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ROBERT HOOKE

NEW STUDIES

Edited by
MICHAEL HUNTER and SIMON SCHAFFER

THE BOYDELL PRESS

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experiments and inventions absorbed him. Thus, it is consistent that the way he thought about and dealt with his own body resembles nothing more than an ongoing series of observations and experiments.

Hooke was extraordinarily open-minded and enthusiastic in his medical behaviour. However, he was not particularly imaginative. Indeed, it is remarkable that, having mastered and manipulated a host of physical and chemical theories which were quite revolutionary in his day, Hooke's approach to therapeutics was firmly rooted in humoralism. Although the experimental method upon which his observations were based was new, in both his suffering and his self-treatment he was quite conventional — even old-fashioned — differing from his contemporaries only in his intensity in approaching these matters and in the meticulousness with which he described it all. But for this meticulousness, this paper would not have been written.

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WHO WAS ROBERT HOOKE?

Steven Shapin

Introduction

The easy answer to the question of Robert Hooke's identity is also an intractably difficult answer: Hooke was an experimental philosopher, or, as we might now say, a scientist. The answer is easy in that it commands instant recognition from late twentieth-century audiences. We know what it is to say someone is a scientist; we have plenty of examples around us in case we want to check the characteristics of a scientist or to show someone unfamiliar with our usage what a scientist is. The images of the scientist's identity are on display as models for anyone who wants to become one; an occupant of the role can defend his behaviour by saying that it is scientific, just as he can condemn other behaviour by claiming that it violates expectations of a scientist's proper conduct.

Yet this easy answer to Hooke's identity begins to look indefensibly glib if only we consider matters from his point of view and from the situation in which he found himself. Mid to late seventeenth-century English society recognised what it was to be a gentleman, a professor, a physician, an architect, an operator, a mechanic, an instrument-maker. It did not, however, automatically comprehend the role of experimental philosopher, nor were resources readily available to explain or justify behaviour by referring it to what was normal and proper for a person performing this role.

The historian can call Hooke an experimental philosopher, even a scientist: the anachronism is unfortunate but not necessarily vicious. However, Hooke's contemporaries did not call him an experimental philosopher. To John Aubrey, Hooke was known either by his official capacities (one of the 'surveyors' of the City; Curator of Experiments to the Royal Society; professor at Gresham College), by his relationship to others ('assistant' to Willis and to Boyle), or according to his practical skills and his routine deployment of them ('He is certainly the greatest mechanick this day in the world.')[1]. Nor did Hooke systematically refer to himself as a philosopher. He did not call himself an experimental philosopher, but he occupied social and cultural terrain staked out by those who did so identify themselves. Where was

[1] John Aubrey, *Brief Lives*, ed. Andrew Clark, 2 vols. (Oxford, 1898), i, 410–11; Anthony Wood, *Fasti Oxonienses* ii, ed. Philip Bliss (London, 1820), 628–31.

the role of the experimental philosopher located on the social and cultural map of mid to late seventeenth-century England? How did one go about establishing one's entitlement to the position? What obstacles might be confronted in the course of this establishment? Finally, what connections were there between the terms of occupancy of the role and the terms in which experimental knowledge was made and justified? Hooke is an apt study for these questions precisely because his entitlement to the role and ascribed attributes of the experimental philosopher was problematic. I want to examine aspects of Hooke's problematic identity as a way of understanding his particular place in the moral economy of the contemporary scientific community. I also want to use this material to illuminate certain fundamental features of that moral economy, especially the relationship between the ascribed characteristics of individuals variously situated on the social map and their capacity to make scientific knowledge.

A Day in a Life

One way of establishing Hooke's identity — who he was understood to be in his society — is to follow him around through the course of a day's work, to trace the diurnal patterns of his movements through his physical, social and cultural environments. What work did he do and where did he do it? What social relationships were transitted and constructed in the course of doing his work, and what was the moral texture of those relationships? What were the connections between Hooke's diurnal movements and the economy of knowledge in which he was a key actor? We cannot, of course, recreate a day in the life of Hooke in its entirety: *cinema verité* is not a seventeenth-century technology and the flies on his walls are long since dead. However, we can pick out certain recurrent features of his movements which bear importantly upon who Hooke was understood to be in his mid to late seventeenth-century environments.

From the mid-1660s the basic diurnal structures of Hooke's life were set in place. After a fitful night's sleep, or sometimes no sleep at all, he rose at varying hours, but usually early, in his rooms at Gresham College. He dined there, sometimes alone, more commonly with his various resident technicians. Alone or assisted by his technicians, he then set to work, at his own mechanical contrivances, at architectural models and drafts, at experiments required by the Royal Society, or at discourses for their benefit. Leaving his rooms in the afternoon, Hooke then met friends and philosophical or mechanical colleagues at one or another local coffee-house or tavern. There he discussed his work and learned of the work of others. Moving about London, he visited the booksellers of St. Paul's churchyard, the laboratory of Robert Boyle in Pall Mall, the apothecaries who provided him with his unending supplies of medicines, the clothiers and shoe-makers whose goods figure so largely in the *Diary*, and the shops of mathematical practitioners, instrument-

makers and apothecaries, where he often spent long hours in collaborative work. As Surveyor he worked in various parts of the City, taking 'views' and supervising building work, frequently undertaking domestic architectural jobs on a private basis. On days when a Cutlerian or Gresham geometry lecture was required, these would be prepared in the mornings, and given, sometimes almost to the bare walls, at two or three in the afternoon. Later in the afternoon, on Wednesdays or Thursdays when the Royal Society met, Hooke was on call to exhibit the experiments or read the experimental discourses he had prepared at home. Afterwards, he and some of the Fellows would repair once more to a City coffee-house, where they had further experimental and mechanical discourse. From 1674 many late nights were given over to astronomical observations in a 'turret' constructed over his Gresham rooms. He rarely went to bed before two or three o'clock in the morning. Sundays followed only a slightly different pattern for Hooke: he generally stayed at home until quite late, and it was a day frequently used to write up his diary or to put his papers and notes in order. And, in the event, the coffee-houses were open even on Sunday evenings. Holidays seem to have affected Hooke's diurnal pattern minimally, though New Year's Day was sometimes used to draw up his financial accounts and his birthday was generally an occasion for reflection and taking maudlin stock of his miserable life thus far. Hooke does not appear to have been familiar with the category 'vacation'.[2]

This is, of course, only the most sketchy picture of how Hooke spent his day. It does not portray the full range of his activities nor does it take adequate account of significant variation at any given time in his life or of changes over the years.[3] Nevertheless, even this sketch allows us to pick out three related features of that pattern which bear upon the question of Hooke's contemporary identity. First, there is the extreme heterogeneity of his daily activities. Hooke not only engaged in a very wide variety of work activities, he also moved through highly disparate social worlds in the course of doing so. Second, there is the relationship of dependence which informed much, though not all, of Hooke's work. A great deal of what Hooke did during a day's work was done at the behest of others, in accordance with their general or specific directions. That relationship of dependence was usually signalled by the exchange of money for services, as in his work as Curator of the Royal

2 The best currently available source for these diurnal patterns is still 'Espinasse, *Robert Hooke*, esp. ch. 6. No one working in this area can fail to owe a large debt to the writings of Margaret 'Espinasse, whether or not they share her impulse to repair Hooke's reputation. The present paper's citations are an inadequate indication of the value I have found in her work. The significance of ill-health for Hooke's daily activities cannot be over-estimated: see Beier (this volume) and Lucinda McCray Beier, *Sufferers & Healers: The Experience of Illness in Seventeenth-Century England* (London, 1987), esp. pp. 151, 165–70.

3 Of course, towards the end of his life, and particularly after the mid 1690s, Hooke's deteriorating physical condition dictated a very considerable slowing down of the pace of his activities. And, apart from the effects of age and ill-health, it also appears that he became increasingly reclusive and temperamental, especially after the death of his niece Grace Hooke in 1687: Richard Waller, 'The Life of Dr. Robert Hooke', in Hooke, *Posthumous Works*, pp. i–xxviii, esp. pp. xxiv–xxvii: Hooke became over time 'to a Crime close and reserv'd'.

Society. By contrast, it would appear that the area of work in which Hooke had the most independent interest and autonomy was that involving the invention of mechanical and optical devices: lenses, lens-grinding machines, telescope sights, clocks and watches, and, not least, his 'thirty several' contrivances for flying which preoccupied him throughout his life and whose secrets he took to his grave.[4] Third, there is the social and cultural significance of Hooke's diurnal physical movements through London. Those movements amount to an active circulation between the private and the public and back again, instanced by the difference between the place where he lived and worked, on the one hand, and the places where he discussed and discoursed, on the other.

One conclusion based on this evidence stands out. Hooke was recognised as a person dependent upon others, a person of at best compromised freedom of action, of ambiguous autonomy, and of doubtful integrity. That is to say, his contemporaries might not generally recognise Hooke as a gentleman. At most, his entitlement to the status and attributes of a gentleman was recognised as problematic. This is not, of course, a conclusion which will come as a revelation to anyone at all acquainted with the details of Hooke's life. Indeed, it seems obvious and banal. Nevertheless, I want to take the trouble to establish the point, to show what it was about Hooke that made his standing problematic. What connections were there between the gentleman and the experimental philosopher? How did the attribution of gentlemanly standing and conduct figure in the moral economy of the English experimental community during Hooke's life? In the course of discussing these matters I shall liberally help myself to certain comparisons between the pattern of Hooke's life and that of a major claimant to the title of experimental philosopher in mid to late seventeenth-century England, his colleague and patron Robert Boyle.

