Science and Recycling in the Long Eighteenth Century

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Historians of science have recently shifted their attention from studying innovation and the production of knowledge to its consumption, dissemination, and circulation.[1] Historians and sociologists of technology have similarly been keen to explore the ways technology is used rather than focus on the process of invention.[2] Such approaches point to the need for a better appreciation of everyday scientific and technical practices, and the ongoing significance they give to existing ideas, techniques, and objects. This essay argues that everyday scientific practice was often as much about preserving, repairing and re-using the old as it was about innovation, and eighteenth-century natural philosophers both participated in and contributed to the creation of a variety of such practices.

To describe these practices collectively, I shall use the term "stewardship", following the work of the American social historian Susan Strasser. Strasser identifies a widespread concern with the maintenance, adaptation and repair of materials in colonial America, which she calls the "stewardship of objects." As she puts it, Americans,

> mended, reused, saved, and made do. They darned socks and fed food scraps to chickens and pigs. They dyed faded dresses and repaired rickety furniture. They handed things down to younger and poorer relatives or to servants; they turned old clothes and sewing scraps into rugs, quilts and other home furnishings.[3]

The goal of this essay is to think about stewardship in settings of natural philoophical inquiry. Stewardship might be thought of as one among many historical manifestations of recycling, though I hesitate to use the term recycling for the early modern period, since the term originated in the twentieth century and has some quite specific meanings.[4]

Nevertheless, this essay is a contribution to a broader history of recycling that is emerging in environmental studies and other disciplines. In addition to the essays in this volume, Martin Melosi, Sabine Barles and Roland Ladwig have thus explored industries managing refuse and recycling in the United States, France and Germany respectively.[5] Tim Cooper and Nicholas Goddard have highlighted the use of waste materials in agriculture and sanitation in Victorian Britain, while Donald Woodward has shown forms of recycling to be widespread in early modern England.[6] This essay examines some of the ways materials were re-used and stewarded in the natural sciences in the long eighteenth century. Practices of stewardship probably extended into diverse sciences in many regions, but here most of the examples will come from the history of physical and chemical natural philosophy in Britain and colonial North America. This is not because there was anything special about these sciences or locations. The choices merely reflect the limits of the author's expertise: this is an initial foray, rather than a comprehensive survey. Nevertheless I wish to argue that stewardship was a relevant aspect of eighteenth-century natural philosophy, and is worth further study, since it helped to shape philosophical practices, experimental agendas, and forms of apparatus. Enlightened science entailed not only the production and circulation of knowledge but also the re-use, repair and adaption of the material culture used to create it.

The Stewardship of Objects

Susan Strasser has pointed to the value placed on 'the stewardship of objects' in the early modern American colonies.[7] The stewardship of objects refers primarily to a widespread thrift and care over materials which operated in American households, and to informal economies of used materials. Strasser points to the routine efforts of men and women to 'make do' in this context, keeping domestic or workshop utensils in good repair, and re-using materials for other purposes. For most people, scarcity, and to a lesser extent poverty, dictated that such activities were a matter of course. As Strasser puts it, 'Everyone was a bricoleur'.[8] For most people, re-use was not a choice, an alternative to throwing things away, but the norm, a situation reflected in the fact that there was no

special vocabulary for these practices in the early modern world. Making do was just what was done.

'The stewardship of objects', 'bricolage' and 'making do' are thus Strasser's categories, not contemporaries', but they do capture a form of life which was widespread. Indeed, the stewardship of objects also extended to the practitioners of science. If we associate the early modern period with a '*new* science' it was also one in which the sciences remained very much engaged, on a practical level, with the old, as philosophers routinely repaired, re-used, and made do with material culture. They extended the scope of domestic stewardship from the household to the laboratory, which, of course, was itself typically an extension of domestic space, a converted kitchen, cellar, or parlor.[9] Household objects and practices were appropriated into novel laboratory practices. A variety of pots, pans, jugs, and bottles were used in early experiments, and this was part of a wider care for preserving and re-using material objects which early modern philosophers, and people in general, exhibited.[10]

