The Selling of Newton: Science and Technology in Early Eighteenth-Century England

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In the past decade the role of science in the early eighteenth century has come in for close scrutiny and increasing debate. There is specifically one rather large and problematic issue, that is, the relationship between science and technology in England in the first half of the eighteenth century when, it is generally agreed, the Industrial Revolution had not yet made any discernible impact. There are those historians who have insisted that the Newtonian natural philosophy had nothing whatever to do with the mechanical creations and innovations of artisans and craftsmen.[1] This may be understandable because Newtonian science has come to be regarded as fundamentally mathematical and experimental—and not even comprehensible, except in the broadest terms, to the Augustan virtuosos.[2] This has often created the version of science as a purely rational and cerebral activity distanced from and above technology, a science unsullied perhaps by the grime of mechanics' hands. One might speculate on the ideological origins of such a universe, but it seems that one can at least see that such a version of events is determined in part by the question that proposes a

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[1] A. Rupert Hall, "What Did the Industrial Revolution Owe to Science?" in *Historical Perspectives: Studies in English Thought and Society in Honour of J. H. Plumb,* ed. Neil McKendrick (London, 1974), pp. 129–51; and Peter Mathias, "Who Unbound Prometheus?" in *Science and Society, 1600–1900,* ed. Peter Mathias (Cambridge, 1972), pp. 54–80.

[2] For a recent sophisticated form of this argument, see Michael Fores, "Constructed Science and the Seventeenth Century 'Revolution,' " *History of Science* 22 (1984): 235–39. Compare Peter Mathias, *The Transformation of England: Essays in the Economic and Social History of England in the Eighteenth Century* (London, 1979), pp. 77–84; and George Timmons, "Education and Technology in the Industrial Revolution," *History of Technology* 8 (1983): 137–38.

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direct causal relation between cerebral science and rank technology.[3] The argument evidently is that, if one cannot find the historical evidence that establishes a precise link between Newton's interparticulate forces and the partial vacuum of the Savery engine, then one must conclude that no relationship existed.

But historical associations are never quite so simple. One could easily demonstrate that the Newtonian natural philosophy was deliberately propagated among men whose interests tended to be more practical than philosophical. It is not to make any grand ideological claim to state that Newton's science found its way into the commercial coffeehouses of London in the early eighteenth century where it encountered an eager and receptive audience. Public lectures were the vehicle by which an otherwise esoteric and incomprehensible mathematical natural philosophy was made intelligible to a wider public than could have been expected to have read the *Principia*. Indeed, in 1735 the schoolmaster, lecturer, and instrument maker Benjamin Martin made this specific objection against some of the more famous explications of Newtonianism. Henry Pemberton's *View of Sir Isaac Newton's Philosophy* may have been "too expensive for the Purse of the Publick in general," as was Newton's *Principia* itself. But John Clarke's *Physics* (Martin meant the translation of Samuel Clarke's commentary on Rohault) was defective in "Order and Method," while even the highly popular *Physico-Theology* of William Derham gave "a delightful view of Nature broke all to Pieces."[4] It was this situation, in part, that authors and lecturers like Martin sought to correct. For example, one of the most prolific of the eighteenth-century lecturers, John Theophilus Desaguliers, endeavored to cover in his courses what he regarded as the essential topics of natural philosophy. These regularly included mechanics, hydrostatics, and Newton's laws of motion as well as his experiments in optics.[5] An undated prospectus, but cer-

[3] Compare Mathias, "Who Unbound Prometheus?" p. 69.

[4] Benjamin Martin, *The Philosophical Grammar; Being a View of the Present State of Experimental Physiology, or Natural Philosophy* (London, 1735), p. vi; and John R. Millburn, *Benjamin Martin: Author, Instrument-Maker, and "Country Showman"* (Leiden, 1976), pp. 13–16. Henry Pemberton, *A View of Sir Isaac Newton's Philosophy* (London, 1728). *Rohault's system of natural philosophy, illustrated with Dr. Samuel Clarke's notes, taken mostley out of Sr. Isaac Newton's philosophy, with additions*, trans. John Clarke (London, 1723). William Derham, *Physico-Theology: or, A demonstration of the being and attributes of God, from his works of creation* (London, 1713).

