institutional backing for science was alleviated during the eighteenth century. Many European rulers, with an eye, as Fox shows, to both practicality and prestige, made it their business to create state support programs for savants through such official bodies as the French Académie Royale des Sciences. Scientific academies, notably those in Paris, St. Petersburg, and Berlin, established clutches of permanent, state-funded posts for men of science; they might be seen as early engines of collective scientific research. In addition, scientific societies sprang up, national and local, formal and unofficial, practical and ornamental, closed and open. In his discussion in Chapter 4, James McClellan speaks of the sprouting of around a hundred of them by the close of the century, from Boston to Brussels, from Trondheim to Mannheim. Through such developments, the eighteenth century constituted, he contends, a "distinct era in the organizational and institutional history of European science," corroborating the view earlier canvassed that "the scientific enterprise became newly solidified in the eighteenth century."[26]

Leading lights in such academies also played other parts in spreading and seeding the natural sciences, for example among the wider circles of the salons. In France this was initially thanks to the efforts of Fontenelle, the perpetual secretary of the French Academy from 1699 to 1741, and also Voltaire, who popularized Newtonianism for French readers. "It was said of Socrates," wrote Joseph Addison, cofounder of the *Spectator,*

> that he brought Philosophy down from Heaven to inhabit among Men; and I shall be ambitious to have it said of me, that I have brought Philosophy out of Closets and Libraries, Schools and Colleges, to dwell in Clubs and Assemblies, at Tea-Tables and in Coffee Houses.[27]

[25] Laurence Brockliss, *French Higher Education in the Seventeenth and Eighteenth Centuries: A Cultural History* (Oxford: Clarendon Press, 1987); H. de Ridder-Symoens (ed.), *A History of the University in Europe*, vol. 2: *Universities in Early Modern Europe (1500–1800)* (Cambridge University Press, 1996); John Gascoigne, *Cambridge in the Age of the Enlightenment: Science, Religion and Politics from the Restoration to the French Revolution* (Cambridge University Press, 1989); Roger Emerson, "The Organization of Science and Its Pursuit in Early Modern Europe," in Olby et al. (eds.), *Companion to the History of Modern Science*, pp. 960–79.

[26] See also James E. McClellan III, *Science Reorganized: Scientific Societies in the Eighteenth Century* (New York: Columbia University Press, 1985).

[27] In D. F. Bond (ed.), *The Spectator*, 5 vols. (Oxford: Clarendon Press, 1965), vol. 1, p. 44. For Fontenelle, see Herbert Butterfield, *The Origins of Modern Science, 1300–1800* (London: Bell, 1949, 1950),

Alongside Addisonian moral and social philosophy, science too was infiltrating elite centers of social intercourse.

And if science was a growing presence within what Jürgen Habermas has styled the "public sphere" – in societies and salons, in lecture courses and museums – it was equally becoming established in the mind, as an ideological force and a prized ingredient in the approved cultural diet.[28] Controversies rage among historians – they are assessed in Chapter 6 by Mary Fissell and Roger Cooter – as to how best to interpret the outreach of science: "diffusion," "trickle down," and "social control" explanatory models have all been proposed, and in their turns severely criticized (here the "fried-egg" paradigm is the prime target for attack).[29]

"Supply and demand" models clearly beg many questions, but they at least have the virtue of recognizing that, in advanced regions of Europe, something like a marketplace in ideas had emerged. Consumers might buy into whichever aspects of science they chose, be they demonstrations in chemistry, or microscopes, or popular books such as Algarotti's *Newtonianism for the Ladies*. And the promoters of science were obliged to adjust their goods to what the market would bear: failure to do so could be disastrous, as is evident from the bankruptcies reported in Gerard Turner's account of the boom-and-bust trade in scientific apparatus (Chapter 22).

In complementary ways, Larry Stewart (Chapter 35) and Rob Iliffe trace the rise of the tangible empire of science, through exploration and colonization, and thereby provide further insights into its growing ideological hegemony.[30] "A comprehension of the power of Newton's natural philosophy, therefore, expanded beyond the colleges, or Crane Court [i.e., the Royal Society], or even beyond the subculture of instrument makers in Fleet Street," Stewart has elsewhere contended, discussing science's broadening appeal:

p. 144. For science within public culture, see Thomas Broman, "The Habermasian Public Sphere and 'Science *in* the Enlightenment'," *History of Science*, 36 (1998), 123–49, and J. Habermas, *The Structural Transformation of the Public Sphere: An Inquiry into a Category of Bourgeois Society* (Cambridge, MA: MIT Press, 1989). Valuable work on public science has been published by Simon Schaffer: "Natural Philosophy and Public Spectacle in the Eighteenth Century," *History of Science*, 21 (1983), 1–43; Schaffer, "The Consuming Flame: Electrical Showmen and Tory Mystics in the World of Goods," in John Brewer and Roy Porter (eds.), *Consumption and the World of Goods in the 17th and 18th Centuries* (London: Routledge, 1993), pp. 489–526. For Voltaire, see F. M. Voltaire, *Letters Concerning the English Nation* (London: printed for C. Davis and A. Lyon, 1733).