The Private World of Robert Hooke

From 1664 until his death in 1703 Hooke's life was played out in and around the suite of rooms he occupied as professor of geometry at Gresham College in Bishopsgate Street.[5] Hooke never travelled abroad; in fact he left London and the home counties only a few times after he took up permanent residence there. Unlike Boyle, Hooke was not sent on the Grand Tour of the Continent.

4 On Hooke's mechanical and architectural activities: Bennett, 'Robert Hooke as Mechanic', and Bennett, this volume; Alan Simpson, this volume; Batten, 'The Architecture of Robert Hooke'; A. R. Hall, 'Robert Hooke and Horology'; Patterson, 'The Royal Society's Standard Thermometer'; Robinson, 'Robert Hooke as Surveyor and Architect'.

5 For the inventory of those rooms at the end of Hooke's life, see 'Hooke's Possessions at his Death', below. From 1678 Hooke may have had access to the laboratory of John Mapletoft, the Gresham professor of physic. Hooke was also landlord of living-spaces occupied by others in the stables of Gresham College. In 1688 the Royal Society rented rooms from him, though it is not clear for what purpose: C. R. Weld, *A History of the Royal Society*, 2 vols. (London, 1848), i, 318 – 19.

His direct experience of the physical world was limited compared to many of his philosophical colleagues. Indeed, there were few of Hooke's philosophical colleagues who travelled less than he did — Isaac Newton being his main rival in this respect. Similarly, his social world — the range of his acquaintance in the Republic of Letters — was narrow when compared, for example, to Boyle's or to Henry Oldenburg's (whom he succeeded as Royal Society Secretary in 1677). Hooke's was not only a London life, it was a life overwhelmingly centred on Bishopsgate Street and its immediate environs. When the Royal Society met at Gresham, all Hooke had to do was to take the experiments he had prepared in his rooms to adjoining or nearby public rooms in order to show them to the Fellows.[6] He read his geometry and Cutlerian lectures in the reading-hall of the College, just behind his quarters. He tended the Society's apparatus and the objects in its Repository located in the West Gallery. From about 1666 he seems to have had his own 'operatory' in his rooms, and, from 1674, he had his turret.[7] When, for seven years, the Society met at Arundel House in the Strand, Hooke was put to considerable inconvenience through having to haul sometimes large and awkward experimental devices, like the air-pump, a mile and a half through the streets of London or possibly taking them to the Thames for water-transport to the quay at Arundel House. It was an imposition Hooke resented, and, when Gresham College became available to the Society again, one of the considerations that moved them to return was 'the conveniency of making their experiments in the place where Mr. Hooke, their curator dwells, and . . . the apparatus is at hand . . .'[8]

Hooke worked where he lived. In the seventeenth century distinctions between places of habitation and places of intellectual labour were not standard. Neither professors nor private gentlemen typically were obliged to leave places of residence in order to produce philosophical knowledge.[9] Oxford, Cambridge and Gresham professors thought, discoursed, wrote and

6 The lodgings of the geometry professor opened behind the 'reading hall' of Gresham College where Hooke lectured and where the precursor group to the Royal Society met; see John Ward, *The Lives of the Professors of Gresham College* (London, 1740), p. 91 and plate 13, below,.

7 On the 'operatory' and 'turret', see Hooke to Robert Boyle, 3 Feb. 1666, in Robert Boyle, *Works*, ed. Thomas Birch, 6 vols. (London, 1772), vi, 505; Hooke, *Diary, 1672 – 1680*, p. 191 (4 Nov. 1675); Ward, *Lives of the Professors of Gresham College* (n. 6), pp. 91, 178; Ian Adamson, 'The Royal Society and Gresham College', p. 4.

8 Thomas Birch, *History* ii, 189 (25 July 1667); iii, 100 (6 Nov. 1673). The circumstances in which the Royal Society originally paid Hooke to reside at Gresham College (before he became geometry professor) are discussed in Simon Schaffer, 'Wallifaction: Thomas Hobbes on School Divinity and Experimental Pneumatics', *Studies in History and Philosophy of Science*, 19 (1988), 275 – 98. Hooke was commanded by the Society in autumn 1663 to live at Gresham at least four days a week specifically in order to get the new pump for the compressing of air ready for the King's projected entertainment at the Royal Society (p. 294).

9 For places of residence as workplaces, see Peter Laslett, *The World We Have Lost* (London, 1965), pp. 1 – 10; also Steven Shapin, 'The House of Experiment in Seventeenth-Century England', *Isis*, 79 (1988), 373 – 404. This article surveys the significance of the physical and social siting of knowledge-making. It contains material on Hooke and Boyle which partly overlaps with the present essay.

occasionally experimented in their lodgings or in attached spaces, and virtuosi like Hartlib, Boyle, Towneley, Power and many others maintained laboratories or observatories in or near their houses. In the mid to late seventeenth century Gresham College had degenerated from a place given over primarily to public instruction to one in which a variety of private persons lodged, some with no connections to educational purposes, some of dubious character.[10] Nevertheless, by the time Hooke had become established as the Royal Society's Curator of Experiments his rooms at Gresham had developed into what was arguably the most important site in England for the performance of experiments. This, together with Boyle's laboratory in Pall Mall, was where experimental *work* was overwhelmingly done, not in the public rooms of the Royal Society where that work was displayed, discussed and discoursed of.

The rhetoric associated with the new experimental programme stressed the public character of proper scientific activity. Nevertheless, Hooke's rooms and workshops constituted, in practice if not in principle, a relatively private place in the economy of seventeenth-century English science. Contained within the Hooke household at Gresham and living with him, there were his various house-keepers, domestic servants, and, from about 1672, his niece Grace Hooke. Technicians, such as Henry Hunt, Thomas Crawley, Denis Papin and others, also lived with Hooke during their periods as his paid assistants. It was not, therefore, by any means a solitary life Hooke led. It was, however, a life relatively isolated and insulated from the public life of his philosophical colleagues and associates in the Royal Society. There were few philosophical friends who were frequent visitors to Hooke's rooms, and fewer still who dined with him in his rooms. Hooke's closest friend in the Royal Society fellowship, and the man he entertained most frequently in his lodgings, was the Hartlibian emigré Theodore Haak, who was thirty years older than him. He played chess with Haak, dined with him, and, perhaps uniquely, never fell out with him or, at least, never recorded that he did so in his *Diary*. Christopher Wren, possibly a distant relation, was also in Hooke's rooms often, though how many of those visits exclusively concerned mutual architectural business matters is unclear. John Aubrey was on good enough terms to use Hooke's rooms as his postal address when he was in London, and, as we know, spoke of his friend in glowing, though improbable, terms ('a person of great suavity and goodnesse').[11] Other philosophers who sought and gained routine access to Hooke's quarters included his Gresham colleague and personal physician Jonathan Goddard, Abraham Hill, John Hoskins, Walter Pope, Daniel Colwall, Jonas Moore and Nehemiah Grew. From time to time Hooke recorded that the Royal Society's Council or a group of key members met,

[10] Adamson, 'The Royal Society and Gresham College', pp. 5–6.

[11] Aubrey, *Brief Lives* (n. 1), i, 411, 415; cf. i, 43 where Hooke was listed as one of Aubrey's 'amici'. The suggestion that Hooke and Wren may have been related by marriage is in 'Espinasse, *Robert Hooke*, p. 114.

and even dined, 'here'.[12] During the period in the mid-1670s when acute concern developed over the Society's experimental lassitude, informal clubs of the most serious and active Fellows were accustomed to meet initially in Hooke's rooms and later in various coffee-houses. These included Brouncker, Croone, Haak, Henshaw, Hill, Holder, Hoskins, King, Lodwick, Moore, Smethwick, Wylde, and Wren. There is a single reference to Newton visiting Hooke's rooms.[13] If, however, attention is shifted from philosophers to instrument-makers, mathematical practitioners, builders, and the like, a different picture emerges. Hooke spent an enormous amount of time with them, often in his rooms working on mechanical and optical projects, often dining with them.