[5] J. T. Desaguliers, *Physico-Mechanical Lectures. Or, an Account of What is Explain'd and Demonstrated in the Course of Mechanical and Experimental Philosophy . . . Design'd for the Use of All Such as have seen, or may see Courses of Experimental Philosophy* (London, 1717), p. 2.

tainly after 1716, Desaguliers's "Course of Mechanical and Experimental Philosophy" included not only hydrostatics, the properties of air, and optics but also "explanations of Newton's law of gravity and a model of an Engine for raising Water by Fire."[6] A similar prospectus of 1725 made it clear that "any one, though unskill'd in Mathematical Sciences, may be able to understand all those Phaenomena of Nature, which have been discovered by Geometrical Principles, or accounted for by Experiments."[7]

While the origins of the public scientific lectures are uncertain, shortly after the Revolution of 1688 they were on their way to becoming an industry. Following a lead set by chemical demonstrators in the late seventeenth century, the Reverend John Harris gave mathematical lectures at the Marine Coffee House in Birchin Lane, behind the Royal Exchange, in a series established by the brewer Charles Cox "for the public good." After almost a decade Harris was succeeded by James Hodgson, who had recently left the employ of the astronomer Flamsteed to join with the elder Francis Hauksbee, the instrument maker, in lectures on experimental philosophy.[8] Hodgson continued to lecture with Hauksbee and at the Marine until 1709 or 1710, having obtained an appointment at Christ's Hospital Mathematical School at the end of 1708. The lectures at the Marine were then continued by Humphry Ditton, one of the most interesting and underestimated of the Newtonian polemicists until his early death in the spring of 1715.[9]

The connection between Christ's and the Marine Coffee House suggests that education, whether formal or popular, was characterized by a deliberate aspect of utility. Christ's Hospital Mathematical School was specifically designed to prepare boys in the art of navigation in order to fit them to become apprentices to the captains of ships.[10] We know that, when Hodgson initially became involved with the elder Hauksbee in 1704, the courses were advertised to be given at Ayers's

[6] J. T. Desaguliers, "A Course of Mechanical and Experimental Philosophy," Bodleian Library (Bodl.), Rawlinson MS D. 871, p. 14.

[7] John-Theophilus Desaguliers, *A Course of Mechanical and Experimental Philosophy* (London, 1725), p. 2.

[8] Margaret Rowbottom, "The Teaching of Experimental Philosophy in England, 1700–1730," *XIe Congres international d'histoire des sciences (1965): Actes IV* (1968), pp. 46–53; William Cudworth, *Life and Correspondence of Abraham Sharp, the Yorkshire mathematician and astronomer, and assistant to Flamsteed* (London, 1889), p. 81.

[9] Until 1710, Hauksbee's shop was located in Giltspur Street, near Christ's Hospital. At that point, Hauksbee moved to Wine Office Court, Fleet Street, near Senex and the Royal Society. (*Dictionary of Scientific Biography* [New York, 1972], 6:169.)

[10] Nicholas Hans, *New Trends in Education in the Eighteenth Century*, 2d impression (London, 1966), pp. 213–14; Ralph Davis, *The Rise of the English Shipping Industry* (Newton Abbot, 1972), pp. 124–26.

Writing School in St. Paul's Churchyard. This may represent the origins of Hodgson's friendship with Thomas Ayers, writing master and teacher of navigation, whom Hodgson nominated to fellowship in the Royal Society in 1707. Ayers's practical interests were indicated by his early activities in the society when he discussed some of the numerous technical proposals and claims made by the Huguenot Denis Papin. Furthermore, Ayers was concerned in the agreement signed with Sir James Lowther in 1715 to exploit the Newcomen engine, a matter in which several of the Newtonians had an interest.[11]

These associations merely represent a glance at a world in which the lecturers as entrepreneurs of science found that they had a commodity that merchants as well as the aristocracy found attractive. Toward the end of the reign of Queen Anne the result was the emergence of a veritable industry of science, joined by Desaguliers from Oxford and William Whiston, sent down from Cambridge for unorthodox religious views that he adamantly refused to conceal. Few of these lecturers, whose numbers continued to grow throughout the first half of the century, stuck to the niceties of experimentalism. On the contrary, many effectively sold their lectures as practical and useful. When the Whig pamphleteer Richard Steele organized in 1712 a series of entertainments, including science, in the institution that he called his "Censorium," he explicitly proposed that "All the works of Invention, All the Sciences, as well as mechanick Arts will have their turn."[12] What Steele and the lecturers were doing was acknowledging that their audience was no longer limited merely to royalty or aristocracy. This was confirmed in 1719 by Desaguliers, who had then become involved with Steele's enterprise. In that year Desaguliers advertised a course of experimental philosophy to include an improvement on the Savery engine "of the greatest Use for draining Mines, supplying Towns with Water, and Gentlemens Houses."[13] It is undoubtedly the case that such an approach was very successful. By 1734 it is estimated that he was engaged in his 121st course, some consisting of 300 experiments.[14]

By the end of the third decade of the century, public lectures had become an enterprise extending far beyond London. Desaguliers had

[11] E. G. R. Taylor, *Mathematical Practitioners of Tudor and Stuart England* (Cambridge, 1954), pp. 141–42, 276; see also Alan Smith, "Steam and the City: The Committee of Proprietors of the Invention for Raising Water by Fire, 1715–1735," *Transactions of the Newcomen Society* 49 (1977–78): 8–9. Ayers died in 1715.