[28] Jan Golinski, *Science as Public Culture: Chemistry and Enlightenment in Britain, 1760–1820* (Cambridge University Press, 1992); Stewart, *The Rise of Public Science*; Larry Stewart, *Industry and Enterprise in Britain: From the Scientific to the Industrial Revolution 1640–1790* (London: Athlone Press, 1995).

[29] See in particular Roger Cooter and Stephen Pumfrey, "Separate Spheres and Public Places: Reflections on the History of Science Popularization and Science in Popular Culture," *History of Science*, 32 (1994), 237–67.

[30] Larry Stewart, "Public Lectures and Private Patronage in Newtonian England," *Isis*, 77 (1986), 47–58; Stewart, "The Selling of Newton: Science and Technology in Early Eighteenth-Century England," *Journal of British Studies*, 25 (1986), 179–92. The ideological uses of science have especially been emphasized by Margaret C. Jacob: *The Newtonians and the English Revolution 1689–1720* (Hassocks, Sussex: Harvester Press, 1976), p. 18:

> . . . the social fluidity and the commerce of rationality in enlightenment England rested on the presumptions of the concrete, the practical and the entertaining. The efforts of those like Joseph Addison and Richard Steele in the coffeehouses, the *Spectator* could easily reflect, forced 'Philosophy out of Closets and Libraries, Schools and Colleges'. The sanction of natural philosophy came to rest in a far wider community than literacy alone might lead us to expect; the liberty of the coffeehouses may have been one reason, just as certainly as the rising cult of money was another.[31]

Within the Enlightenment project, the discourses of philosophy, poetry, religion, and politics appropriated the scientific methods and models associated with Bacon and Descartes, Galileo and Gassendi, and, above all, Newton. There were Newtonian poems galore, Newtonian theories of government, corpuscularian models of society, of political economy, of the mind and the passions, all disseminated by magazines and spread through provincial assemblies from Newcastle to Naples. Although such revisionist historians as J. C. D. Clark have recently questioned the importance of natural science to the consciousness of the age, E. P. Thompson was surely nearer the mark in maintaining that "the bourgeois and the scientific revolutions in England . . . were clearly a good deal more than just good friends"; the same holds for the relations between science and polite society in the Dutch Republic, the German principalities, the Italian duchies, and the Swiss cantons.[32]

Although the Enlightenment assuredly involved far more than the uptake of natural science, it would have been unthinkable without the surge of confidence in human powers over Nature conferred by the new philosophy. For the *philosophes*, scientific inquiry was the new broom *par excellence* that would sweep mystifications and obscurantism aside, removing the mumbo-jumbo of the Church and the "feudal" ways that kept the masses poor, hungry, and oppressed – that much is evident from a glimpse at any of the twenty-eight

> This social explanation for the triumph of Newtonianism in the late seventeenth century stresses what previous commentators have ignored – its usefulness to the intellectual leaders of the Anglican church as an underpinning for their vision of what they liked to call the "world politick." The ordered, providentially guided, mathematically regulated universe of Newton gave a model for a stable and prosperous polity, ruled by the self-interest of men.

The idea of the empire of humankind over nature, central to the understanding of eighteenth-century science, is well expressed by Paula Findlen's title: *Possessing Nature: Museums, Collecting, and Scientific Culture in Early Modern Italy* (Berkeley: University of California Press, 1994). See also James A. Secord, "Newton in the Nursery: Tom Telescope and the Philosophy of Tops and Balls, 1761–1838," *History of Science*, 23 (1985), 127–51.

[31] Stewart, *The Rise of Public Science*, pp. xxxi–xxxii.

[32] E. P. Thompson, "The Peculiarities of the English," in his *The Poverty of Theory and Other Essays* (London: Merlin Press, 1978), pp. 35–91, especially p. 60. Contrast J. C. D. Clark, *Revolution and Rebellion: State and Society in England in the Seventeenth and Eighteenth Centuries* (Cambridge University Press, 1986).

For science and the *philosophes*, see Hankins, *Science and the Enlightenment*, and Dorinda Outram, *The Enlightenment* (Cambridge University Press, 1995). Colin Kiernan's *Enlightenment and Science in Eighteenth-Century France*, 2nd ed. (*Studies on Voltaire and the Eighteenth Century*, 59, Genève, 1968), although stimulating, employs a Lovejoyan "history of ideas" approach that now looks very dated.