Natural philosophers thus shared in the common practice of passing on clothes, books, and material possessions between friends and relations, or from one generation to the next. Samuel Pepys, president of the Royal Society, inherited his terrella magnet from William Barlow, and wore, he tells us, a 'grey cloth suit and faced white coat, made of one of my wife's petticoats'.[11] Thrift pertained in the philosophical household as it did in any other. Robert Hooke routinely ordered his servants to mend his clothes, and he grumbled in his diary when his housemaids broke glassware.[12] Used books, of course, were regularly sold or exchanged among the learned, assisted by a variety of second-hand booksellers, and were also sold at numerous auctions, an important site for early modern natural philosophy. In England, the earliest of these auctions took place in coffee-houses in the City of London, the same places where the virtuosi gathered to conduct experiments.[13] Hooke noted how he met friends and philosophical acquaintances at auctions, which he attended very regularly, so that besides supplying philosophers with books and later specimens and instruments, auctions were an important place for encouraging sociability, that key ingredient in seventeenth-century science.[14] In the

provinces, taverns served as auction sites. In Cambridge, they took place in the Eagle and Child. In the 1680s, the Eagle hosted an auction of the library of Royal Society fellow Edmund Castell by the former bookseller Edward 'Ned' Millington. Millington claimed he had started auctions on the authority of Herodotus, 'who' as he put it 'commends that way of sale for the disposal of the most exquisite and finest beauties to their amoroso's', a reference to the 'bridal auctions' of the Babylonians described in the *Histories*.[15]

Like domestic goods, scientific goods were scarce, and so exchange was just as important, if not more so, than production or collection. The same was true in the case of repair. Philosophers often worked hard to preserve instruments and keep materials in good order, rather than make or buy new ones. When instruments broke, artisans routinely offered repair services, which became more prominent in places where instrument-use was high and instrument-makers were scarce: in the provinces, in ports, or colonial outposts, for example.[16] The concern to prolong the life of instruments also influenced their design and the effects they produced – experimental agendas were shaped by a concern over maintenance. Makers preferred robust, easily repairable instruments, and abandoned experiments if they threatened to damage the apparatus. In his version of the Torricellian experiment, Robert Boyle noted that warming the air increased the height to which a column of mercury in a glass tube was raised, yet, he wrote, 'I made no doubt, that it might have been rais'd much higher, but I was unwilling by applying a less moderate heat to hazard the breaking of my Glasses, in the place I then was in, where such a mischance could scarce have been repair'd.'[17] Glass, like other materials, was expensive and not to be thrown away. In the eighteenth century Joseph Priestley, Tiberius Cavallo, Benjamin Wilson, and other electricians agonized over the best ways to preserve the glass of Leyden jars, which were liable to crack during electric discharges.[18] Wilson described how to use wax, resin, turpentine and olive oil to seal cracks in a Leyden jar, while the lecturer Cadogan Morgan advocated using lower charges in experiments to avoid this problem.[19]

Philosophers also 'made do' by incorporating old and discarded materials into their labours. Glass and metals were expensive and probably many early modern instruments

were made with recycled materials. It has been estimated that some 10% of all iron used in seventeenth-century England was recycled, and the trade in 'old brass' was international. Galileo purchased old brass for his instrument-maker Mazzoleni from Germany, for a third of the price of new, and made his first telescopes using organ pipes and lenses ground on a cannon ball.[20] Natural philosophers also adapted domestic waste to philosophical uses, a practice illustrated by the uses of playing cards. Because early modern playing cards were only printed on one side, the blank sides of defunct cards were used for a variety of purposes, as note-paper, as calling cards, or even as a form of currency. Dr. John Morgan of the College of Philadelphia, later the University of Pennsylvania, thus advertised 'A course of lectures on the materia medica' on a playing card in 1765.[21] Domestic space, Morgan's house, provided the venue for the lectures, while the card was made authoritative by applying Morgan's wax seal below his announcement. Botanists may have taken playing cards into the field to make notes on. In 1783 the French naturalist Jean-Pierre Bergeret proposed that the principles of his new system of botanical nomenclature 'can be written on fewer than twelve playing cards.'[22] Certainly Jean-Jacques Rousseau wrote his *Reveries of a Solitary Walker*, a series of philosophical contemplations, on playing cards, during countryside walks punctuated with botanizing.[23] Used cards also enabled new ways of organizing knowledge. Edward Gibbon employed old playing cards to create one of the earliest card indexes, in this case of the books in his library.[24]