[12] John Loftis, "Richard Steele's Censorium," *Huntington Library Quarterly* 14 (1950): 43, 54; Marjorie Nicolson and G. S. Rousseau, *"This Long Disease, My Life": Alexander Pope and the Sciences* (Princeton, N.J., 1968), p. 143.

[13] *The Weekly-Journal or Saturday's-Post* (January 10, 1719).

[14] Hans, pp. 138–41; Rowbottom, pp. 47, 51.

lectured in Holland, the chemist Peter Shaw had entertained in Scarborough, and even the aging William Whiston had taken to wandering the provinces discoursing on Providence and the Millennium.[15] As early as 1712 James Jurin, a product of Christ's Hospital Mathematical School as well as of Cambridge, was lecturing on natural philosophy at Newcastle. Jurin, who became prominent as secretary of the Royal Society, had important contacts among such northern industrialists as William Cotesworth. Perhaps the increasing industrialization of the area, even in the early part of the century, ensured sufficient interest in the possibilities claimed for natural philosophy.[16]

Jurin was succeeded in the north by John Horsley, a Presbyterian minister who lectured at Morpeth and Newcastle on natural philosophy in the early 1720s. Horsley was also the agent of the York Buildings Company, which, after the Jacobite Rebellion of 1715, purchased from the crown the confiscated estate of Widdrington, near Morpeth. This episode was one that turns out to be critical to the connections between science and industrialism this essay will try to establish.[17] Although he was later in Bath and London and was elected a fellow of the Royal Society in 1730, Horsley continued to lecture at Morpeth until just before his death in 1732. By that time the rage for scientific lectures had its own momentum. Isaac Thompson was lecturing in Durham in 1730 and in Newcastle in the following year. The northern lecturers met with such success that Desaguliers was reported to have given some thought to challenging them for an audience. In 1741 the *Newcastle Courant* reported that Desaguliers intended to perform a course on experimental philosophy and that "he will be particularly serviceable to Gentlemen concerned in Collieries &c, as knowing an infallible Method to clear Coal Pits of Damp."[18]

[15] See James E. Force, *William Whiston: Honest Newtonian* (Cambridge, 1985), pp. 20–21.

[16] A. E. Musson and Eric Robinson, *Science and Technology in the Industrial Revolution* (Toronto, 1969), pp. 159–60; F. J. G. Robinson, "A Philosophic War: An Episode in Eighteenth Century Scientific Lecturing in North-East England," *Transactions of the Architectural and Archaeological Society of Durham and Northumberland* 2 (1970): 102; Edward Hughes, *North Country Life in the Eighteenth Century: The North East, 1700–1750* (London, 1952), pp. 99, 343, 376, 417; and Joyce M. Ellis, *A Study of the Business Fortunes of William Cotesworth, c. 1688–1726* (New York, 1981), passim.

[17] There is a reference to a Mr. Horseley in J. Cockburne to [Christian Cole?], October 26, 1721, Scottish Record Office (SRO), York Buildings Society Papers, Gifts and Deposits (GD) 1/170/1/3. Employment with the company and its purchase of the Widdrington Estate is suggested by John Horsley, "An Account of the Depth of Rain fallen from April 1, 1722 to April 1, 1723, Observed at Widdrington in Northumberland," *Philosophical Transactions of the Royal Society of London* 33, no. 377 (May–June 1723): 328–29.

[18] Robinson, pp. 103–4. On Desaguliers's interest in the problem, see Royal Society,

The importance of such entrepreneurs of science as Desaguliers or Harris lies not merely in their roles as proponents of Newtonian philosophy. Equally significant were the claims that such individuals made for those who attended the lectures and became well versed in natural philosophy and experimentalism. The Newtonians made the most of their opportunities in a world that made public support of their lectures and subscription to their books just as possible as private patronage had once been limited. That is not to say that private patronage was insignificant. On the contrary, in some circumstances it was very much alive, as it was for Desaguliers, who cultivated the support of James Brydges, the first duke of Chandos. Yet this too led into the world of entrepreneurs and financiers in the warrens and alleys around the Royal Exchange. It was in these quarters, as in the Marine in Birchin Lane, that opportunities abounded in the flood of projects that very nearly swamped early eighteenth-century commerce.

When we look closely at some of the commercial projects both before and after the South Sea Bubble of 1720, at a time when scientific lectures were the newest rage, we find a remarkable convergence of scientific and financial interests. It is undoubtedly the case that the fantastic growth of inventions for raising water in the late seventeenth and early eighteenth centuries had a great deal to do not only with difficulties in mining but also with the great financial benefits that might accrue to the successful inventor. Both the Savery and the Newcomen engines for raising water by fire fit this mold.

