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The Truth of Newton's Science and the Truth of Science's History: Heroic Science at Its Eighteenth-Century Formulation

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Lecturing on Newtonian mechanics and dynamics around 1800, the natural philosopher John Dalton employed all the standard demonstrations in what had become by then a well-established genre of scientific education. On his tabletop he used oscillating devices, pendulums, balls made of various substances, levers, pulleys, inclined planes, cylinders of wood, lead in water, and pieces of iron on mercury to illustrate phenomena as diverse as gravitation, the "3 laws of motion of Newton," impulse or the "great law of percussion," force and inertia, specific gravity, attraction and magnetism.[1] There was nothing extraordinary in what Dalton was doing, first in his Quaker school then at New College in Manchester. The genre of British lecturing focused on Newtonian mechanics had begun in the second decade of the eighteenth century with the travels and publications of Francis Hauksbee, Jean Desaguliers, and Willem s'Gravesande who lectured in the Dutch Republic.[2] Dalton was deeply indebted to their legacy. His terse manuscript notes on his lectures – charred from a fire in 1940 – tell us that in one lecture he used a "machine with mercury, water-cork," and it was intended to illustrate, of all things, the effect on the planets of the "Cartesian Vortices."

In talking about the Cartesian vortices, and in explaining how wrongheaded they had been as a conceptual device for understanding

1 The manuscript lecture notes made by Dalton survive at the John Rylands University Library of Manchester, John Dalton Papers, no. 83, and appear to be dated randomly from 1796 to 1818. They have been partially damaged by fire. I wish to thank National Science Foundation (NSF) grant no. 9310699, which made possible this research and Dale Bowling for his work in the Manchester archives. On Dalton's lectures and his debt to popular Newtonianism, see Arnold Thackray, *John Dalton: Critical Assessments of His Life and Science* (Cambridge, Mass.: Harvard University Press, 1972), pp. 47–8, 66–7.

2 See *A Course of Mechanical, Optical, Hydrostatical, and Pneumatical Experiments. To be perform'd by Francis Hauksbee . . . lectures read by William Whiston, M.A.* (London, [1713]); J. T. Desaguliers, *A Course of Experimental Philosophy*, 2 vols. (London, 1745).

planetary motion, Dalton was repeating an old Newtonian trope. In the process he was flogging a truly dead horse. Indeed, even in French colleges after the 1750s Descartes's horse had survived only in a few places and then by artificial resuscitation.[3] By midcentury the pressure to teach Newtonian science had become all but overwhelming. In Britain the vortices had been passé by the 1720s.[4] By then Desaguliers had dismissed Newton's great predecessor with this historical aside: "When M. DesCartes's philosophical Romance . . . had overthrown the Aristotelian Physicks, the World receiv'd but little Advantage by the Change."[5] The demise of the vortices among the literate and scientifically curious had been insured by Newtonian lecturers like Desaguliers who never missed an opportunity to attack the fundamentals of Cartesian science. His colleague on the Newtonian lecture circuit, Benjamin Martin, went further and denounced Decartes because "he adopted the old atheistical Tenets of Lucretius."[6] In illustrating the vortices as late as the 1790s, Dalton was perhaps being a bit lazy; he was just following a tried and true lecture format passed along over two generations. He was also – unwittingly – teaching the heroic history of the new science that had been put in place during Newton's lifetime. The science, and the history told about it, were of a piece. But Dalton was a natural philosopher, soon to become famous and join the pantheon of heroes who laid the foundations of modern chemistry. Like his Newtonian predecessors, Dalton was not, nor did he aspire to be, a historian.

The contributors to this volume do aspire to being historians. Indeed, we have written on this occasion to honor a master of the historical genre, the late Betty Jo Teeter Dobbs. To illustrate her importance we have chosen to deal with one of the most fundamental

3 L. W. Brockliss, *French Higher Education in the Seventeenth and Eighteenth Centuries* (Oxford: Clarendon Press, 1987), pp. 353–8, 376–80, 366. There was still, however, a strong emphasis on mathematical skills in French university courses. The French colleges are the nearest equivalent to the dissenting academies. In the year XI, the first *Bulletin de la société pour l'industrie nationale* (Paris), p. 179, still complained that "on s'est peu occupé en France de technologie, et jamais cette étude n'a fait partie de l'instruction publique." This reference was supplied by Jeff Horn.

4 On the rise of Newtonian science in the universities, see Gordon Donaldson, *Four Centuries. Edinburgh University Life, 1583–1983* (Edinburgh: University of Edinburgh Press, 1983), p. 34; and John Gascoigne, *Cambridge in the Age of the Enlightenment: Science, Religion and Politics from the Restoration to the French Revolution* (Cambridge: Cambridge University Press, 1989).