Franklin and Priestley

The thrifty stewardship of objects might affect the material culture of natural philosophy, experimental agendas, and methods of organizing knowledge. It equally helped to shape new theories. Perhaps the most thrifty of early modern philosophers was Benjamin Franklin. From an early age Franklin extended the thrift common in American households to his philosophical pursuits. He often bought goods second-hand and valued the chance to borrow books from friends and acquaintances.[25] This desire to avoid buying new books led Franklin to establish Philadelphia's first library among his fellow members of the Junto, and following that he founded a popular subscription library which

was copied throughout the United States.[26] Franklin also worked to bring order to the streets through the collection of waste. He carried out studies on efficient street-sweeping and introduced the first scavengers to Philadelphia, to pick up re-usable waste materials.[27]

As he grew older, Franklin developed this thrift into what he called a 'philosophy of virtue' encouraging industry and frugality, both in himself and others. 'Frugality' he defined as 'Make no expense but to do good to others or yourself; i.e. waste nothing.'[28] Franklin exploited his skills as a printer to spread this philosophy, printing proverbial sentences on thrift in his journal *Poor Richard's Almanack*, which he collated into a famous essay, 'The Way to Wealth' in 1757. Here he exhorted his audience not to waste money on superfluities, 'The Art of getting Riches consists very much in Thrift.'[29] Domestic thrift was thus conjoined with philosophy and with commerce, and Franklin's print-shop, as an extension of his artisan household, was likewise a place of thrift. For example his wife helped in the printing shop by 'purchasing old linen rags for the paper-makers.'[30] Franklin was also a keen accountant, urging the need for careful bookkeeping, since even a tiny profit or loss could quickly turn into a significant one. As Otto Sibum has shown, Franklin's bookkeeping habits extended through his moral life, his commercial transactions, and his scientific inquiries. He kept careful accounts of his own virtues, entering dishonorable acts into a ledger which he made using a re-usable ivory memorandum book written in pencil and rubbed out when necessary. He resolved arguments by drawing up a balance sheet of pros and cons, which he then matched and cancelled out until only one side predominated. To refine this method he proposed a more abstract 'moral or prudential algebra' which gave a weighting to the different arguments. As Sibum shows, Franklin approached electricity in the same quantitative way, treating a surplus of electricity in a body as a credit, and a deficit as a debit, termed plus or minus. Electrical theory thus became 'a bookkeeping problem that was to be solved algebraically.'[31]

Franklin extended the arts of domestic thrift to the workplace, and to his moral and natural philosophy. No doubt thrift was also a part of the daily practice of many other natural philosophers, especially after the rise of public science encouraged a broader

public to participate in scientific endeavors. In Britain, chemical experimenters made a virtue of thrift in the laboratory. Franklin's friend and correspondent Joseph Priestley was often short of money, and explained his turn to original experimentation as a result of not being able to afford the many books he needed to purchase in order to compile a history of vision, light and colours.[32] Priestley turned to chemical experiments on airs because, as he put it, they were good for 'keeping off such as would involve me in expense.'[33] Like Franklin, Priestley extended domestic thrift to the new arena of experimentation. Priestley often adapted kitchen and household utensils to chemical ends, making an earthen trough to collect gases with a container 'commonly used for washing linen' which he passed on to a friend after he had finished with it.[34] As Crosland notes, 'mice, candles, and green plants also cost next to nothing.'[35] Domestic interests and thrift also threatened Priestley's programs, however, and in 1772 he wrote to Franklin, 'Frugality and an attention to a growing family will, at length get the better of experimenting, and I shall then write nothing but *Politicks* and *Divinity*.'[36]