There were numerous demands for a mechanical invention that might make a water supply both more reliable and more economical. One suspects that Sir James Lowther may well have been associated with the New River Company, which dated from Jacobean times but which, in the early eighteenth century, undertook studies on the feasibility of the introduction of engines to assist it to bring water from Islington and Uxbridge in the west to London. By 1712 Lowther apparently examined steam engines in London, and by 1715 he was a major figure in the group that was attempting to market the Newcomen engine.[19] The designs to divert the Uxbridge water were continually re-

London, Royal Society MSS, Register Book (C), 19:193–94; and J. T. Desaguliers, "An Account of an Instrument or Machine for changing the Air of the Room of sick People in a little Time, by either drawing out the foul Air, or forcing in fresh Air; or doing both successively, without opening Doors or Windows," *Philosophical Transactions of the Royal Society of London* 39, no. 437 (April–June 1735): 48. On ventilators, see D. G. C. Allen and R. E. Schofield, *Stephen Hales: Scientist and Philanthropist* (London, 1980), pp. 81 ff.

[19] British Library (BL), Loan 29/2, New River Co., Miscellaneous Papers, May, 1704; Smith, p. 8.

born in the first decades of the century until, in 1721, Desaguliers became involved in a survey to demonstrate that the project was indeed viable. His advice was taken so seriously that he testified before the House of Commons on behalf of the proposal, although the scheme faltered because of enormous opposition in the counties drained by the Uxbridge streams.[20] The plan, however, was revived in 1724 when Desaguliers suggested that the fears of mill owners might be allayed if their waterwheels were converted from undershot to overshot. Desaguliers's calculations were challenged for their accuracy, however, along with his reputation "as a projector, a profess'd Mathematician, and Experienced Philosopher."[21] This obstacle to his project provoked Desaguliers into a printed open letter in which he offered to demonstrate the benefits to the millers, provided they would drop their opposition if he succeeded. His associates, he reported, were ready to drop their intentions if he failed.[22] The involvement of such a prominent Newtonian as Desaguliers in such an enterprise was only a minor aspect of a wide range of such practical concerns in which they were engaged.

One of the most important of the water-supply groups was that involved in the York Buildings in the Strand, the site of the major concert rooms during the reign of William and, later, of Steele's Censorium. At least as early as 1712 several Savery engines were in use in London. The most significant was one that the York Buildings Company, otherwise known as the Thames Water, employed to supply London with water. The Thames Water Supply Company had received its royal patent in 1675, but the old company was sold in 1719 on the eve of the South Sea speculations to a group of shareholders under the direction of Case Billingsley, something of a financial buccaneer who had an interest in the applications of scientific discovery. This group also involved James Brydges, who had, in 1716, appointed Desaguliers his personal chaplain. In fact, Desaguliers's prime responsibilities were that of a consultant to the duke and to the companies in which Chandos was engaged.

[20] J. T. Desaguliers, "A Plan of the Design for bringing Water from the Village of Drayton for the better Supplying the Cities of London and Westminster with Water" (marginalia) (March 1720/1), Public Record Office (PRO), MPF 259; and PRO, State Papers (SP) (Domestic) 35/25, no. 104, March 4, 1720/1; Mathias, "Who Unbound Prometheus?" (n. 1 above), p. 68, n. 1.

[21] Jno. Warner to [George Cooke?], January 9, 1724[/5?], BL, Lansdowne MS 841, fols. 113–14; Cooke to [Warner?], February 8, 1723/4, BL, Lansdowne MS 841, fols. 120–21.

[22] BL, Lansdowne MS 1056, fol. 47. J. T. D——rs, "A Letter to W. Bow——r, Esq:" January 9, 1724/5. See BL, Lansdowne MS 841, fols. 116–18, January 12, 1724/5.

The kinds of opportunities made possible by the water-supply companies were only a small part of a much wider array of commercial contacts that sought to exploit the scientific entrepreneurs of the period. There is no question that those whom we have known largely as scientific lecturers spent ample time trying to secure patents for one kind of invention or another. For example, in 1720 Desaguliers, along with Daniel Niblet, a coppersmith, and William Vream, an instrument maker, obtained a patent for a device that used the heat of steam to dry various substances from hops to gunpowder and turpentine.[23] William Vream had formerly been employed by the elder Francis Hauksbee, who died in 1713, and had more recently been associated with Desaguliers.[24] Niblet maintained his alliance with Desaguliers at least until 1736, when they were still assessing improvements to the steam engine.[25] The younger Francis Hauksbee, who had carved out a position for himself as an instrument maker, lecturer, and, ultimately, curator of experiments for the Royal Society, attempted in 1728 to secure a patent for "a new Method of Applying the Centrifugal Force of a Body Moving in a Curve Line to the Moving of all the Various kinds of Mechanical and Hydraulical Engines or Instruments."[26] Unfortunately, like most patent applicants in the early part of the century, Hauksbee was as vague as he could be and still maintain his credibility. A much more mundane example was the application in 1724 of Case Billingsley, of the York Buildings Company, for a patent for a newly improved water engine. Probably a column-of-water engine, it was likely the result of efforts to avoid the difficulties that the York Buildings Company was having with its engines.[27]