5 Preface to Desaguliers, *A Course of Experimental Philosophy*.

6 B. Martin, *A Panegyrick on the Newtonian Philosophy, shewing the Nature and Dignity of the Science; and its absolute Necessity to the perfection of Human Nature; the Improvement of the Arts and Sciences, the Promotion of True Religion, the Increase of Wealth and Honour, and the Completion of Human Felicity* (London, 1754), p. 6.

questions raised by her work, and explicitly by her lecture that opens this collection. Was there a Scientific Revolution in the period from 1543 to 1687? Is it even appropriate to use the term "revolution"? Some historians of science think it was borrowed only in the eighteenth century, largely from political events, and used by Enlightenment polemicists intent upon distancing modern Western culture from its religious foundations. Dobbs argued that the term was an anachronism. She followed I. B. Cohen in believing that none of the major participants in the so-called revolution of the seventeenth century ever used the term to describe what had happened. But Cohen had overlooked evidence of Boyle's having used it precisely to describe the transformation in intellectual life he experienced in midcentury England. In addition, Dobbs believed that "the word 'revolution' hardly began to acquire its modern meaning until the eighteenth century." We now know that, just as we should have expected, the term was being applied to political events by the late 1650s.[7] It was evolving just then to signal the occurrence of irrevocable, dramatic change. In addition, this modern usage in late seventeenth-century political affairs, which then took hold in the eighteenth century to describe the rise of the new science, was far more widespread than simply what can be found in the polemics of the French *philosophes*. Indeed, as I am about to argue, the revolutionary character of science was one of the central premises at work among the post-1700 British and European disseminators of the new science. They described it as revolutionary almost as an afterthought, as a way of introducing their science. The linkage of their heroic and revolutionary account of the history of science with the explication of Newtonian science gave extraordinary staying power to the first long after the second had been transformed. But saying it was revolutionary and heroic – a dramatic and irrevocable change effected by a few individuals – need not make it so.

Old or new, contemporaneous or posthumous, the notion of there having been a Scientific Revolution might still just be quite simply wrongheaded. Or alternatively its eighteenth-century version might be obviously, incontrovertibly, true. In his essay Richard Westfall argues (also posthumously) in contrast to Dobbs's position, that because science is everywhere a part of our present-day lives, there must have been, metaphorically speaking, a revolutionary moment. Unashamedly, Westfall embraces an essentially eighteenth-century narrative.

7 Ilan Rachum, "The Meaning of 'Revolution' in the English Revolution (1648–1660)," *Journal of the History of Ideas* 56 (1995): 195–215. Cohen did not have this article available but he also thought that between 1640 and 1660 no changes of lasting value occurred. See I. Bernard Cohen, *Revolution in Science* (Cambridge, Mass: Harvard University Press, 1985), p. 67.

He dates the "moment" according to the publications of its heroes, as commencing with Copernicus in 1543, continued by Galileo, Kepler, and Descartes, completed by Boyle and Newton. The revolution was all over with the *Principia* (1687). Indeed, Westfall would have the Scientific Revolution be more important than the Renaissance or the Reformation, without for a second considering that it would never have happened had those other two epochs not preceded it. So, too, he effortlessly attributes historical causation. Both the Enlightenment and the Industrial Revolution were directly the product of the earlier revolution in science. Westfall never tells us how Newton could have been deeply pious, obsessed with both God's work and word, and an enlightened deist – in Westfall's account almost a secret *philosophe*. Nor does he provide a narrative of how the linkages were established between the new scientific culture of the eighteenth century and the technological innovation that comes at its end. Late in the twentieth century the Scientific Revolution remains a subject fraught with assertions.

Given such massive disagreements among the masters, predictably many of our contributors have implicitly steered away from the meta-issue of – or if – the Scientific Revolution. Instead they have wisely reiterated the importance of religion and "magic" to nearly every one of the major players in the revolution that may never have happened, or they have pointed to how very little about it was self-evident to contemporaries. To them Kircher might have been another Newton. Who in northwestern Europe around 1650 thought that alchemy had at best a generation left to its vitality? Previous historians have seen Boyle and his contemporaries fighting over correct science; since the late 1970s with the work of James R. Jacob we have seen them awash in the revolutionary turmoil of mid-seventeenth-century England.[8] Where once we read only Boyle's *The Sceptical Chymist*, now every tick and dot in his manuscripts have been analyzed. It is not so much that works have been decanonized. Rather the canon of what is deemed relevant to the rise of the mechanical philosophy has been vastly expanded now to include alchemy, theology, religious convictions, and political interests. All the once-designated "heroes" are in fact still very much central to the story this volume addresses, only now their complexity has served to make them seem more accessible and certainly less "scientific." In this volume we are even prepared to take seriously a comparison of Newton with the anti-Copernican Jesuit, Athanasius Kircher. If Protestant heroes could rise up from their graves, I would not want to be Paula Findlen.

8 James R. Jacob, *Robert Boyle and the English Revolution* (New York: Burt Franklin, 1977).

Historical judgments about canonicity and stature depend upon a lengthy process of shifting and weighing, of accumulation, of the new being assessed and assimilated, of values as well as creativity being defined, recognized, and then enshrined. The would-be king of Denmark got to be immortalized as *Hamlet* and the lad from Lincolnshire got to be one of the heroes of modern science as a result of a historical process. Heroes are not born, they are made. However brilliant Kepler or Newton had been, their innovative contributions would have remained relatively unknown, or esoteric, possibly even banished, without a larger transformation in the way literate westerners conceived both nature and history. My task here is to examine the historicity of scientific hero formation complete with its revolutionary implications. I seek not to relativize so as to dismiss the revolutionary character of the new understanding of nature, or to deny the obvious genius of the leading figures whose work helped bring it about. Rather my point is to get beyond the hyperbole and to examine the values – what was at stake – to those who took up the new learning and enshrined its revolutionary and heroic mystique. If this exercise in historicizing the history of science is successful, then it may occur to readers (would that my friend Betty Jo could be one of them) that the stakes were then, and are now, very high. If we make the move to diminish, or dismiss, the depth and breadth of the intellectual transformation in the Western understanding of nature (bracketed between roughly 1540 and 1750), we want to be sure about what it is that we are giving up.