His early eighteenth-century biographer Richard Waller said that Hooke was accustomed to a 'rather Monastick Life', that he lived 'like an Hermit or Cynick'.[14] Waller presented Hooke as someone who cared little for the conventions, customs and corporeal rewards of the world. He said, and the *Diary* tends to bear him out, that Hooke slept little and erratically, that he worked hard (often 'continuing his Studies all Night, and taking a short Nap in the Day'), and that his temperament ('Melancholy, Mistrustful and Jealous') was not one which suited him to a life of conventional sociability.[15] This was not an uncommon presentation for early modern intellectuals, both sacred and secular. As we know, Isaac Newton presented himself similarly, and was understood to stand outwith the normal ambit of society's conventions.[16] The presentation of the philosopher's persona as hermit was a way of understanding not only who the philosopher was and what might be expected of him, but also a way of warranting his claims to knowledge. A man so abstracted from the world was a man free of the hold of its idols and in immediate contact with reality, divine or mundane. However, as we have

[12] On meetings in Hooke's lodgings, see, for example, Hooke to Robert Boyle, 5 Sept. 1667, in Boyle, *Works* (n. 7), vi, 508–9 (where Hooke mentioned the presence of 'about half a score of the Society . . . at my chamber this afternoon, where we had some discourse of philosophical matters . . .'). For the Society's presence in Hooke's quarters, see, for example, Robert Hooke, *Diary, 1672–80*, pp. 108 (18 June 1674) ('Councell in my Dining Room.') and 129 (9 Nov. 1674) ('Councell at my chamber.'). The Council met occasionally at Hooke's lodgings through the 1680s: Birch, *History*, iv, 226, 228 (21 and 24 Nov. 1683). For possible allusions to the Society being entertained in Hooke's rooms, see Hooke, *Diary, 1672–80*, p. 141 (14 Jan. 1674–75): 'Society Dind here', though whether 'here' meant his rooms or elsewhere in Gresham or in nearby eating-houses is unclear in most cases. See also pp. 132 (23 Nov. 1674) and 149 (25 Feb. 1674–75), where 'Society Dind Here, I not' may support the case that 'here' did not necessarily mean Hooke was playing host.

[13] Hooke, *Diary, 1672–80*, p. 148 (18 Feb. 1674–75): 'Mr. Newton, Cambridge, here.'

[14] Waller, 'Life of Hooke' (n. 3), p. xxvii. The sense of Waller's description of Hooke as 'Cynick' is partly lost to the modern ear: it may have resonated with its Greek derivation (kynikos, dog-like, surly, snarling, disinclined to recognise or believe in goodness or selflessness — following *Chambers Dictionary*), or it may have referred to the Athenian sect of philosophers, the Cynics or followers of the dog, who 'deliberately flouted convention, "doing in public what is generally considered should be done in private" ': John Silverlight, 'Words'. *The Observer*, 26 July 1987.

[15] Waller, 'Life of Hooke' (n. 3), p. xxvii.

[16] On Newton's solitude, see J. V. Golinski, 'The Secret Life of an Alchemist', *Let Newton Be*, ed. John Fauvel et al. (Oxford: 1988), pp. 147–168 and R. C. Iliffe, *'The Idols of the Temple': Isaac Newton and the Private Life of Anti-idolatry* (Ph.D. thesis, Cambridge, 1989), esp. ch. 5.

seen, there seem to be problems with characterising Hooke as hermit. The pattern of his life seems, at a glance, to be neither obviously monastic nor private.

Yet there is a significant contrast discernible between the diurnal pattern of Hooke's life and that of some other notable experimental philosophers in London. For example, while Boyle's London laboratory was a place of pilgrimage, both for English and foreign philosophers, Hooke's was visited scarcely at all by philosophical travellers. Boyle was celebrated, both during his lifetime and upon his death, for his openness of access to the 'curious of all nations'.[17] Such accessibility was identified, by Boyle himself and by others, as a defining characteristic of the new experimental philosopher. His laboratory, unlike those of the alchemists, was to be a place of public resort and collective witnessing. Easiness of access was also, in the seventeenth century, a defining characteristic of a gentleman. Boyle, like Hooke, worked where he lived, and the obligation to hospitality was one that he acknowledged even though it lay heavily upon him.[18] By contrast, so far from being sought out by visiting philosophers and the 'curious of all nations', Hooke was rarely even mentioned by those visitors who thronged to Boyle's company. The personal relations that subsisted between the two reflect their relative public standing. Hooke was a constant guest at Boyle's (or, rather, at Lady Ranelagh's) table. There were long periods during which Hooke recorded dining at Boyle's house at least once a week. By contrast, there is no convincing evidence that Boyle ever dined at Hooke's table, nor that he visited Hooke's rooms more than once or twice during the period covered by the *Diary*.[19] Hooke and the philosophical world came to Boyle; Boyle and the philosophical world did not come to Hooke. This pattern of movement was understood in the seventeenth century to be a visible sign of the relative standings of the persons involved. In the most influential seventeenth-century English guide to the code of the gentleman, Henry Peacham said of an individual who was our social superior that 'We must attend him and come to his house and not he to ours.'[20] Indeed, if we wish to be precise about seventeenth-century gentlemanly usage, it might be better to say that Hooke did not have a 'home'. His lodgings were a fit place to work and, on some occasions, to talk work; they were not a place fit to receive and to entertain gentlemen.

17 R. E. W. Maddison, 'Studies in the Life of Robert Boyle, F. R. S. Part I. Robert Boyle and Some of His Foreign Visitors', *NRRS*, 9 (1951), 1 – 35, esp. p. 3; idem, 'Studies in the Life of Robert Boyle, F. R. S. Part IV. Robert Boyle and Some of His Foreign Visitors', *NRRS*, 11 (1954), 38 – 53, esp. p. 38. For the significance of public and private life in Boyle's work, see Shapin, 'House of Experiment' (n. 9), esp. pp. 383 – 90.

18 Gilbert Burnet, *Select Sermons . . . and a Sermon at the Funeral of the Honourable Robert Boyle* (Glasgow, 1742), p. 201. On contemporary gentlemanly obligations to hospitality, see, for example, Lawrence Stone and Jeanne C. Fawtier Stone, *An Open Elite? England 1540 – 1880* (Oxford, 1984), pp. 307 – 10.

19 Others who entertained Hooke frequently at their homes include Viscount Brouncker, Jonas Moore, Christopher Wren and Seth Ward.

20 Henry Peacham, *The Complete Gentleman*, ed. Virgil B. Heltzel, from 1622, 1634 and 1661 editions (Ithaca, N.Y., 1962), p. 24.

The relative privacy of Hooke's place of habitation and work is underlined by the typical pattern of his daily movements through the streets of London. Hooke's experimental work was, as I have already noted, conducted overwhelmingly at home. This was the place where, in contemporary parlance, experimental 'trials' were performed, and this, as we have seen, was not a place much frequented by Hooke's philosophical colleagues. However, on leaving his Gresham rooms, Hooke entered a highly public domain. The coffee-house was a major (arguably the major) site at which the outcomes of experimental trials were made known, their significance assessed, relevant information, books and materials exchanged. Indeed, the coffee-house was occasionally even a place where experimental trials were conducted.[21] The active core of Royal Society Fellows often resorted to the Crowne Taverne in Threadneedle Street, around the corner from Gresham College, while Hooke's 'clubb' migrated between Joe's, Garaway's, and Child's coffee-houses, latterly meeting at Wren's house. The Restoration London coffee-house was a highly democratic institution. It was a place of open entry, largely shorn of the patterns of deference and the segregation of social worlds that obtained outside its doors. While the coffee-house welcomed all comers (except women, of course) and mixed them together promiscuously, the great courtiers, the high aristocracy, and the morally squeamish tended to shun them.[22] Hooke loved coffee-houses, even if he was unsure of the safety and value of either coffee or chocolate. By contrast, Boyle shunned them. Hooke, who reliably recorded his meetings with Boyle and the company he met at coffee-houses, gives us no certain evidence that Boyle ever visited a London coffee-house.[23]

When Hooke moved from the coffee-house to the meeting rooms of the Royal Society, he entered upon another sort of public stage. Here Hooke met with the gentlemen and philosophical colleagues who paid his salary and directed his experimental efforts. As Curator, he performed for them the discursive and manipulative tasks he had been contracted to do. Despite much rhetoric associated with it, the Society was not a place of promiscuous public access. Nevertheless, this audience constituted the relevant public for the experimental trials that Hooke performed at home. This is where Hooke 'shewed' the experiments, that is, displayed them as reliable producers of matters of fact, where he read 'discourses' narrating experimental trials

21 On the coffee-house and science, see Hunter, *Science and Society*, pp. 33 – 34, 76 – 77; Aytoun Ellis, *The Penny Universities: A History of the Coffee-Houses* (London, 1956), pp. 37 – 52, 73 – 88, 255 – 63; Shapin and Schaffer, *Leviathan and the Air-Pump*, pp. 292 – 93. For experimental trials and displays at coffee-houses and taverns, see, for example, Hooke, *Diary, 1672 – 1680*, pp. 276 – 77 (3 March 1676 – 77), 279 (15 March 1676 – 77), 431 (15 Nov. 1679).