What little we have seen suggests that the lecturers evidently sought to exploit the kinds of contacts we might have expected them to make in the coffeehouses of London. This intense concern with practicality is reflected in such works as John Harris's *Lexicon Technicum*

[23] Warrant for patent dated June 9, 1720, BL, Hardwicke Papers, Additional (Add.) MS 36123, fol. 5. Vream seems to have been employed as Desaguliers's assistant at this point (see James Brydges to J. T. Desaguliers, February 15, 1719/20, Huntington Library [HL], Stowe MS 57, vol. 17, fols. 11–12).

[24] E. G. R. Taylor, *Mathematical Practitioners of Hanoverian England* (Cambridge, 1966), p. 145.

[25] Duke of Chandos to Sir George Beaumont, March 26, 1736, HL, Stowe MS 57, vol. 47, fols. 171–72.

[26] PRO, SP (Domestic) 36/10/95–100, March 8, 1728.

[27] Pat Rogers, "Gulliver and the Engineers," *Modern Language Review* 70 (1970): 264, n. 1; BL, Add. MS 36123, fols. 41–42, July 31, 1724. The patent was issued on May 25, 1727 (BL, Add. MS 36276A).

and Desaguliers's *Course of Experimental Philosophy*.[28] Harris was engaged as an investor in various projects given birth in Exchange Alley. During 1709 and 1710, when Harris was secretary of the Royal Society, he was also a member of the Court of Assistants of the recently united Mines Royal and Mineral and Battery Works, of which Newton was a deputy governor.[29] It was the charter of this company that was the target of a purchase by the petitioners for a marine insurance scheme known as the Royal Exchange Assurance led by Billingsley.[30] It can further be established that the York Buildings Company, in which both Desaguliers and Chandos were involved, was the central link in this circle of enterprises. The group had access to King George's advisers through Christian Cole, a York Buildings operative who provided stock to courtiers who assisted the company over the hurdles of obtaining patents.[31] We know as well that John Harris was among the subscribers of what then ultimately became the Royal Exchange Assurance and that he was also directly involved in the initial formation of the Sun Fire Office, which insured the buildings and merchandise of traders rather than their ships.[32] The links among Harris, the Sun Fire Office, and the Royal Exchange Assurance serve as only one example of the connections between the companies and the lecturers on experimental philosophy.

By 1719, in the midst of Billingsley's maneuvers, Desaguliers had become engaged with Steele's Censorium when he began a course of experiments, this time in French, possibly in response to an interest among the French refugees in the capital.[33] A parallel series was then introduced in the evenings by Benjamin Worster and Thomas Watts.[34] The involvement of Worster and Watts in the Censorium is an important indication of the widening circle of connection among the lecturers and their patrons. Worster was engaged in 1720 by Watts at the

[28] John Harris, *Lexicon Technicum: or, An universal English dictionary of arts and sciences* (London, 1704–10); and J. T. Desaguliers, *A Course of Experimental Philosophy* (London, 1734–44).

[29] Sir George Clark, *Science and Social Welfare in the Age of Newton,* 2d ed. (Oxford, 1970), pp. 66–67; BL, Loan 16, Records of the Mines Royal and the Mineral and Battery Works, vol. 2, fol. 233; vol. 3, fol. 98.

[30] For some of Billingsley's activities, see John Carswell, *The South Sea Bubble* (London, 1960), pp. 167–68, 171–72; and Rogers, pp. 263–64.

[31] Case Billingsley to Cole, February 21, 1718[/9?], Billingsley to Cole, January 6, 1718/9, and Billingsley to Cole, January 29, 1718/9, SRO, GD 1/170/1.

[32] P. G. M. Dickson, *The Sun Insurance Office, 1710–1960* (London, 1960), p. 268.

[33] *Daily Courant* (April 5, 1714); likewise Bodl., Rawlinson MS D. 871, n.d.

[34] *Daily Courant* (January 12, February 25, September 28, and November 11, 1719). With Richard Steele, see *Daily Post,* no. 26 (November 2, 1719).

Academy in Little Tower Street to teach experimental natural philosophy.