As we broaden the canon and explore the context, we need to understand that although Newton and Boyle – and who knows how many others among their contemporaries – were, in their different ways, practicing alchemists, this fact does not alter the profound character of the intellectual transformation described by the somewhat misleading, shorthand phrase, the Scientific Revolution. That intellectual transformation can be dismissed only if we believe that two elements alone define it: the heroes had to be pure, simply great "scientists," and they alone made it happen. In effect, if the older historiography erred on the side of simplicity, then the history it sought to convey can be dismissed. The logic of the dismissal is flawed. Finally, and not least, if the history of science as a discipline abandons a central problematic, that of explaining how and why Westerners moved to mechanize the world picture, then it would lose, not enhance, one of its most important raisons d'être. In the West, at least, revolutions tend to keep their readerships.

Let me now return to the end of the history making about deification and rapid change in the Western approach to nature, to 1800 and

John Dalton, to the latter stages of a process that had been underway for at least three generations. In one set of lectures Dalton set the stakes and proclaimed the importance of the science he was about to teach. "It will be universally allowed that the cultivation of Mechanical Science, in the present state of society especially, is an object of primary importance. It is true, the arts and manufactures, are all interested in the science." Such interest in mechanics for manufacturing had not always prevailed. The ancients, in contrast to the moderns, knew "little of Mechanics as a science." Both duty and self-interest require that people now employed in mechanical occupations, or in their supervision, need to know mechanical principles in detail. Dalton believed that the very success of British ingenuity in manufacturing, transportation, and instrumentation hung upon a knowledge of Newtonian mechanics. As they contemplated French competition, Dalton's audience – he trusted – would have been the first to acknowledge the importance of national prestige and wealth, and hence the importance of mechanical science. By the late eighteenth century natural philosophers added to the heroic story of science's achievements a message about its essential role in progress and prosperity. It was a global and competitive vision with which we in the late twentieth century are still familiar.

The modern science of mechanics, as well as mathematics, had its unique heroes, its founders and originators. Dalton laid them out in a simple historical narrative: Galileo "who lived about two centuries ago," followed by Newton, Leibniz, and the Bernouillis. There have been many other contributors but only a few, Dalton implies, are worth naming. As had his predecessors, Dalton aimed his lectures at the industrious part of the nation. He told them that only one eighteenth-century person stood worthy to be ranked with the Galileos and the Newtons: John Smeaton, civil engineer, canal builder, harnesser of water power in the service of mechanized industry.[9] So coupled, engineers like Smeaton, as well as their friends and employers, could imagine themselves to be scientists.

The Smeatons and the Watts could even try to become amateur historians, collecting letters and memorabilia of their great predecessors. Writing to Smeaton's and Dalton's contemporary, James Watt, a friend sought to know about letters between Newton and Fatio de

9 Michael Adas, *Machines as the Measure of Men: Science, Technology, and Ideologies of Western Dominance* (Ithaca, N.Y.: Cornell University Press, 1989), chap. 2. On the early history of Cartesian lecturing in France, see J. L. Heilbron, *Electricity in the 17th and 18th Centuries: A Study of Early Modern Physics* (Berkeley: University of California Press, 1979), pp. 146–59; by the 1740s women were more numerous than men at the Parisian lectures (p. 163).

Duillier. Watt was supposed to have acquired them and "I would give anything to have a Scrap, however insignificant of his writing."[10] During his life and long after, Newton enjoyed a large crowd of worshipers. If in those letters Watt had discovered Newton's millenarianism, he would have found it quaint, but hardly a reason to stop his sons from mastering mechanics or dim his own admiration for either science or Newton.

The inspiring history Dalton told, and someone like Watt believed, claimed in passing that science required genius and promoted mechanized industry and progress. The stakes raised by both science and its history could hardly have been higher. Within the culture of practical science that emerged in eighteenth-century Britain participants as diverse as itinerant lecturers, craftsmen in metal and steam, engineers as well as entrepreneurs could imagine themselves – however unoriginal their daily contributions – as standing on the shoulders of giants. Only piety and Godliness were missing from Dalton's remaining lecture notes. But there was no shortage of preachers and teachers willing to make the godly connection.

Dalton and his Newtonian predecessors added to the true science of Newton what could be presumed by his audience to be an equally true history of science. All the history one needed to know was there: Newton had been right about the vacuum and Descartes had been wrong about the vortices. The development of science was a progressive story of great discoveries punctuated by the occasional misdirected theory; such had been the swirling vortices. In the eighteenth century the history of the heroes of true science framed the presentation of natural knowledge. Their history got told with the science, almost as the filler, the enticement to spark interest among a restless, not scientifically literate, audience. Within this history lay the key to human enlightenment, to a new intellectual freedom. Watt and his industrial friends actually believed that true science and philosophy promised to destroy "the very foundation of Enthusiasm, Superstition, and all Kinds of Imposture. . . . What glaring instances of this Truth has this last century produced? Where are now the Wizards and Necromancers, the Pseudo-Prophets, the Demoniacs, the Wonder-working Relicts, and the Group of Omnipotent Priests that formerly swarm'd in this Island?"[11] The articulation of English liberty, religious freedom for Protestants, the demise of quackery, the progress of industry, and the history of science were seen to be of a piece.