22 Ellis, *The Penny Universities*, (n. 21), pp. 43 – 44, 73.

23 Hooke, *Diary, 1672 – 1680*, p. 289 (11 May 1677): 'Saw Mr. Boyle at Garways.' Given Hooke's economical and erratic way with punctuation, even this reference could mean that he saw Boyle and then went to the coffee-house. A further possible reference — 'Read Newtons letters to Boyle at Garways' (p. 434 [24 Dec. 1679]) — probably does not bear the reading that Boyle was in attendance.

performed at home, and where those 'shows' and 'discourses' were considered and assessed by the Fellows. This perpetual circulation between Hooke's rooms and the meeting place of the Royal Society, between the relatively private and the relatively public, was a necessary process in the making of experimental knowledge. It was a circulation insisted upon by those who engaged Hooke's services.[24]

Hooke as Philosophical Servant

Hooke's *Diary* provides abundant evidence of his acute sensitivity to social rank and to the patterns of deference that expressed and maintained social hierarchies. Even in this private document, Hooke took pains to refer to his friends and acquaintances by their proper designations. The Society's President, Brouncker was almost invariably referred to as 'Lord Brouncker'; John Wilkins as 'Lord Chester'; Seth Ward as 'Lord Sarum'; Petty as 'Sir W. Petty'; Goddard as 'Dr. Goddard'; Ent as 'Sir G. Ent'; and so on. Even as close a friend as Haak was generally 'Mr. Haak', while as vexing a patron as Cutler was 'Sir J. Cutler'. Boyle was, of course, most commonly designated 'Mr. Boyle', though the honorific was exceptionally dropped when Hooke was angry with him or for reasons not evident in the *Diary*.[25] By contrast, Oldenburg was almost always just 'Oldenburg' (when he wasn't 'lying dogg', 'villain', or 'huff' Oldenburg), and Hooke's various technicians and craftsmen-associates tended to be designated informally: 'Tom', 'Tom Hewk', 'Harry' (tending towards 'Mr. Hunt' when he became economically independent), 'Shortgrave' (occasionally 'Mr.'), 'Tompion', 'Crawley', 'Papin' (or 'Young Pappin').[26] Until 14 November 1673, when Hooke noted that his friend Christopher Wren had been knighted, the *Diary* invariably designated 'Dr. Wren'. On his next appearance in the *Diary* on 16 December 1673 he became 'Sir Ch. Wren', and so he almost invariably remained in Hooke's usage. Similarly, Hooke carefully noted and observed the translation of 'Mr. J. Hoskins' into 'Sir J,' in 1676 and that of 'Mr. J. Moore' into 'Sir Jonas' in 1680.[27]

24 The distinction between trials and shows, and their distribution in private and public space, are discussed in Shapin, 'The House of Experiment' (n. 9), pp. 399 – 404.

25 Hooke, *Diary, 1672 – 1680*, pp. 191 (3 Nov. 1675), 343 (5 Feb. 1677 – 78), 364 (20 June 1678). In Hooke's published texts deference to Boyle was, of course, magnified according to recognisably standard formulae governing client-patron relations. In Hooke's *Micrographia*, Boyle was 'the most illustrious Mr. Boyle', 'the truly honourable Mr. Boyle', 'the Incomparable Mr. Boyle', and 'the most illustrious and incomparable Mr.Boyle' ('Preface', sig. dv, and pp. 54 – 55, 69, 227).

26 There is some evidence in the *Diary* of a falling-off of honorifics over time. This may be a function of the rather more stenographic style of later *Diary* entries, or it may, indeed, testify to Hooke's allegedly growing cynicism.

27 Hooke, *Diary, 1672 – 1680*, pp. 69 (14 Nov. 1673), 75 (16 Dec. 1673), 215 (30 Jan. 1675 – 76), 450 (2 Aug. 1680). See also Aubrey, *Brief Lives* (n. 1), ii, 312 for Hooke telling Aubrey immediately after the event that Wren had been knighted.

Hooke knew and cared where his friends and acquaintances were located on the social map. He also showed signs that he cared deeply about his own place on that map. On the one hand, he displayed standard patterns of deference to those who were his undoubted social superiors, but, on the other hand, he became violently agitated when he felt that he was not being treated in a manner appropriate to his real standing or worth. In Hooke's case eternal vigilance seems to have been the price of maintaining his integrity. What was rightfully his had ceaselessly to be made publicly evident, insisted upon, fought for. Fairness could not be taken for granted; anyone might at any time turn into a cheat, a spy or a traitor; conspiracies might be hatched against his interests; snubs and incivilities lurked around every corner. Lady Ranelagh, for example, employed Hooke over the years to renovate her houses in Pall Mall and Chelsea. In Hooke's view she dealt with him as a mere tradesman, and he periodically bridled at such treatment: 'Dind at Lady Ranalaughs', Hooke recorded in 1674: 'Never more.' When Hooke had been working on Lady Ranelagh's Pall Mall house for some time, he finally erupted: 'At Lady Ranalaughs, she scolded &c. I will never goe neer her againe nor Boyle.' Within a week he was back at Boyle's and on speaking terms with both him and his sister.[28]

As Curator of the Society's experiments from 1664 to 1677 Hooke was employed to do the Fellows' bidding. Geoffrey Keynes only marginally overstated the case when he described Hooke as 'the Society's dog's-body'.[29] When, however, he succeeded Oldenburg as co-Secretary (with Nehemiah Grew), Hooke clearly expected better treatment and more autonomy. He was vigilant that he be dealt with appropriately. At the meeting of 13 December 1677 he recorded that he 'Read notes Distinctly. Grew placed at table to take Notes. It seemed as if they would have me still curator, Grew Secretary.' The next month Hooke was outraged by the fun-loving new President, Sir Joseph Williamson, who suggested, 'Ironically', that the hunch-backed Secretary wanted a higher chair.[30]

His precise role and function within the Royal Society and the philosophical community generally remained a source of uncertainty and trouble to Hooke through much of his life. Initially, he publicly accepted the identity of philosophers' assistant. Hooke had been accustomed to a deferential relationship with gentlemen-philosophers since his student days at Oxford, where he was an impecunious chorister and 'servitor to a Mr. Goodman' at Christ Church. Probably while still a student, Hooke entered into remunerated assistantships, first with Thomas Willis, then with Boyle, with whom he lived and worked at Deep Hall from about 1657.[31] In Hooke's first publication of 1661 the dedication to Boyle was unrestrained even by the hyperbolic

28 Hooke, *Diary, 1672 – 1680*, pp. 81 (20 Jan. 1673 – 74) and 364 (20 June 1678).

29 Geoffrey Keynes, *A Bibliography of Dr. Robert Hooke*, p. ix.

30 Hooke, *Diary, 1672 – 1680*, pp. 333 (13 Dec. 1677), 340 (16 Jan, 1677 – 78).

31 Aubrey, *Brief Lives* (n. 1), i, 410 – 11.

standards of the genre: he feared that the 'Minuteness' of his text would make it 'a Present very unfit for so great a Personage' as his master.[32] Boyle was the Sun, the source of light in Hooke's life. But if Hooke accounted himself 'minute' with respect to his gentlemen-benefactors, he reckoned himself considerable with respect to those he viewed as his inferiors. In *Micrographia* Hooke tellingly placed himself in a condition riven with social tension and ambiguity. He identified himself as a master of technicians and a technician of masters: 'all my ambition is, that I may serve to the great Philosophers of this Age, as the makers and grinders of my Glasses did to me; that I may prepare and furnish them with some *Materials*, which they may afterwards *order* and *manage* with better skill, and to far greater advantage.'[33]

Hooke continued in Boyle's employment at least until 1662 when Boyle recommended him to the Royal Society as their Curator, and there are some reasons to believe that Hooke was paid by Boyle until 1664 when he began to acquire alternative sources of income.[34] Yet the deferential relationship with Boyle continued intact after that time. Neither in *Micrographia* nor in subsequent publications did Hooke ever claim authorship of devices and findings to which many historians think he had a 'right': 'Boyle's air-pump', 'Boyle's Law', 'Boyle's theory of colours'.[35] There is only fragmentary evidence that Hooke's relations with Boyle had a remunerative basis after he began his work for the Royal Society and Gresham College: Boyle made a personal contribution to Hooke's turret in 1674 and Hooke designed and constructed a new laboratory for Boyle in 1676 – 1677. As late as 1678 he

32 Robert Hooke, *An Attempt for the Explication of the Phaenomena, observable in an Experiment published by the Honourable Robert Boyle, Esq. . . .* (London, 1661), 'The Epistle Dedicatory', sig. A2 – A3. And see the panegyric to John Wilkins in *Micrographia*, 'Preface', sig. dv for Boyle as Hooke's 'particular patron'.

33 Hooke, *Micrographia*, 'Preface', sig. d1v. Michael Hunter cites an interesting Hooke manuscript of 1683 which, in connection with the Cutlerian lectures, makes very clear the distinction Hooke recognised between his command of the 'speculative & rational part' and 'tradesmen's' knowledge of the 'operative part' of mechanical knowledge: Bowood House William Petty MSS H[8]15, cited in Michael Hunter, 'Science. Technology and Patronage: Robert Hooke and the Cutlerian Lectureship', in Hunter, *Establishing the New Science*, p. 313. Lotte and Glenn Mulligan, 'Reconstructing Restoration Science', pp. 346 – 50, claim that Hooke actively used his Secretaryship to recruit a much higher proportion of merchants and artisans into the Royal Society; cf. Michael Hunter, 'Reconstructing Restoration Science', pp. 455 – 59.

34 Between 1662 and 1664 Hooke continued to refer to himself as Boyle's creature. In 1663 he wrote to Boyle about his encounter with Hobbes at Richard Reeve's instrument shop, speculating whether Hobbes realised 'to whom I belonged', and on 5 June of the same year he begged Boyle to dispense with his service 'from attending on you for two or three days . . ., having wholly resigned myself to your disposal': Boyle, *Works* (n. 7), vi, 486 – 87, 482. See also Hooke, *Micrographia*, 'Preface', sig. dv for Boyle as Hooke's 'particular Patron'.