While this school was well enough known, little seems to have been determined of its activities and of those engaged there. Watts's academy was only one of several such establishments, of which the most famous in the eighteenth century was probably the Soho Academy, founded about 1718 by Martin Clare, later a fellow of the Royal Society. Watts's institution seems to have predated the Soho Academy by about three years and was initially located in Abchurch Lane near Exchange Alley in Cornhill. In 1719 Watts moved further to the east, to Little Tower Street, closer perhaps to the instrument makers' shops near the Tower and the river.[35] This school, originally called the Accomptant's Office, catered primarily to the education of clerks and accountants, but the demand for natural philosophy provided an opportunity Watts could not ignore. This was largely the result of Watts's association with William Whiston and Humphry Ditton. By 1727 the school had been so successful that it included several courses on mathematics and natural philosophy by James Stirling the mathematician, Peter Brown, and William Vream the instrument maker. Stirling and Brown were employed in the academy, and Vream, who made the instruments, we have already met as Desaguliers's assistant.[36]

The activities of many of these lecturers constantly suggest contact with the commercial world. This was true of Harris, and it was true of Whiston and Ditton, whose proposals on navigation would have struck a responsive chord among the merchants and traders who frequented many of the coffeehouses near the Royal Exchange, where Watts's academy first took form. Likewise, Watts deliberately straddled the spheres of commerce and natural philosophy and so should forestall the temptation of historians to separate these worlds too readily.

The move in the early eighteenth century from private patronage to the public of the coffeehouses represents a venture into commerce

[35] Musson and Robinson (n. 16 above), pp. 41, 119; Geoffrey Holmes, *Augustan England: Professions, State and Society, 1680–1730* (London, 1982), p. 51; and Mary M. Robischon, "Scientific Instrument Makers in London during the Seventeenth and Eighteenth Centuries" (Ph.D. thesis, University of Michigan, 1983), p. 166.

[36] Stirling evidently owed his post to the influence of Newton until he left in 1735 for employment with the Scotch Mines Co. at Leadhills in Lanarkshire. Stirling likely was engaged earlier with this group, probably through the connections of Watts. (Musson and Robinson, pp. 41–42; HL, Stowe MS 57, vol. 45, fol. 135.) On Stirling, see Charles Tweedie, *James Stirling: A Sketch of His Life and Works along with His Scientific Correspondence* (Oxford, 1922).

for the entrepreneurs of science. They were not shy in responding to the needs of the patrons they encountered. In part this explains the emergence of a great number of practical inventions from those who were otherwise active in public lectures. Besides Desaguliers and Watts, there was the younger Francis Hauksbee, who, with Benjamin Robinson of the York Buildings Company, obtained a patent in 1728 "for preserving the Planks and Sheathing of Ships sailing to the East and West Indies."[37] Within two months Hauksbee obtained yet another patent, this time with Benjamin Lund, a Quaker merchant of Bristol, for "a method for the more advantagious manufacturing of Copper Oare & extracting Silver from Copper and mixing of Copper Calamy & Charcoale together for making Brass."[38] Their patent was immediately challenged by the Bristol Brass Company, especially their claim to be able to extract silver from the copper ores, although the crown upheld the patent.[39]

It was this web of connection among a wide range of companies that provided the philosophical lecturers the chance to exploit their talents as inventors. This was especially true of the water-supply companies and those engaged in extractive industries such as mining, where knowledge of the latest steam devices or of the methods of assaying and smelting of ores might be in great demand. The utilization of the Savery and Newcomen inventions by partnerships and joint stocks is a good example. This was even the case among the groups created to export knowledge of the Newcomen engine to Europe at a time when the aftermath of the South Sea Bubble was making it difficult for joint-stock companies to operate with their customary abandon. Several of the individuals concerned were connected with Desaguliers, who was, as his advertisements for his lectures tell us, actively demonstrating the principles of steam technology. It was Desaguliers who recommended Joseph Fischer von Erlach to his former student the Dutch experimentalist s'Gravesande in 1721 for a proposed engine to be built for the landgrave of Hesse. In September 1720, the engineer John O'Kelly, about whom very little is known, arrived in Liege to construct an engine to drain the coal mines with his partners Canon Wanzoulle, Baron d'Eynstatten d'Aubay, and Lambert van den Steen. O'Kelly too seems to have had some connection with Desa-

[37] PRO, SP (Domestic) 36/5/115–20, February 8, 1727/8.

[38] PRO, SP (Domestic) 36/5/253–62, March 30, 1728. On Robinson's involvement with the York Buildings Company, see PRO, Treasury Board Papers, T1/258, fols. 92–93.

[39] PRO, SP (Domestic) 36/2/86–109, January 6, 1727; BL, Hardwicke Papers, Add. MS 36142, vol. 714, fols. 135–39, October 23, 1730.

guliers, for, when the partners had a falling out and O'Kelly was in danger of being imprisoned for debt, it was Desaguliers's patron, the duke of Chandos, who intervened with the secretary of state, Lord Carteret, once he had obtained details of the case.[40] Such connections were important even in international affairs.