Little wonder that the heroic narrative of socially isolated geniuses,

10 See Eric Robinson and D. McKie, eds., *Partners in Science: Letters of James Watt and Joseph Black* (London: Constable, 1970), pp. 272–3, dated 1797.

11 Ibid., p. 50.

first articulated in the eighteenth century, survived well into the twentieth. Decoupling it from the truthfulness of scientific laws has taken a generation or more of historical scholarship. It has been difficult and controversial to create a textured, nuanced, and historically informed understanding of modern science at its origins. The rise of postwar and now contemporary scholarship about science has required the dismantling of assumptions about isolation, about disinterest, about purity as the key to brilliance – in short, about the way history and human beings work – which were once taken to be as certain as the very science learned in lecture hall, pulpit, and school. The search for a richer, more textured history should not, however, lead us to turn away from some of the earliest historical associations of the new science. We cannot imagine that the revolutionary legacy of science has nothing to do with us, that in effect we have never been modern. As both modern historians with our methods, and as citizens with our expectations, we are in part science's beneficiaries.

Our legacy received its most widespread, European dissemination in the revolutionary decade of the 1790s. What Dalton taught to his paying audiences, teachers inculcated into their captive ones. The youngest son of James Watt, Gregory, being of Scottish origin was suitably trained at Glasgow College. There in the 1790s the education for the whole man rested on philosophy and science. Drawn to the radical voices of the decade and deeply interested in reform, the young Watt scribbled in his student notebooks his belief that natural knowledge and virtue bear a relation "more intimate than one can imagine." The "tree of science never flourishes where good dispositions have not prepared the soil." Wealth and power without virtuous industry and learning produce "a crowd of servile sycophants." Even Francis Bacon got his office by his own exertions, and Bacon was, of course, a true son of the Reformation. In rather florid terms Watt was being taught – rightly in my view – that Bacon could not have written as he did had he not been a Protestant. History, he was being told with hyperbole, teaches that when the Catholic Church dominated the "blossoms of science continued to droop." No progress was made until Bacon like the "rising sun illumined the learned world . . . [and] The system of Aristotle sunk beneath him."[12] At Glasgow, science and its history revealed the revolutionary progress of Protestants. On their odyssey away from superstition toward science and good government, piety and Godliness ensured a providentially guided progress.

In the 1790s one did not have to be a radical or an industrialist to

12 Gregory Watt's exercise book, 1793; James Watt MSS, C4/C18A, Birmingham City Library.

learn the meaning of science and its history. One did not even have to be a man. Teaching science to young women outside of London at precisely the same moment as Dalton lectured and Watt studied, Margaret Bryan told a very similar historical and scientific tale. Her textbook in mechanics, *Lectures on Natural Philosophy: The Result of Many Years' Practical Experience of the Facts Elucidated* (London, 1806), grew out of her many years as headmistress of a girl's school. Bryan dedicated it to Princess Charlotte of Wales and the naturalist, Charles Hutton, who encouraged the project. According to Bryan, piety was the reward promised by the mastery of both science and its history. She proposed to arm young women and all readers "with a perpetual talisman," which will "guard your religious and moral principles against all innovations." Bryan presents herself as "merely a reflector of the intrinsic light of superior genius and erudition" who is translating and moderating knowledge for readers without "profound mathematical energies." Male writers and lecturers often said similarly modest and enticing things.

Bryan confesses to being a follower of William Paley's version of natural theology. In effect, she revered a century-long tradition of Newtonian preaching that became fashionable with the 1705–6 Boyle Lectures of Samuel Clarke. Physicotheology based upon mechanical science taught that order and harmony in the universe sanctioned tranquillity and hierarchy in society as well as the rule of law. A century and more of political stability, born out of revolution, only confirmed the theology.

Like Desaguliers (a mere youth in 1688–9), Margaret Bryan begins with Newtonian definitions of matter and gravity and in the process introduces students to the history of the new science beginning with Galileo and leading to brief historical discussions of Boyle, Guericke, through to Newton. In now tried-and-true fashion, the textbook of 1806 simultaneously turns to levers, weights, and pulleys to illustrate Newtonian mechanics. Air pumps, atmospheric pressure, pneumatics in general, hydrostatics, hydraulics, magnetism, electricity, optics, astronomy (on which she had written another whole book) are all illustrated by experimental demonstrations. Bryan concludes with "Of Man as a Machine," which despite its materialist sounding title, attributes the wonderful mechanism of the human body to divine artifice. She caps off the scientific instruction with a preachy lecture on stoicism, obedience, cheerfulness, affection, and duty. True to her general conservatism, piety, science, and history are then placed in the service of politeness.