35 See, for example, Hooke, *Micrographia*, 'Preface', sig. dv: 'the wonderful progress made by the *Noble Engine* of the *most illustrious Mr. Boyle*, whom it becomes me to mention with all honour, not only as my particular Patron, but as the *Patron* of *Philosophy* it self; which he every day *increases* by his *Labours*, and *adorns* by his *Example*.' And see also ibid., p. 227 for Hooke's attribution to Boyle of the law relating pressures and volumes of air. Cf. Waller, 'Life of Hooke' (n. 3), p. iii, where Hooke's manuscript autobiography claims responsibility for *making* the air-pump while identifying it as *Boyle's*: '. . . in 1658 or 9, I contriv'd and perfected the Air-pump for Mr *Boyle* . . .', though the device Hooke constructed remained 'Mr. *Boyle*'s *Pneumatick Engine*'.

recorded that he was coming to Boyle's presence on command.[36] And it is evident that Hooke continued to perform major services for Boyle in obtaining and delivering instruments, books and medicines, and in acting (together with Oldenburg) as intermediary between Boyle and a host of printers, engravers, builders and other craftsmen. For all that, the New Year's Eve 1676 summing up of monies owed by and to him shows nothing relating to Boyle.[37]

The terms of Hooke's engagement with the Royal Society made his dependent position clear. He was, as we know, strictly charged to supply each meeting 'with three or four considerable Experiments' and also to perform whatever other experiments were suggested by Fellows. He was, therefore, as J. A. Bennett has demonstrated, unmistakably an employee at the outset of his career, and, even though his circumstances altered somewhat over time, he could never assume that he would be uniformly treated as a colleague.[38] When Hooke was admitted to the Fellowship ('to come and sit amongst them'), it was on different terms than those that then applied to the rest of the Fellows. His membership fees were waived, and, as already noted, he was paid to lodge at Gresham for the purpose of looking after the Society's growing Repository and to carry out the Society's work. Hooke was, therefore, both in a collegial and in a dependent relationship with the other Fellows. The sanctioned mode of dealing with a colleague stood in contrast to that of dealing with a servant. Hooke's position was, therefore, deeply ambiguous. Which mode of conduct would he be confronted with in any given circumstance? Was he wholly a colleague or wholly a servant? Was he a free agent in experimental matters or was he the directed instrument of others' free action? How did he see himself and how did he present himself to others?

For more than fifteen years, certainly the most experimentally active years of Hooke's life, his daily work was largely subject to the will of others. These others manifested no doubt about their entitlement to set the terms of Hooke's scientific work and to chastise him when he failed to give satisfaction. In the mid 1660s, for example, Sir Robert Moray chided Hooke (through Oldenburg) for 'his slackness' and complained about the time Hooke allegedly frittered away in his mechanic activities: 'I easily beleeve Hook was not Idle, but I could wish hee had finisht the taskes lyet upon him, rather then to learn a dozen trades . . .'[39] The language used by his Royal Society colleagues and masters to direct Hooke's work has been widely noted by other historians.

36 For Hooke's work on Boyle's laboratory, see, e.g., Hooke, *Diary, 1672 – 1680*, pp. 247 (28 Aug. 1676), 257 (18 Nov. 1676), 260 (1 Dec. 1676), pp. 279 (17 March 1676 – 77), 307 (18 Aug. 1677), 308 (24 Aug. 1677), 460 (28 Dec. 1680). And see ibid., p. 362 (13 June 1678): 'to Sir Ch. Wrens, then Mr. Boyles who had sent for me.'

37 Ibid., p. 265 (31 Dec. 1676).

38 Bennett, 'Robert Hooke as Mechanic', esp. p. 34.

39 Sir Robert Moray to Henry Oldenburg, 12 and 16 Nov. 1665, in *Oldenburg*, ii, 605 – 7, 608 – 11 (cf. Moray to Oldenburg, 10 Oct. 1665, ibid., 560). The context of these remarks was the dispute over comets between Auzout and Hevelius. An informal group of Fellows at Oxford urgently required Hooke's observations and interpretations in order to help resolve the controversy between the two foreign astronomers.

After an initial period lasting no more than a few months when the *Journal* records that Hooke was treated like other Fellows and 'desired' to perform his experiments, by early in 1663 he was being increasingly 'directed' and 'ordered' to do so.[40] These usages persisted through the 1660s, during which period there are no more than a handful of references to any other Fellow — other than Oldenburg, also an employee — being 'ordered' to do anything. By contrast, usage with reference to Boyle scarcely varied: requests for experiments or discourses to him uniformly took the form of 'desires'. By the early to mid 1670s, when the Royal Society began fully to recognise the extent of its dependence upon Hooke for its experimental performances, usage changed. Now injunctions alternated between 'orders' and 'desires'. And, of course, when Oldenburg died in 1677 and Hooke succeeded him as Secretary, the form shifted over entirely to 'desires', together with the *Journal* portraying a much more prominent and aggressive role for Hooke's experimental and discursive activities. Doubtless, these usages, and their change over time, are partly a reflection of who was taking the minutes. But it is evident that they also reflect Hooke's standing *vis-à-vis* the other Fellows, and their perception of his dependence. As late as December 1675 Hooke was content to record in his *Diary* that Brouncker 'ordered' him to do experimental work.[41] And one need only thumb through the *Journal* to see what a matter of routine it was for Fellows of the Society to cause Hooke to prosecute concerns other than those he was most interested in.[42]

This is not to say that Hooke accepted his dependent status without reservation — at any stage of his career. For example, the boundary between the identity he acknowledged and that of a mere mechanic was one that Hooke carefully policed, especially after his succession to the Secretaryship of the Royal Society. Evidently feeling himself badgered by excessive demands for experimental entertainments, Hooke explained why he had not, and would not, 'trouble the Society at their meetings with a confused enumeration of experiments' of any given type. His job, Hooke said, was to innovate and to illustrate those innovations; the repeated display of a well-working experimental apparatus was 'only the work of a labourer or operator to perform, when once the instruments were contrived, and the method chalked out.'[43] While he acknowledged without serious question the right of his legitimate superiors to direct his labours, he bridled at unseemly treatment from those he either did not know or whom he considered to be his mere equals or inferiors, particularly when those perceived slurs were committed in the gaze of Hooke's masters. The case between Oldenburg and Hooke is the most spectacular

40 It is possible, but not certain, that this shift in usage corresponds to Hooke's change in status from non-remunerated to remunerated Curator. Hooke's original appointment in November 1662 was without 'recompense'; formal arrangements for paying him were not made until the end of July 1664. (Birch, *History*, i, 123 – 24, 453.)

41 Hooke, *Diary, 1672 – 1680*, p. 197 (3 Dec. 1675).

42 For tensions between the often conflicting aims of Hooke, the Royal Society and Sir John Cutler, see Hunter, 'Science, Technology and Patronage' (n. 33).

43 Birch, *History*, iii, 364 (13 Dec. 1677).

instance of this, though Hooke's dealings with foreign practitioners like Hevelius are also instructive. Oldenburg was not only the Society's other major retainer, he was also the other important, and equally long-serving, recipient of Boyle's patronage. Hooke could not abide him, and used no discretion in dealing with him in public or recording his private sentiments about him. Oldenburg was, in Hooke's view, a common thief and traitor. He had betrayed Hooke's rights in his inventions to foreigners. More importantly, he constituted the major threat to Hooke's standing among the philosophical colleagues in the Royal Society. He refused, in Hooke's opinion, accurately or fully to record Hooke's experiments and inventions; he fomented trouble between Hooke and colleagues with whom Hooke had no quarrel.[44] By 1676 Hooke had become so vexed at the 'Grubendolian Caball' in the Royal Society that he 'Resolved to Leave Royal Society', typically abandoning his resolution almost as soon as it was made.[45] Hooke's transactions with Newton are also indicative of the way he assessed his relative standing in the philosophical world. He appears, like others in the Royal Society, to have known little about who Newton was on their first engagement. As keen as Hooke was initially to insist upon his priority and even superiority to Newton, he was equally content to withdraw to a more defensible position as soon as Newton insisted upon it and leading Fellows of the Royal Society took Newton's side. Making peaceable noises, Hooke explained to Newton that it was Oldenburg who had been wholly responsible for the troubles between them.[46]

How did Hooke deal with his own servants? How did those dealings compare with the ways in which other experimental philosophers dealt with their servants, and even with Hooke himself? And what do those dealings tell us about Hooke's identity? The contrast in these respects between Hooke and

44 The ways in which Oldenburg dealt with his dependent status *vis-à-vis* Boyle and the Royal Society are briefly treated in Steven Shapin, 'O Henry [essay-review of Oldenburg, Correspondence]', *Isis*, 78 (1987), 417 – 24. Unlike Hooke, Oldenburg adapted to his dependency by assuming a cloak of invisibility. Cf. Michael Hunter, 'Promoting the New Science: Henry Oldenburg and the Early Royal Society', *History of Science*, 26 (1988), 165 – 81. esp. pp. 170 – 71. On Oldenburg's disputes with Hooke, see particularly Hall, 'Oldenburg, the *Philosophical Transactions*, and Technology'. While most modern historians unreservedly take Oldenburg's side, Hooke was not without contemporary supporters. Hooke's friend Christopher Wren entirely shared his opinion of Oldenburg's duplicity; see Stephen Wren, publ., *Parentalia: or, Memoirs of the Family of the Wrens . . .* (London, 1750), pp. 199, 247. A recent historian who enthusiastically takes Hooke's side is E. N. da C. Andrade, 'Robert Hooke' esp. p. 470.