Politics, likewise, in the form of the Jacobite rebellions, provided more opportunities. In the north of England during 1721 and 1722, the York Buildings Company was desperately seeking ways to exploit the land that it had agreed to purchase from the Forfeited Estates Commission. Instrumental in this activity was the lecturer John Horsely.[41] York Buildings was one company that was linked through the partners Case Billingsley, John Essington, and Thomas Chambers to the Corporation of Copper Miners in England by an agreement signed in 1720.[42] Throughout the next decade this turned into a cause for much dispute between the partners and a source of many problems for the York Company. This may be one reason that Hauksbee and Benjamin Lund sought to exploit their knowledge of copper ores by way of a patent. By 1730, however, there is no question that the connections were established between the York Company and Lund, for he was then employed on their estates in Scotland building a furnace to be used in the smelting of copper ores they had discovered.[43] When the copper ores did not prove to be as plentiful as they first thought, James Marye, who was an agent of both the York Company and the English Copper Com-

[40] Chandos to Mr. Bridges, January 19, 1721/2, HL, Stowe MS 57, vol. 18, fol. 363; Chandos to Lord Carteret, April 28, 1722, HL, Stowe MS 57, vol. 20, ms Film 417, fol. 206; G. J. Hollister-Short, "The Introduction of the Newcomen Engine into Europe," *Transactions of the Newcomen Society* 48 (1976–77): 11–12, 21. On O'Kelly, see Herve Hasquin, *Une Mutation: Le "Pays de Charleroi" aux XVIIe et XVIIIe siecles: Aux origines de la Revolution Industrielle en Belgique* (Brussels, 1971), pp. 135–36. I owe this reference to Margaret Jacob.

[41] Cockburne to [Cole?], October 26, 1721, and Cockburne to [Cole?], November 21, 1721, SRO, York Buildings Society Papers, GD 1/170/1.

[42] John Essington, Billingsley, and Tho: Chambers to Cole, March 31, 1721, SRO, GD 1/170. *Articles of Agreement Made, Constituted, and Agreed upon upon the twentieth day of July in the Year of our Lord One thousand, seven hundred and twenty. Between the Governor and Company of Copper-Miners in England, of the First Part. Thomas Chambers, jun. of the Transfer-Office in the East-India House, London, Gent. of the Second Part. And John Essington of Wandsworth in the County of Surrey, Esq; James Bradley, and Case Billingsley of London, Merchants, of the Third Part* (London, 1725) (BL shelf mark 522.m.12 [3]).

[43] Chandos to James Marye (of the York Buildings Co.), June 25, 1730, HL, Stowe MS 57, vol. 35, fol. 101; Chandos to Colonel Samuel Horsey (of the York Buildings Co.), July 5, 1730, HL, Stowe MS 57, vol. 35, fol. 133; Chandos to Horsey, July 16, 1730, HL, Stowe MS 57, vol. 35, fol. 161; and Chandos to Horsey, August 28, 1730, HL, Stowe MS 57, vol. 35, fol. 225.

pany, attempted, unsuccessfully, to obtain a patent to refine lead ore.[44] Only two months later Lund and Hauksbee succeeded in defending their patent for refining copper ores against the attacks of the Bristol Brass Company.

The lines of interlocking directorships and joint stocks among the companies would, and sometimes did, take a parliamentary inquiry to disentangle. Throughout the 1720s Billingsley was engaged in a series of lawsuits that even the courts could not manage. Disputes arose involving the English Copper Company, the Welsh Copper Miners Company, James Bradley, who had been Billingsley's partner as solicitor operating from the Royal Exchange, and John Essington, who owned and operated mills and furnaces at Wandsworth and Wimbledon in Surrey, as well as Thomas Chambers, who was apparently treasurer of the English Copper Miners.[45] Many of the participants in the suits, such as Essington and John Hardwar, were members of the committee that oversaw the operations of the York Buildings Company.[46] In such an atmosphere it is no wonder that the patent of Lund and Hauksbee turned contentious so quickly.

What is important about these companies and many others like them is that they provided numerous opportunities that the natural philosophers, experimentalists, and their instrument makers were able to exploit. Unfortunately, this rich vein has long remained unexplored, occasioning comment only when it became obvious to the eye, and then it was far too often dismissed as a mere curiosity. We know now that, when James Stirling, who taught mathematics in Watts's academy for virtually a decade, left to become manager of the Scotch Mines Company at Leadhills in Lanarkshire, he was following a track well-worn by the scientific entrepreneurs of the period—literally. In 1734 both Watts and Stirling consulted about a trip to Scotland and about the prospects of the York Buildings Company, of which the Scotch Mines Company may merely have been an outcrop. In any case, there is no doubt that the Scotch Mines were run from London by the Sun Fire Office and Thomas Watts. When their Scottish agent Sir John Erskine gave up because of the "wretched order" of their affairs, it

[44] BL, Hardwicke Papers, Add. MS 36142, vol. 714, fols. 117–19, August 6, 1730.