British men and women of the eighteenth century, and beyond, found in Newtonian science and its edifying history of genius upon genius, beginning with Galileo and culminating in Newton, one source of immense national pride and accomplishment. Theirs was a nationalist history of science. As Francis Hauksbee told his audiences as early as the reign of Anne, "after many ages had pass'd, with little or no Progress in the True Knowledge of the nature of things, greater advances have been made within the compass of a small number of years, than was easily to be imagined." Boyle and Newton have been principally responsible for the extraordinary, recent progress of science.[13] A few decades later, in the age of Whig oligarchy, the nationalist theme was still going strong, and James Ferguson explained how back in the 1650s, inspired by Francis Bacon, Boyle came on the scene. He eradicated "the old notions of the schools so strongly possessed [in] people's minds at that time." Then in the 1660s came the Royal Society and "true philosophy began to be the reigning taste of the age, and continues so to this day." The British were the first to lay the foundations of physics; the followers of Newton, now named by Ferguson one by one, along with their Continental followers from s'Gravesande to Nollet in France, "have . . . also acquired just applause."[14] From Newton's lifetime to his second generation of followers, scientific achievement inspired national pride. English science complemented an edifying history created, it was believed, by freeborn English people. It also justified an imperial expansion that supposedly brought light into a darkness bereft of scientific knowledge.

The history of science we inherited was not simply a self-serving British invention. On the European Continent, particularly in the French academies, teachers and eulogists charged with reporting on "an extraordinary revolution in science" had been extolling the virtues of the scientific heroes for much of the eighteenth century.[15] In addition, late-seventeenth-century Cartesians had pioneered the genre of the public lecture aimed at the literate and affluent. During the reign of Louis XIV, even the most cautious among the French lecturers were prepared to proclaim science as vaguely "progressive," if not shackled by the antique and the dogmatic.[16] Here too history fitted implicitly into the story. Where we can find lecture notes comparable with those left by Dalton – for example, Samuel Koenig's vastly more detailed

13 F. Hauksbee, *Physico-Mechanical Experiments On Various Subjects . . .* (London, 1709), pref.

14 *Ferguson's Lectures on Select Subjects . . . ,* ed. David Brewster (Philadelphia, 1806), preface by Ferguson (d. 1776), pp. xiii–xv.

15 Charles B. Paul, *Science and Immortality. The Éloges of the Paris Academy of Sciences (1699–1791)* (Berkleley: University of California Press, 1980), p. 20; the phrase belongs to Charles B. Paul.

16 Jacques Rouhault, *Physica. Latine reddidit . . . S. Clarke* (London, 1697), author's preface.

lectures of 1751 – we can see the integration of science with its history, all now in the service of an enlightenment for educated elites.[17] By the 1730s the scientific culture of the French, particularly as disseminated by Newtonians like Voltaire, became Western.

Trained by the foremost Newtonian explicator, Madame du Châtelet, Koenig supplemented his income by lecturing, in this instance in The Hague. Of course, by the time of his lectures Dutch audiences had been hearing about Newton and his heroic feats for at least two generations.[18] In the early 1700s students at Leiden learned from Boerhaave that "Newton is the miracle of our time." Perhaps only Francis Bacon could be described as being in some sense his intellectual equal.[19] But by 1750 The Hague enjoyed a rich, international clientele. The city housed embassies and the court of the newly restored Dutch stadholder and his entourage. Among them were Charles and William Bentinck, connoisseurs of the moderate Enlightenment and patrons of various reform-minded intellectuals; both Diderot and Rousseau would become their guests.

Koenig's audience to whom he spoke in French were "un certain nombre de personnes de goût . . . de distinction et de mérite." Here at a provincial outpost of the Enlightenment Koenig aimed to show how the logic of nature, properly understood, could deliver men from their prejudices, "nous armons contre la superstition qui entend la tirannie sur la surface de la terre." Koenig's task was to explain the movement and force of bodies as well as the construction and power of new and old machines. In fact, he said little about machines to these men and women of the court, but much about the history of the science they were meant to illustrate.

The new science, he explained, is distinctively European; America, Africa, and all of Asia are ignorant of things "about which we speak." Astronomy lit the way as Europe came out of the dark ages led by Regiomantus. In between the ancients and the moderns lay the barbarian invasions and Scholasticism. First emerged Copernicus. A great battle ensued over his views, but aided by Tycho Brahe and Kepler –

17 MS X B I, "Lecons de physique de Mr. le Prof. Koenig qu'il a donne a la Haye, 1751–52," University Library, Amsterdam. Jacques Rohault was giving lectures in his home in Paris in the mid-1650s. See his *Traité de physique* (1671); by 1730 there were ten separate publications of it. Samuel Clarke did a Latin translation in 1697, expanded upon in 1710, and he added Newtonian footnotes that refuted the vortices among other aspects of Cartesian science.

18 See the lectures of Daniel G. Fahrenheit, University Library, Leiden, MS BPL 772 (from the collection owned by van Swinden), "Natuurkundige Lessen van Daniel Gabriel Fahrenheit . . . 1718," ff. 6–11, on Descartes and Newton, ff. 88ff. on Boyle.

19 E. Kegel-Brinkgreve and A. M. Luyendijk-Elshout, eds., *Boerhaave's Orations* (Leiden: Brill and the University of Leiden Press, 1983), p. 160, and for Bacon, pp. 175ff.

whose laws Koenig explicates – heliocentrism triumphed. Galileo followed in their footsteps and in 1633 he had the "great courage to defend the Copernican system against the Inquisition."[20] But the "great genius" of the period was Descartes, and his system in the hands of Leibniz (who had influenced Koenig as he had Madame du Châtelet) became "le Antichambre de la veritable philosophie."