45 Hooke, *Diary, 1672 – 1680*, pp. 188 (15 Oct. 1675), 193 (11 Nov. 1675), 253 (8 – 14 Oct. 1676).

46 For Hooke's dealings with Newton, see A. R. Hall and M. B. Hall, 'Why blame Oldenburg?'; Westfall, 'Newton's Reply to Hooke'; A. R. Hall and Westfall, 'Did Hooke concede to Newton?'.

Boyle could not be more extreme. In the whole of Boyle's published work and letters I can find no more than six occasions when his employed technicians were mentioned by name. These technicians include Hooke himself, Denis Papin, and John Mayow (once only, and then by initials).[47] This is not because Boyle did not employ technicians; indeed, he employed a great number, some of them resided with him, and their role in his experimental work was of enormous importance. It appears, rather, that Boyle's technicians and various assisting presences were largely invisible to him. Naming them would be one way of acknowledging their agency in the work over which Boyle presided. Boyle evidently saw no reason so to acknowledge their presence and role in that work.[48]

Hooke dealt with his technicians according to an entirely different pattern, a pattern which tells us as much about who Hooke was as it does about who they were. Unlike Boyle, Hooke treated his technicians on the model of craft apprenticeship. Boyle was in no way concerned to train his technicians to do what he did; in a sense they could not do what he did because they could not be who Boyle was.[49] But Hooke *was* vitally concerned with such training. In 1675 he told Aubrey, who was recommending a young man for employment with Hooke, what his terms were. He wanted a full commitment on the young man's part to live with Hooke for seven years. He was to have adequate lodgings and a plain but reasonable diet. In return, Hooke would teach him how to do what Hooke did: 'to fit him for the doing my business'. And Hooke reminded Aubrey what a success he had made of Henry Hunt, who was considering taking a position at £150 – 200 a year. The training Hooke offered was both informal (watch-and-do) and formal. There were occasions in the late 1670s when most of his audience for his lectures at Gresham was made up

47 It is not clear that Mayow was engaged on a remunerated basis, and it would be wrong to assume that Boyle did not recognise the partial integrity of such remunerated assistants as Papin and Hooke. Yet no other assistants were ever named by Boyle. For some information on Boyle's technicians, see R. E. W. Maddison, 'Studies in the Life of Robert Boyle, F.R.S. Part V. Boyle's Operator: Ambrose Godfrey Hanckwitz, F.R.S.', *NRRS*, 11 (1955), 159 – 88, see p. 159 for a partial list.

48 I have in draft an extended study of technicians in seventeenth-century England. Some comments on technicians' work and its invisibility are in Shapin, 'House of Experiment' (n. 9), pp. 394 – 5 and idem, 'The Invisible Technician', *American Scientist*, in press.

49 Aubrey, in referring to Boyle's laboratory at Lady Ranelagh's house, said that Boyle had 'severall servants (prentices to him) to looke to it . . .', but there is no evidence whatever that Boyle offered training to his technicians: Aubrey, *Brief Lives* (n. 1), i, 121. For guild patterns of master-apprentice relationship in the London instrument-making trade, see M. A. Crawforth, 'Instrument Makers in the London Guilds', *Ann. Sci.*, 44 (1987), 319 – 77. It was expected that masters make themselves responsible for their apprentices' moral conduct. Hooke was not a guild member, though some of his behaviour is consistent with a strong guild influence. Certainly, Hooke's father considered a formal apprenticeship for him. Waller ('Life of Hooke' [n. 3], p. li) said that Hooke's father 'thought to put him Apprentice to some easy Trade (as a Watchmakers or Limners) . . .'

of his current and past technicians and other independent mechanics.[50] Indeed, Henry Hunt succeeded Hooke as the Royal Society's Curator, Papin also became Curator after serving Hooke, and several others became independent craftsmen. Hooke was therefore in fact exactly what he portrayed himself to be in *Micrographia* — a master of technicians. They were not his equals, but they were youths who might become, ideally should become, his equals.

In Hooke's *Diary*, his various resident and non-resident technicians are major presences. Far from being invisible, as in Boyle's narratives, Hooke's technicians are seen to figure hugely as named presences in the structure of his working day. They were, it is true, rarely alluded to in Hooke's published works. Here the pervasive use of the first person singular accurately reflects, as it does not in Boyle's practice, the extent to which Hooke acted as his own technician, while Hooke, unlike Boyle, was concerned in a material way with the establishment of his innovative priority. But his awareness of technicians' work and identity is well displayed in the *Journal* of the Royal Society, where his accession to the Secretaryship is immediately marked by changes in the *Journal*'s conventions: now there are repeated named allusions to the Society's Operator (Henry Hunt) and chief clerk (Michael Wicks).[51] Those he engaged to live and work with him were, as 'Espinasse pointed out, treated as members of the family. He dined with them, rowed with them, and made up with them, exactly as he did with the women with whom he had sexual relations, though what one ought to make of the reference to an occasion when a technician, Thomas Crawley, 'Slept by' Hooke is unclear.[52]

Robert Boyle and the Christian Virtuoso

From early in his philosophical career Robert Boyle laboured to establish the identity of the new experimental philosopher. What sort of person was this? How did he go about producing knowledge that was true, potent and safe? How could his identity be made publicly visible as a surety for the knowledge he produced? In Boyle's vision, the new knowledge was to be made by a new sort of practitioner, working in new sorts of social spaces. This practitioner

50 Hooke to Aubrey, 24 Aug. 1675, in Gunther, 'Life and Work of Robert Hooke', i (*Early Science in Oxford*, vii), 434 – 5. For Gresham College lecture audiences, see, for example, Hooke, *Diary, 1672 – 1680*, pp. 430 (13 Nov. 1679), 431 (20 Nov. 1679). It was, of course, standard for seventeenth-century bourgeois and aristocratic households to include residential servants, typically engaged on an annual basis, though apprentices' term was commonly seven years. And modern historians have noted the intimacy and lack of concern for privacy of such arrangements. The contrast I want to stress is that between the evidence of Hooke's recognition of his servants and the transparency of, for example, Boyle's servants.

51 Birch, *History*, iii, 343, 369, 409, 417, 419, 421, 427, 429. For Wicks and Hunt, see H. W. Robinson, 'The Administrative Staff of the Royal Society 1663 – 1861', *NRRS*, 4 (1946), 193 – 205, on pp. 194 – 7.

52 'Espinasse, *Robert Hooke*, pp. 131 – 38; Hooke, *Diary, 1672 – 1680*, p. 338 (3 Jan. 1677 – 78); cf. p. 302 (20 July 1677).

had, as an urgent practical business, to be characterised and modelled. The new experimental natural philosopher required a template, and from this template copies could be multiplied. Throughout his career Boyle offered two sorts of pattern upon which proselyte experimentalists might model themselves and their practice. One was textual. In *The Christian Virtuoso* and related tracts composed from the 1650s Boyle delineated the identity of the new philosopher and located his practice in existing and in as-yet-uncharted cultural terrain. The other template was corporeal. Boyle constructed his own life as a visible exemplar of Christian virtuosity. The authority of Boyle's textual depictions was understood to reside in the real moral character of the author.[53]

Boyle's portrayal of the experimental philosopher was substantially novel. The pattern he traced publicly contrasted the new role with a number of existing roles, for example, that of the combative professor, the secretive and selfish 'chymist', the over-confident mathematician, the facile and speculative 'wit', and the tawdry mechanical 'wonder-mongerer' or 'juggler'. On the other hand, in constructing the experimental persona Boyle practised moral bricolage, pointing to and recombining the moral characteristics of roles which were very widely understood in seventeenth-century English society. Put simply, Boyle modelled the experimental philosopher on the recognised patterns of the devout Christian and the English gentleman.

First, such a man was said to be personally uninterested in the material rewards that might flow from genuine natural philosophy. Although proper science would undoubtedly yield useful outcomes, the Christlan virtuoso set himself against Mammon; his concern was solely with the truth whose evidences God left in the natural world; making that truth manifest was his ambition. Boyle said that the 'genius and course of studies' of 'an experimentarian philosopher . . . accustoms him to value and delight in abstracted truths; . . . such truths as do not at all, or do but very little, gratify mens ambition, sensuality, or other inferior passions and appetites.' Indeed, experimental study was an effective antidote to sensuality: the only personal goal of the Christian virtuoso was to 'entertain his understanding with that manly and spiritual satisfaction, that is naturally afforded it by the attainment of clear and noble truths . . .' The Christian virtuoso was a moral hero. His work, Boyle said, satisfied him 'of the vanity of the world, and the transitoriness of external, and especially sinful engagements . . .' The Christian virtuoso set himself against the search for lucre and against unwonted secrecy; he was open and generous with his findings and inventions.[54]

53 On Boyle and the moral constitution of the experimental philosopher, see Shapin and Schaffer, *Leviathan and the Air-Pump*, esp. chs. 2, 7; Simon Schaffer, 'Godly Men and Mechanical Philosophers: Souls and Spirits in Restoration Natural Philosophy', *Science in Context*, 1 (1987), 55 – 85, esp. pp. 75 – 77.