[45] PRO, Chancery Bills and Answers, C11/1455/8. On Thomas Chambers, see Cyril Hart, *The Industrial History of Dean* (Newton Abbot, 1971), pp. 105–7.

[46] SRO, York Buildings Society Papers, Court of Assistants, GD 1/170; *Benjamin Bradley* v. *Governor and Company of Copper Miners,* June 6, 1730, PRO, C11/1483/14. Billingsley's partner, James Bradley, was the son of Benjamin Bradley of the Merchant Taylors' Co. (Guildhall Library, London, Index to Freemen, 1530–1929, s.v. "Merchant Taylors' Co., 1711").

was Watts's associate Stirling who filled the breach.[47] Like Desaguliers before him, Stirling later was engaged in surveying of waterways.[48]

The fleeting glimpses we catch of scientific lecturers near the Royal Exchange or in the coffeehouses of country towns tell us a little of the dynamism of Newtonian England. In the early eighteenth century there was emerging the kind of social and economic structure that made the manipulation of nature not only possible but also desirable. Who better to do so than those who claimed to know nature best? Who better to encourage them than improving landlords and financiers who were spurred to act by a financial revolution that promoted exploitation? What is striking about this attitude, which some found to be reprehensible and corrupt, was that the disruptions of the financial markets wrought by the South Sea Bubble in 1720 merely caused many to pause momentarily before engaging in the next project.

It needs to be recognized that landowners were no more immune to the promises of self-styled engineers than were the early industrialists. Witness the constant ventures of Sir James Lowther of Whitehaven, the earls of Dudley, or the earl of Hopetoun and Archibald Grant in Scotland to exploit the resources of their estates or of land they leased on a speculative basis—in some measure by employing those who were familiar with the world of the London natural philosophers and public lecturers.[49] Natural philosophers such as Desaguliers were effective in marketing their knowledge as the foundation for improvement. Because of this, improvement—as an eighteenth-century spectacle—has an epistemological foundation closely linked to the success of Newtonian natural philosophy. This is not the same thing as claiming Newtonianism produced industrialism. But nor were these aspects of eighteenth-century culture in effective quarantine from one another. Newtonian science, and especially the manner in which it was so vigorously sold, fits nicely into the power relations of a society that was just constructing the incipient framework of capitalism that was to make the Industrial Revolution possible. This should not, however, be reduced to a necessary foundation or to an ideological one. Rather, the

[47] Dickson (n. 32 above), app. 6; T. C. Smout, "Lead-Mining in Scotland, 1650–1850," in *Studies in Scottish Business History,* ed. Peter L. Payne (London, 1967), pp. 119–20, 124–25; Chandos to Mr. [Thomas] Watts, November 28, 1729, HL, Stowe MS 57, vol. 34, fols. 3–4.

[48] Chandos to Mr. Farquharson (his steward), October 28, 1734, HL, Stowe MS 57, vol. 45, fol. 135; Musson and Robinson (n. 16 above), pp. 41–42.

[49] Smout, pp. 115–19; John S. Allen, "The 1712 and Other Newcomen Engines of the Earls of Dudley," *Transactions of the Newcomen Society* 37 (1964–65): 57–84, and "The 1715 and Other Newcomen Engines at Whitehaven, Cumberland," *Transactions of the Newcomen Society* 45 (1972–73): 237–68.

relationship between natural philosophy and the emergence of an industrial England was a subtle one that was tied to the forces of land as much as to the marketplace, to the interests of the aristocracy who scoured their estates as to those views of radical materialists or heterodox theologians.

If we are to approach the meaning of Newtonianism for the early eighteenth century, we have to recognize that Newton's followers created from his natural philosophy a social movement of many facets within the intellectual and political circumstances of late Stuart and early Hanoverian England. Perhaps Newton would not have recognized such a creation, although it is doubtful that anyone kept awake by the noise and smoke of the Mint could have missed what was happening. It was not Desaguliers's position as chaplain to the duke of Chandos that helped to establish the acceptability of the technologically oriented lectures. Such lectures were obviously successful beyond the social world of the aristocracy and would have been so without either Desaguliers or Chandos.[50] Both were responding to the circumstances that helped to engineer the transformation that found expression in the Industrial Revolution. What is remarkable about the lecturer and his lordship was that they were aware of the small role they had in the larger scheme that they tried time and time again to orchestrate. Obviously, natural philosophers were not immune to the blandishments of commercialism. If this led them to project technical success that they failed to deliver, we must not ignore the involvement of Newton's apostles with incipient industrialism. Only in appreciating their context as they did will we see the consequences of Newton's disciples as clearly.

[50] Compare Arnold Thackray, *Atoms and Powers: An Essay on Newtonian Matter-Theory and the Development of Chemistry* (Cambridge, Mass., 1970), pp. 235–36.