By redeploying common household items as chemical apparatus Priestley created an experimental culture open to a broad public, and so helped usher in the popular fascination with chemistry in the late eighteenth century.[37] This was also a geographically distinct enterprise, contrasting with French chemistry, which at this time was more concerned with distinction from the popular experimenter than with frugality. In Paris, novel and expensive instrumentation marked chemistry rather than pots and pans.[38] Nevertheless, the close links of domestic and laboratory stewardship remained salient in scientific practices of the nineteenth century. This is evident, for example, in Michael Faraday's *Chemical Manipulation*, first published in 1830 and based on a series of lectures given at the London Institution three years earlier.[39] *Chemical Manipulation* was filled with methods to avoid waste in the laboratory, based on Faraday's own experience and his observations of current chemical practice. Hints on how to preserve instruments from damage and how to re-use old materials were abundant. The remnants of kitchen frugality are evident in advice on how to use broken pots and jars, old metal saucepans, glass dishes, china cups, and damaged tobacco pipes in chemical inquiry. While he made clear that some instruments could not be re-used – crucibles, for example, had to be

discarded in case any remnants of their contents contaminated a subsequent experiment - Faraday urged that even the most expensive instruments could always be repaired or re-used in some way. Air-pumps, for example, should be sent to an instrument-maker for repairs until they were unusable, and even then, Faraday wrote,

> When an instrument is absolutely bad, and cannot be replaced or repaired, the student must compensate for the imperfections as far as he can, by interposing a stop-cock between [the pump] and the retort, flask, or other vessel… and close the communication as soon as, by rapidly working the instrument, he has effected the best exhaustion he can attain.[40]

Conclusion

Scientific stewardship thus continued into the nineteenth century, and no doubt remained a part of laboratory practice whenever there was a need to deal with scarcity and economy. Stewardship certainly formed a common aspect of seventeenth and eighteenth-century laboratory life. Domestic space might be adapted to scientific labors, while scarcity and economy prompted a busy economy of exchange and second-hand use of materials among philosophers. Domestic thrift and stewardship extended from the household into the laboratory, in practices of repair, re-use, and adaptation. Concerns over the maintenance and preservation of apparatus and materials influenced the direction of experimental investigations, and thrift could also inspire novel theoretical accounts of natural phenomena.

It remains to point out that stewardship should not be seen as the only way in which the sciences have been engaged with the re-use of materials. To conclude, another form of recycling might be briefly mentioned, which serves to clarify what was distinctive about practices of stewardship, both in terms of the scale and nature of practices and where they took place. While stewardship occurred at a domestic scale in laboratories and adapted rooms, the so-called "utilization of waste products" which came to prominence in the nineteenth century entailed the industrial use of waste and by-products to manufacture

new materials or products in factories on a massive scale. Coal tar, for example, was a waste product in the distillation of coal to produce coal-gas for lighting circa 1810, but by the close of the nineteenth century it was being used to manufacture medicines, antiseptics, smelling salts, fuels and dyestuffs.[41] Such an enterprise was not pursued from of a tradition of thrift or to meet scarcity, but was motivated by profit, and the profitable use of waste would come to be seen by figures such as Charles Babbage as a foundational element, along with mechanization, of capitalism.[42] The utilization of waste products also generated a substantial body of knowledge, as natural philosophers and industrialists sought to compile information on different materials and their potential as new products.[43] In contrast, stewardship practices, because they were just "what was done" were typically recorded only in passing, and most were probably not recorded at all. The Victorian literature on waste made waste into a problem for the nineteenth century, which was solved in part through new sciences of work, sanitation, hygiene and thermodynamics.[44] The industrial use of waste in factories thus generated a quite different set of scientific practices and knowledge compared to the stewardship of the home and laboratory.

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[1] On circulation, see James Secord, "Knowledge in Transit," *Isis* 95 (2004): 654-672; David Livingstone, *Putting Science in Its Place: Geographies of Scientific Knowledge* (Chicago and London: University of Chicago Press, 2003), 135-78.

[2] David Edgerton, *The Shock of the Old: Technology and Global History since 1900* (Oxford; New York: Oxford University Press, 2007); Nelly Oudshoorn and Trevor Pinch,

eds., *How Users Matter: The Co-Construction of Users and Technology* (Cambridge, MA: MIT Press, 2003).

[3] Susan Strasser, *Waste and Want: A Social History of Trash* (New York: Metropolitan Books, 1999), 22.

[4] Peder Anker discusses some of the history of the idea of recycling in the twentieth century. See Peder Anker, "The Ecological Colonization of Space," *Environmental History* 10 (2005): 239-268.