Koenig's tastes in natural philosophy were catholic and he saw merit in the ideas of Descartes, Leibniz, and Newton. The latter Koenig labeled "the second Archimedes" who had the good fortune of many disciples. In an oblique reference to the Leibniz-Clarke imbroglio, Koenig claims that Newton's disciples did, however, reintroduce occult qualities after Descartes and Leibniz had banished them. Koenig blames a few unnamed Newtonians for hypothesizing too much. Newton, however, comes out blameless and much time is spent explaining the law of universal gravitation. Leibniz was, of course, another "Hercule de science." Yet given "the disputes among the various schools, the true physicist should be neither Newtonian, Cartesian nor Leibnizian." All this history, interspersed with science and mathematics, had been packed into just one lecture.[21]

Subsequent lectures explained that science and mathematics enhance trade and commerce just as reason and evidence drawn from nature promote belief in God's existence. Koenig attacks skeptics and "les mille beaux esprits." He also accuses Spinoza and Locke of trying to establish that miracles had never occurred. Within the context of 1751 and the recent revolution in the Dutch Republic, his attack seems focused on its radical wing, agitators like Rousset de Missy who had sought to use Locke to argue for deeper reform than William IV would endorse and who were known to be pantheists.[22] Science and its history had many uses. In the aftermath of a revolution that restored the stadholderate and threatened more radical reforms, the circle of acceptable philosophy is being drawn very tightly; even Newtonians were suspected of insufficient piety. All these ideological signals are being flashed amid lessons in natural philosophy and science: first, "the preliminaries," that is, definitions of extension and the divisibility of bodies; then, the applications of natural philosophy from density to porosity and specific gravities, from Boyle's law to the microscope.[23]

20 Ibid., ff. 1–16, here summarized.

21 Ibid., f. 31; second lecture is on ff. 32–79. These lectures appear to be verbatim as they were delivered. In the lecture covered on ff. 234–6, Koenig returns to the early history.

22 See Margaret C. Jacob, *The Radical Enlightenment: Pantheists, Freemasons and Republicans* (New York: Harper Collins, 1981).

23 Ibid., ff. 130–91.

Dynamics, hydrostatics, mechanics, optics, explications of Newtonian gravitation with fairly complex mathematics – all appear in Koenig's lectures that were in fact more technically sophisticated than what was being routinely given across the Channel by British lecturers.

English, French, and Dutch language explications of the new science throughout the eighteenth century relied upon the story of heroic science to promote specific and often different, but not necessarily incompatible, agendas. Progress, industry, piety, moderation could all be supported by the same history that reformers, even revolutionaries, enlisted. The progressive nature of scientific knowledge and the rapidity with which its expansion had occurred in the seventeenth century impressed all observers. Most notably in Protestant lands, from as early as the 1660s in England, some clergy took up mechanical explanations and integrated them with traditional theological positions. Also liberal Dutch pastors such as Bernard Nieuwentyt offered their own version of physicotheology, and it in turn was translated into English.[24] Gradually, in select Protestant circles throughout the Euro-American world, God's work came to be more prominent than the reading of his word.

Physicotheology had been intended to shore up the church, to create a stable status quo, and to arm the pious against the radical freethinkers who emerged as early as the 1690s. But storytelling in the interest of order and hierarchy can come back to haunt its promoters. Late in the eighteenth century the revolutionary nature of science, its almost miraculous ability to reveal order in nature, fueled a different set of passions. It fed into a growing discontent found among the literate from Amsterdam to Paris, in both Protestant and Catholic Europe. In the 1780s in the Low Countries and France – each with markedly different sets of issues – educated people grew increasingly critical of the disorder perpetrated by courts and their minions.

Dutch manufacturers who sided with the Revolution of 1787 collected books by Descartes, Locke, and Voltaire, one noting in the margin "superstition is the opposite of religion just as astrology is the opposite of astronomy."[25] Indeed in the generation after the stadholderate of William IV (d. 1751), many *patrioten* and reformers with industrial interests turned revolutionary. For them, like their French counterparts, the heroes of science became beacons in the night; only exceptional men could follow their example. "Newton gave us a wonderful theory of how the heavenly bodies worked but a century passed before men could use the wonderful theory in navigation,"

24 B. Nieuwentyt, *The Religious Philosopher* (London, 1720).

25 Cited in C. Elderink, *Een Twentsch Fabriqueur van de achttiende eeuw* (Hengelo: Broekhuis, 1977), p. 29.

said the Amsterdam patriot and distinguished scientist, J. H. van Swinden.[26] What we need now are men of both theory and practice – like Franklin – who will seize the day and institute reforms in industry and government. For reformers like van Swinden, Newton became an exemplar of the meritorious and the extraordinary, to be imitated in whatever task was necessitated by one's calling.[27] Within the revolutionary circumstances of the time, van Swinden invoked the achievements of science as indicative of what human effort could accomplish, of what revolutionaries could effect.

The revolutionary mystique of science cannot easily be excised from the Western imagination. The metaphor of there having been a "scientific revolution" eventually became both a conceptual resource widely used in the historiography of science and a trope integrated into the histories of political transformation. The uses to which the history of science was put throughout the eighteenth century bespoke the revolutionary. Eventually by the 1780s, as I. B. Cohen has shown, the phrase itself, a scientific revolution or a revolution in science – thanks to Bailly – became fashionable.[28] It served the needs of secularism just as it affirmed the revolutionary tradition so basic, we still believe, to the creation of Western democracy.