54 Robert Boyle, 'The Christian Virtuoso . . . The First Part', in Boyle, *Works* (n. 7), v, 522; Boyle, 'The Christian Virtuoso . . . The Second Part' , ibid., vi, 717.

Second, the Christian virtuoso was humble. Modesty and the rejection of presumption was both the ideal 'temper of mind' for the practice of experimental philosophy and the natural outcome of a proper engagement with God's creation. Reading God's Book of Nature engendered in the Christian virtuoso 'a great and ingenuous modesty of mind'. It was an activity designed to give its practitioners a 'well grounded . . . docility' serviceable to religion.[55] Third, the Christian virtuoso was a man of honour and he dealt honourably with his philosophical colleagues. Honour was an integral part of experimental social relations. It was unavoidable that the practitioner accept on trust both the 'historical experience' represented by the testimony of past philosophers and the vicarious experience represented by the testimony of present-day philosophers whose experiments could not, in principle or in practice, be physically replicated.[56] This meant that the practice of experimental philosophy and the solidarity of the experimental community were founded upon trust. The Christian virtuoso was obliged to deal with other authentic philosophers as honourable men, and he must give other philosophers the visible signs that they could and should treat him as an honourable man.[57]

Fourth, and fundamentally, the authentic experimental philosopher was a devout Christian; he displayed himself as such, and he identified his work as a form of religious practice. Boyle described the experimental philosopher as a 'priest of nature' and compared his laboratory to a place of divine worship.[58] The Christian virtuoso devoted equal study to the Book of Scripture and to God's Book of Nature. Boyle said that experimental philosophers ought to be 'assiduous studiers of the Scriptures', and, of course, that experimental study afforded 'divers motives to piety, and incentives to devotion . . .'.[59] Boyle offered himself as the pattern of a Christian virtuoso. His was not a Christianity of mere belief; it was one of active practice, as his texts, his pattern of worship, his engagement with evangelical work, and finally his Will made clear. It was said of him that he never mentioned the name of God, which he did with great frequency, without an audible pause in his discourse.[60]

Finally, the experimental philosopher was independent. He relied upon the authority of nature, not upon the authority of other men. He displayed no

55 Boyle, 'The Christian Virtuoso . . . The First Part' (n. 54), pp. 522 – 23, 536.

56 Ibid., pp. 525 – 26, 528.

57 The management of trust was a practical problem for the experimental community in the mid to late seventeenth century. In the main, the problems potentially posed by reliance upon natural historical and experimental testimony were dealt with by mobilising taken-for-granted identifications of 'honourable men' or 'credible witnesses'. The importance of this practical solution was, however, periodically indicated by the reaction of responsible agents to its breakdown. See, for example, the handling of experimental testimony from a group of physicians in Danzig: *Oldenburg*, iii, 548 – 9; iv, 26 – 8.

58 Shapin and Schaffer, *Leviathan and the Air-Pump*, p. 319; Shapin, 'House of Experiment' (n. 9), pp. 383 – 4; Harold Fisch, 'The Scientist as Priest: A Note on Robert Boyle's Natural Theology', *Isis*, 44 (1953), 252 – 65.

59 Boyle, 'The Christian Virtuoso . . . The Second Part' (n. 54), p. 757.

60 Burnet, *Select Sermons* (n. 18), p. 195.

deference to reputation or standing, going on 'the visible testimony of nature'. The experimental philosopher's freedom of action, the freedom to say what he witnessed and believed to be the case, was a pre-condition for the production of reliable knowledge. Boyle largely assumed the condition in which the Christian virtuoso was able to act independently of the opinions, reputation and power of other men. But other apologists for the new science explicitly discussed the necessity of independent free action. Thomas Sprat, for example, while advertising the social heterogeneity of the Royal Society's membership, deemed it essential that 'the farr greater Number are Gentlemen, free, and unconfin'd'. Neither the model of master and servant, nor that of master and pupil, were appropriate for the experimental community. How, Sprat asked, could the philosopher come to his own conclusions and give his own witness 'in the presence of one, whom he *fears* and *reverences*'?[61] Boyle's identification of the experimental natural philosopher can be economically summed up. The authentic experimental philosopher was a Christian gentleman. Gentility in conduct and piety in belief were the proper postures in which to undertake experimental study, just as the experimental study of nature reinforced the attributes of a gentleman and a Christian.

Boyle's portrayal was locally potent. Neither his associates during his lifetime nor his eulogists after his death missed the point: Boyle himself was the Christian virtuoso. He was reckoned to be the very paragon of a Christian gentleman, who brought his piety and gentility to the altar of nature and who extracted from the study of nature further inducements to right religion and genuine morality.[62] If Boyle was the Christian virtuoso, who, then, was Robert Hooke? How did the pattern Boyle constructed bear upon Hooke's identity? How did it affect Hooke's practice as an experimental philosopher and the career of knowledge Hooke helped to make?

'The Greatest Mechanick this Day in the World'

Hooke did not present himself to his contemporaries as unconcerned with lucre and the material rewards that might flow from a life in experimental natural philosophy. Indeed, within a year of making the acquaintance of the Honourable Robert Boyle and his friends at Oxford, Hooke was concealing alleged mechanical secrets from them and negotiating patent rights by which he might make 'a considerable advantage'.[63] It was a practice he persisted with. Throughout his career, Hooke kept technical secrets from his colleagues,

61 Sprat, *History*, pp. 67 – 9.

62 See, among many examples, Gilbert Burnet, *History of His Own Time*, 6 vols. (Oxford, 1833), i, 351 ('[Boyle] was looked on by all who knew him as a very perfect pattern.'); idem, *Select Sermons* (n. 18); Maddison, 'Studies in the Life of Boyle. Part IV', (n. 17), esp. p. 38; Daniel Defoe, *The Compleat English Gentleman*, ed. Karl D. Bülbring (London, 1890), p. 69.

63 Waller, 'Life of Hooke' (n. 3), pp. iv – vi; see also [John Robison], [art.] 'Watches', in *Encyclopedia Britannica*, 3rd ed., 18 vols. (Edinburgh, 1797), xviii, 802 – 6.

and made sure that they knew he was doing so. Hooke's *Diary* massively testifies to the extent of his association with Mammon. He was vigilant, indeed he was at times genuinely obliged by others' turpitude to be vigilant, in insuring that he obtained what was owing to him. Hunter has meticulously documented Hooke's problems with Sir John Cutler, involving hundreds of pounds.[64] But Hooke was also anxious about much smaller sums. He kept careful records of even relatively petty amounts of cash lent to intimate friends: 'Lent Mr. Aubery 5sh., which with the former made 40sh.'; and three months later, 'Lent Mr. Aubery 3sh. which maketh 43.'[65] Hooke's work in providing Boyle with books and scientific instruments was also a continuing source of financial anxiety. In 1673 he sent Henry Hunt to convey a new microscope to Boyle. Boyle gave Hunt 5 shillings: 'twas worth 20sh', Hooke noted.[66] Five years later Hooke recorded the problems he had getting Boyle to pay up for books supplied: 'Got from Boyle, Lana booke, also the 6sh. and 6 pence not without much asking for.'[67] Similarly, Hooke scrupulously noted acts of petty generosity when rightly extended to himself or wrongly to others. In 1674 he recorded that he had dined at Wren's: 'He would not let me pay.'[68] In 1676 he was evidently overwhelmed when Haak treated him to chocolate worth £1 5s. 6d., but was annoyed when Oldenburg 'was excused from paying' his share of the dinner bill.[69] When Hooke entertained friends in his rooms he observed the consumption of claret with the carefree generosity of an Edinburgh accountant.[70]

Yet we know that Hooke was not a poor man, and we are reasonably justified in assuming that his associates also knew that. Through his surveying and architectural work in the re-building of London Hooke had, as Aubrey said, 'gott a great estate'. By the 1670s Hooke had stuffed a chest in his Gresham rooms which by his death contained 'In ready money', 'old money', 'gould and silver' over £8000, that is, enough to keep his household going at its normal levels of consumption for most of another lifetime. Nor, having amassed a sizeable fortune, could Hooke bring himself to act upon intermittently expressed intentions to endow a lectureship and laboratory for the Royal Society.[71] There is nothing inherently deplorable in such behaviour, nor, of course, is it of any interest in the present context to pass moral

64 Hunter, 'Science, Technology and Patronage' (n. 33).

65 Hooke, *Diary, 1672 – 1680*, pp. 116 (3 Aug. 1674), 123 (26 Sept. 1674).

66 Ibid., p. 62 (29 Sept. 1673).

67 Ibid., p. 370 (3 Aug. 1678); cf. p. 364 (25 June 1678); 'deliverd Mr. Boyle 12 Journall de Scavans, he owes me 6sh.'

68 Ibid., p. 103 (16 May 1674).

69 Ibid., pp. 245 (31 July – 10 Aug. 1676), 136 (17 Dec. 1674).

70 E.g., ibid., p. 309 (26 Aug. 1677).

71 Waller, 'Life of Hooke' (n. 3), pp. xiii, xxvli; Aubrey, *Brief Lives* (n. 1), i, 411. The contents of Hooke's trunk are listed in the manuscript inventory. One of Hooke's contemporaries reckoned his total wealth at his death at £12,000: letter from Sir Godfrey Copley to ?, ca. 1703, quoted in [art.] 'Hooke (Robert)', in Alexander Chalmers, *The General Biographical Dictionary*, new ed., 32 vols., (London, 1812 – 17), xviii, 128 – 35, on pp. 132n. – 133n. A passionate attempt to gloss over Hooke's alleged meanness is 'Espinasse, *Robert Hooke*, pp. 141 – 42.

judgments on an historical actor. No doubt Hooke came to be what he was through the interaction of an innate temperament and a unique set of environmental circumstances. Nevertheless, there were structural patterns in his culture which were available to him as ways of modelling and justifying his developing conduct, and which were available to others as ways of locating and comprehending such behaviour.