[5] Strasser, *Waste and Want*; Martin V. Melosi, *Garbage in the Cities: Refuse, Reform, and the Environment* (Pittsburgh: University of Pittsburgh Press, 2004); Sabine Barles, *L'invention des déchets urbains: France 1790-1970* (Seyssel: Champ Vallon, 2005); Roland Ladwig, ed., *Recycling in Geschichte und Gegenwart: Vorträge* (Freiberg: Georg-Agricola-Gesellshaft, 2003); see also Carl Zimring, *Cash for Your Trash: Scrap Recycling in America* (New Brunswick, NJ: Rutgers University Press, 2005); Heather Rogers, *Gone Tomorrow: The Hidden Life of Garbage* (New York: New Press, 2005).

[6] Tim Cooper, "Rags, Bones and Recycling Bins," *History Today* 56 (2006): 17-18; Nicholas Goddard, "19th-century Recycling: The Victorians and the Agricultural Use of Sewage," *History Today* 31 (1981): 32-6; Donald Woodward, "Swords into Ploughshares: Recycling in Pre-Industrial England," *Economic History Review* 38 (1985): 175-191; see also Beverly Lemire, "Consumerism in pre-industrial and early industrial England: the trade in second-hand clothes," *Journal of British Studies* 27 (1988): 1-24; Erland Mårald, "Everything Circulates: Agricultural Chemistry and Recycling Theories in the Second Half of the Nineteenth Century," *Environment and History* 8 (2002): 65-84.

[7] Strasser, *Waste and Want*.

[8] Strasser, *Waste and Want*, 22-3.

[9] Pamela H. Smith, "Laboratories," in Lorraine Daston and Katharine Park (eds.), *The Cambridge History of Science, Vol. 3: Early Modern Europe* (Cambridge: Cambridge University Press), 290-305; Maurice Crosland, "Early Laboratories c.1600-1800 and the Location of Experimental Science," *Annals of Science* 62 (2005): 233-53.

[10] Elaine Leong has highlighted the use of cooking and household implements in the making of medicaments in early modern households. See her "Making Medicines in the Early Modern Household," *Bulletin of the History of Medicine* 82 (2008): 145-68, on 162.

[11] Quoted in Woodward, "Swords into Ploughshares," 177-8; Patricia Fara, "'A Treasure of Hidden Vertues': The Attraction of Magnetic Marketing," *British Journal for the History of Science* 28 (1995): 5-35, on 16.

[12] Henry W. Robinson and Walter Adams, eds., *The Diary of Robert Hooke, 1672-1680* (London: Wykeham Publications Ltd, 1968), 106, 144, 187.

[13] Larry Stewart, "Other centres of calculation, or, where the Royal Society didn't count: commerce, coffee-houses and natural philosophy in early modern London," *British Journal for the History of Science* 32 (1999): 133-153; Giles Mandelbrote, "The Organization of Book Auctions in Late Seventeenth-Century London," in Robin Myers, Michael Harris, and Giles Mandelbrote, eds., *Under the Hammer: Book Auctions Since the Seventeenth Century* (New Castle, Delaware: Oak Knoll Press; London: The British Library, 2001), 15-36; on the history of scientific auctions more generally, see J. M. Chalmers-Hunt, *Natural Historical Auctions 1700-1972: A Register of Sales in the British Isles* (London: Sotheby Parke Bernet, 1976).

[14] *Diary of Robert Hooke*, 358-59, 414, 443; Leona Rostenberg, *The Library of Robert Hooke: The Scientific Book Trade of Restoration England* (Santa Monica, CA: Modoc Press, 1989), 66-81.

[15] Mandelbrote, *Under the Hammer*, 31-2; John Nichols, *Literary Anecdotes of the Eighteenth Century*, 6 vols. (London, 1812), vol. 4, 29.

[16] On colonial instrument-makers and repairs, see Silvio A. Bedini, *Thinkers and Tinkers: Early American Men of Science* (New York: Scribners, 1975), 184-204.