Nowhere in Europe did the revolution in science find greater admirers than in France during the 1790s. The task was to translate the central premises of the French Enlightenment into the life of the entire nation. In 1794 the abbé Grégoire told the National Convention in Paris that "*Les Savants* and the men of letters carried out the first coups against despotism. . . . If the career of liberty has opened before us, they were the pioneers."[29] Just as had befitted free-born Englishmen of the seventeenth century, science now adorned the inheritance of late eighteenth-century French democrats and republicans. Not surprisingly, the French Revolution, coupled with its seventeenth-century antecedent in England, held the key to why heroic science – and the closely related concept of revolutions in science, politics, and industry

26 J. H. van Swinden, *Redenvoering en aanspraak ter inwijding van het gebouw der maatschappij Felix Meritis te Amsterdam* (Amsterdam, 1789), pp. 24ff.

27 For the truly heroic, see the opening of J. H. van Swinden, *Oratio de philosophia Newtoniana* (Franeker, 1779). Note the influence of Koenig (p. 40).

28 I. Bernard Cohen, *The Newtonian Revolution: With Illustrations of the Transformation of Scientific Ideas* (Cambridge: Cambridge University Press, 1980), pp. 120–2. Cf. by the same author, *Revolution in Science.*

29 Quoted in Luc Rouban, *L'État et la Science. La politique publique de la science et de la technologie* (Paris: Éditions du Centre National de la Recherche Scientifique, 1988), pp. 26–7.

– became so dominant and pervasive, particularly in Anglo-American historiography.

We all know that in the first instance Copernican science also provided one source for the notion of there being "revolutions" in matters of state. Indeed, the language of astronomy, partly indebted to Copernicus's "revolutions of the heavenly orbs," provided vocabulary for the profound changes in England during the 1640s and 1650s. By 1660 the terms "revolutions and commotions" in the state had become commonplace. Under the impact of those midcentury events, both political and intellectual, revolutions in the state and in thought began to take on the modern meaning of progressive, irrevocable change, not simply a returning to a previous place or a revolt that occurs periodically with little to show for the trouble. In 1651 Robert Boyle himself used the term "revolution" to describe the progress he expected in philosophy and divinity as a result of the civil wars: "I do with some confidence expect a Revolution, whereby Divinity will be much a looser, & Real Philosophy flourish, perhaps beyond men's Hopes."[30] For Boyle and his friends the expected revolution had millenarian associations; by the 1690s a more secular understanding of time had become commonplace in England. So too had the use of the term "revolution" to describe the events of 1688–9.

Largely because of seventeenth-century events, in the eighteenth century in English, French, and Dutch the term "revolution" became working linguistic capital.[31] It could function as both political and cultural currency. In 1766 Josiah Wedgwood, speaking about what would come to be known as the Industrial Revolution, wrote to a friend: "Many of my experiments turn out to my wishes, and convince me more and more, of the extensive capability of our Manufacture for further improvement. It is at present (comparatively) in a rude, uncultivated state, and may easily be polished, and brought to much greater perfection. *Such a revolution, I believe, is at hand,* and you must assist in, [and] profit by it."[32] It is a myth of recent origin, perpetuated by proponents of the so-called new economic history, that early industrialists experienced the changes they themselves wrought in manufac-

30 Jacob, *Robert Boyle and the English Revolution*, p. 97, citing the manuscript in the Royal Society of London.

31 In Dutch the more authentic term is "omwenteling" but by the mid-eighteenth century "revolutie" was also in use.

32 *The Letters of Josiah Wedgwood, 1762–1772*, ed. Katherine Euphemia, Lady Farrer (London, 1903), p. 165 (emphasis added). Once again in following E. Hobsbawm and others, I. B. Cohen placed the usage of this term in an industrial setting too late; cf. Cohen, *Revolution in Science*, p. 264.

turing as something gradual, almost imperceptible. Having available the notion of revolutions born out of profound political transformations and out of the history of science, early mechanists and industrialists like Wedgwood possessed the vocabulary to describe unprecedented transformation effected not by the sword or the air pump but by the machine.

As in most things modern, the French Revolution gave extraordinary circulation both to the word and, more important, to the concept of revolution as a sharp and irrevocable break with the past. Almost predictably by the 1790s the term "revolution" began to be applied by the French to economic phenomena, particularly to what was happening in British industry. A spy first identified as revolutionary the events about which Wedgwood had privately mused. In 1794 Le Turc wrote home with the following description of British technological development: "[When traveling in England] I saw with dismay that a revolution in the mechanical arts, the real precursor, the true and principal cause of political revolutions was developing in a manner frightening to the whole of Europe, and particularly to France, which would receive the severest blow from it."[33]

The spy knew whereof he spoke. He was addressing his urgent comments on British industry to the revolutionary ministers charged with the task of improving French manufacturing and mechanization. At that moment the leader of the effort was the minister, François de Neufchâteau, and to stimulate technological innovation he created a system of national exhibitions where craftsmen and women would come from throughout the country to display their skill and ingenuity. At the opening of the first exhibiton in 1798, François de Neufchâteau spoke about science and technology – and about history – to the thousands assembled in Paris for *ce spectacle républicain*. He explained that in the old regime "la technologie ou la théorie instructive des arts et des métiers[,] cette science était presque entièrement ignoreé." It was only Francis Bacon, and later Diderot in his *Encyclopèdie*, who saw that the mechanical arts were essential, a branch of philosophy based on the assumptions now championed by the new regime, that "l'industrie est fille de l'invention, et soeur du génie et du goût."[34] In the mind of the revolutionaries, industry, invention, genius, and taste