[17] Robert Boyle, *A continuation of new experiments physico-mechanical, touching the spring and weight of the air and their effects* (London, 1669), 13. Boyle heated the air with hot iron or tongs held near the receiver of the air-pump, but "without making it touch the Instrument, for fear of breaking it.' Robert Boyle, *Animadversions upon Mr. Hobbes's Problemata de vacuo* (London, 1674), 72.

[18] See e.g. Benjamin Wilson, "New Experiments upon the Leyden Phial, respecting the Termination of Conductors," *Philosophical Transactions* 68 (1778): 999-1012, on 1011-12.

[19] George Cadogan Morgan, *Lectures on electricity*, 2 vols. (Norwich, 1794), vol. 2, 460.

[20] Woodward, "Swords into Ploughshares," 185-86; Giorgio Strano, "Galileo's telescope: history, scientific analysis, and replicated observations," *Experimental Astronomy* 25 (2009): 17-31, on 22.

[21] General Collection of the University of Pennsylvania, 1740-1820. UPA 3. Matriculation and Lecture Ticket Collection 1620. Morgan, John. Materia. Medica and Practice of Physick: incomplete, 1765. Thanks for this reference to Karen Reeds.

[22] Jean-Pierre Bergeret, *Phytonomatotechnie universelle* (Paris, 1783), 158. Thanks for this reference to Sara T. Scharf.

[2323] See Eli Friedlander, *J. J. Rousseau: An Afterlife of Words* (Cambridge, MA: Harvard University Press, 2004), 74, 163.

[24] British Library Add Mss 34716; Geoffrey Keynes, ed., *The Library of Edward Gibbon*, 2nd ed. (Godalming: St. Paul's Bibliographies, 1980).

[25] Benjamin Franklin, *Autobiography of Benjamin Franklin* (New York: Modern Library, 1944), 10, 17, 50.

[26] Franklin, *Autobiography*, 87-9.

[27] Franklin, *Autobiography*, 140-2, 145.

[28] Franklin, *Autobiography*, 94.

[29] Franklin, *Autobiography*, 209.

[30] Franklin, *Autobiography*, 90.

[31] H. Otto Sibum, "Nature's Bookkeeper: Benjamin Franklin's Electrical Research and the Development of Experimental Natural Philosophy in the 18th Century," in J. A. Leo Lemay, ed., *Reappraising Benjamin Franklin: A Bicentennial Perspective* (Newark: University of Delaware Press, 1993), 221-246.

[32] Maurice Crosland, "Priestley Memorial Lecture: A Practical Perspective on Joseph Priestley as a Pneumatic Chemist," *British Journal for the History of Science* 16 (1983): 223-238, on 231.

[33] Quoted in Crosland, "Priestley Memorian Lecture," 232.

[34] Crosland, "Priestley Memorian Lecture," 233.

[35] Crosland, "Priestley Memorian Lecture," 234.

[36] Crosland, "Priestley Memorian Lecture," 234.

[37] Jan Golinski, *Science as Public Culture: Chemistry and Enlightenment in Britain, 1760-1820* (Cambridge: Cambridge University Press, 1992).

[38] Lissa Roberts, "The Death of the Sensuous Chemist: The 'New' Chemistry and the Transformation of Sensuous Technology," *Studies in History and Philosophy of Science* 26 (1995): 503-529.

[39] Michael Faraday, *Chemical Manipulation*, 3rd ed. (London, 1842).

[40] Faraday, *Chemical Manipulation*, 376-7.

[41] "The Waste Products of Coal." *Scientific American*, 27 no. 7 (17 Aug 1872): 97.

[42] Charles Babbage, *Economy of Machines & Manufactures*, 3rd ed. (London, 1846), 6, 11-12.

[43] See e.g. Peter Lund Simmonds, *Waste Products and Undeveloped Substances: or, Hints for Enterprise in Neglected Fields* (London, 1862); Timothy Cooper, "Peter Lund Simmonds and the Political Ecology of Waste Utilization in Victorian Britain," *Technology and Culture* 52 (2011): 21-44.

[44] See Crosbie Smith and M. Norton Wise, "Work and Waste: Political Economy and Natural Philosophy in Nineteenth-Century Britain," *History of Science* 27 (1989): 263-301, 391-449; 28 (1990): 221-261.

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