33 MS U 216 Le Turc to Citoyen, 14 Nivoise An 3 [December 1794], Conservatoire des Arts et Metiers, Paris. Le Turc was born in 1748 and in the 1780s as an engineer and spy he had traveled extensively in England, describing techniques and recruiting workers. I owe this splendid quotation to the kindness of the late J. R. Harris, and to my knowledge it is the earliest use of the term to describe industrialization.

34 Printed in *Reimpression de l'ancien moniteur*, vol. 29, 1847, pp. 402–3, no. 1, 1 Vendémiaire, Year VII, September 26, 1798.

were of a piece, and science and technology were exemplars of all that genius and invention could achieve. To the leaders of the revolution like Jean-Marie Roland, Girondist and the minister of the interior in 1793, responsible for financing the elite academies of science, the true genuises of science formed academies, not the reverse. "Rousseau, Bacon, Newton, Euler, Bernouilli and a multitude of other celebrated *savans* . . . were not *savans* because they were named to a seat (in the academy)."[35] The academicians, once necessary when science was less mature, should now concentrate their energies on giving public courses, in effect to imitating the culture of practical science that had been in place across the Channel for much of the eighteenth century. Roland's suspicion of the academies foreshadowed their demise. At the Terror they were ruthlessly purged, with 25 percent of their members executed and exiled.[36] In their place Roland wanted institutes and lycées; he and his compatriots wanted to "créez une immense aristocratie professoriale, vous établissez dans la république un sacerdoce scientifique."[37]

By the late eighteenth century heroic science provided a cherished model for revolutions, both political and economic. Helen Maria Williams put the linkage well in 1790 when she urged Britons to accept the French Revolution: "Why should they not be suffered to make an experiment in politics? I have always been told, that the improvement of every science depends upon experiment."[38] The coupling of science and politics had not been invented by Williams out of thin air; it derived from the way Westerners understood their political and scientific history. More than any other body of culture, science released the revolutionary imagination, helped to develop its fantasies, to eliminate doubt about what human beings could accomplish. After 1700 radicals and moderates on both sides of the Channel, and across the Atlantic – even conservatives interested in piety and politeness – could embrace the imaginary of revolutions whether in cotton or in regimes.

35 Jean-Marie Roland, *Compte rendu à la convention nationale de toutes les parties de son département, de ses vues d'amélioration & de prospérité publique*, January 6, 1793, BN, Lf 132.3, p. 225, Bibliothèque Nationale, Paris; "Je ne dirai pas que Rousseau, Bacon ne furent d'aucune académie; car on me répondroit aussitôt que Newton, Euler, Bernouilli et une multitude d'autres savans célèbres en furent; mais je dirai que ces derniers ne furent pas savans, parce qu'ils furent appelés au fauteuil académique. Au contraire, c'est parce qu'ils étoient savans qu'ils y furent appelés avec beaucoup d'autres qui ne l'étoient pas."

36 Dorinda Outram, "The Ordeal of Vocation: The Paris Academy of Science and the Terror 1793–95," *History of Science* 21 (1983): 251–73.

37 Roland, *Compte*, p. 226.

38 Helen Maria Williams, *Letters Written in France 1790* (London, 1790; reprint, Oxford: Woodstock Books, 1989), p. 220.

The histories of science that they told were filled with exaggeration and hyperbole, with assumptions that we would now characterize as naive. But the first believers in science had also allowed for, indeed celebrated, the possibility of rapid, irreversible transformations. In societies encumbered by hierarchy, blood, and birth, they had imagined, and experienced, significant intellectual changes.

We may find it fashionable now late in the twentieth century to cast doubt on the very notion of there having once been a "scientific revolution." But by 1720, with the exception of Fatio, not one of Newton's close followers, not Desaguliers, or Pemberton, or Clarke, or even the millenarian Whiston, or the student of the Temple of Solomon, William Stukeley, could have understood the master's alchemy.[39] They hung on his every word, but I think it to be the case that not one of them could have explicated his alchemical texts. Such a rapid shift may justly be imagined as revolutionary. It took historians like Dobbs, Westfall, and Karin Figala years of hard labor to penetrate a mind-set that had disappeared within one generation. By 1750 few among the literate in northern and western Europe and the American colonies would have found it remarkable that alchemy had become obscure, esoteric, and, the enlightened said, ignorant. The historiographical notion of there having been a revolution in Western thinking about nature makes for an inheritance that cannot be erased so easily. Bringing it down will entail dismantling a set of interrelated mental structures that support beliefs as basic to Western thought as the value of technological development, industry, human freedom, the rule of law, and the possibility of progress. Saying that it never happened cannot alter the gulf between Newton and his first generation of followers. We may be better served both as historians and people by a finer honing of our historiographical legacy, not by attempting its wholesale deconstruction.

39 For Stukeley's manuscripts on the Temple of Solomon, see the collection at Freemasons' Hall, Great Queen St., London.