Aubrey, we know, described his friend as 'the greatest mechanick this day in world'.[72] Indeed, the diurnal pattern of Hooke's day definitively reveals how important the identity of mechanic was to him. It appears clear that the greatest proportion of Hooke's working day was devoted to mechanical and architectural activity. Bennett has rightly criticised 'Espinasse for claiming that Hooke's work on scientific instruments 'must be regarded as by-products of a constant preoccupation with the basic general problems of science . . .' Instead, Bennett has stressed the importance of Hooke's identity as a mechanic and the conceptual significance in Hooke's philosophical work of that identity.[73] In fact, for Hooke the the real and potential economic significance of mechanical innovation and architectural work was far greater than that associated with Gresham and Cutlerian lectures, Royal Society curatorial work, or the authorship of predominantly philosophical texts like *Micrographia*. We know how lucrative Hooke's architectural work was, and we also have solid evidence of his expectations from mechanical invention. The contract drawn up in 1657 looked for thousands of pounds from the chronometer designed to solve the longitude problem.[74] Towards the end of his life Hooke was actively engaged in a project for a joint-stock company involved in glass-making.[75] And there are traces in the *Diary* of intermittent negotiations over patents on his inventions with politicians like Sir Joseph Williamson.[76]

Hooke's mechanic work was therefore central to his perceived social identity and to his economic position. It was one thing for a son of the Earl of Cork to portray himself as unconcerned with his personal reputation, priority, or with the ownership of philosophical goods, and it was quite another thing for Hooke to do so. There is no sign that Hooke laboured under a code of conduct which obliged him to display openness and humility. He did not so much 'violate' one code as operate normally under another code. If his priority in inventing time-keeping devices was challenged by Huygens, or if the necessity of telescopic sights was denied by Hevelius, Hooke's uniform

72 Aubrey, *Brief Lives* (n. 1), i, p. 411.
73 'Espinasse, *Robert Hooke*, p. 74; Bennett, 'Robert Hooke as Mechanic', p. 41.
74 On the rewards of Hooke's architectural and surveying work: Robinson, 'Robert Hooke as Surveyor and Architect'; on the 1657 contract: Waller, 'Life of Hooke' (n. 3), pp. iv – v.
75 'Espinasse, *Robert Hooke*, p. 149; Simpson, this volume.
76 E.g., Hooke, *Diary, 1672 – 1680*, p. 395 (3 Feb. 1678 – 79). The glass-making project of 1691 also involved a patent. See also Robert Hooke, *Lectures De Potentia Restitutiva, or of Spring . . .* (London, 1678), in Gunther, *Cutlerian Lectures*, p. 338 (for reference to Hooke securing a patent).

response was vigorously to defend his interests, insisting that his originality and proprietorship be publicly acknowledged. Justice required it. His sensibilities in such matters were informed not by the patterns of the Christian virtuoso but by those of the crafts. In his Cutlerian lectures Hooke referred continually to the proprietary problems faced by mechanical inventors. Spies and traitors were lurking everywhere in Hooke's world, especially in the Gresham College lecture room. Oldenburg was, of course, a professional spy, but Hooke's watchfulness extended to members of his own household. At one time he even noted 'Grace a spy.'[77] Secrecy was not a regrettable and intermittent retreat from the free communication that characterised the ideal community of experimental philosophers; it was an absolute necessity in order to secure Hooke in his authentic rights. It seems that at least some of the Royal Society's discussions of the advisability of secret and closed meetings were instigated by Hooke. He clearly relished the secrecy of his 'New Philosophicall Clubb' of 1675 – 1676 whose members 'resolvd upon Ingaging ourselves not to speak of any thing that was then revealed *sub sigillo* to any one nor to declare that we had such a meeting at all.'[78]

When Hooke apparently felt that his interests were materially engaged in experimental or mechanic dispute, his dealings with real or imagined adversaries showed little restraint. Frequently, if not invariably, Hooke refused to deal with his antagonists as men of honour, men whose words might be relied upon. In the most public possible way, Hooke declined at various times to accept the testimony of Oldenburg, Hevelius, Huygens and Newton about, so to speak, what they knew and when they knew it. In the 1620s Henry Peacham spelled out the code governing the word of a gentleman: 'We ought to give credit to a noble or gentleman before any of the inferior sort.'[79] Indeed, by refusing publicly to credit a person's testimony, one was understood to be contesting his entitlement to the standing of gentleman. By contrast, both Boyle and the Royal Society's other major servant Henry Oldenburg well understood the necessity of refraining from any public suspicions about the factual status of experimental testimony originating from gentlemen-philosophers. Any public withholding of trust in these matters would, Oldenburg affirmed, 'certainly prove very destructive to all philosophical commerce . . .'[80] Conversely, anyone who refused publicly to accept the word of a gentleman advertised the dubiousness of his own credentials. Moreover, it does not appear that Hooke behaved as he did because he was

77 Hooke, *Diary, 1672 – 1680*, p. 236 (8 June 1676).
78 See, for example, Hooke, *Diary, 1672 – 1680*, pp. 131 (17 Nov. 1674) ['Drew up proposalls about Secresy and Secretary'] and 205 – 6 (1 Jan. 1675 – 76); Birch, *History*, iii, 137 – 38 (15 Oct. 1674).
79 Peacham, *The Complete Gentleman* (n. 20), p. 24.
80 Henry Oldenburg to Robert Boyle, 10 Dec. 1667, in *Oldenburg* (n. 39), iv, 26 – 28.

unfamiliar with the code. Among the books that Hooke recorded he owned and lent was one called *The Rules of Civility*.[81]

If the pattern of Hooke's behaviour was deprecable in a Christian gentleman, it was widely considered to be nothing exceptional among tradesmen. Indeed, contemporary social guides to the code of English gentility stressed the contrast between the openness, the generosity and the reliable truth-telling of the gentleman and the secretiveness, the 'sordid interests' and the duplicity of the tradesman and the merchant. Some commentators condemned what they saw as increasing associations between the English gentry and trade. Tradesmen were widely said to be 'a baser sort of people'; the practice of trade was incompatible with the honour of a gentleman.[82] It is interesting in this connection that we have so little evidence that Hooke's conduct was condemned by his associates. Sir Godfrey Copley said that Hooke was a miser and that 'he hath starved one old woman [house-keeper] already'; Thomas Molyneux called him 'the most ill-natured, self-conceited man in the world, . . . pretending to have had all other inventions when once discovered by their authors to the world'; Leibniz accounted Hooke's illegitimate claims to priority 'unworthy of his own estimate of himself, unworthy of his nation, and unworthy of the Royal Society'; Moray complained of the 'folly' of Hooke's secretiveness about his mechanical inventions and the 'inconvenience' he thereby caused to others; and Oldenburg (albeit without mentioning Hooke by name) told Boyle that 'Some body of ye [Royal Society], . . . hath too slender thoughts of all what comes from abroad of a philosophicall nature, or is done by strangers . . .'[83] However, in the main, Hooke's gentlemen-associates seem not to have found the overall pattern of his behaviour worthy of significant remark. Gentlemen did not behave like that, but tradesmen, merchants and mechanics notoriously did.

When Boyle described the ideal experimental philosopher as Christian virtuoso, he did not conceive of Christian obligation in a merely conventional sense. The Christian virtuoso was publicly to display his piety, in his

81 Hooke, *Diary, 1672–1680*, pp. 229 (1 May 1676) and 276 (25 Feb. 1676–77). This text was almost certainly [Antoine de Courtin], *The Rules of Civility or Certain Ways of Deportment observed amongst all Persons of Quality* (London, 1671), translated from the French *Nouveau Traité de la Civilité*. This was a popular guidebook to the exact ritual and ceremonial forms of manners to be observed when dealing with one's equals, inferiors and superiors.

82 Edward Chamberlayne, *Angliae Notitia; or the Present State of England*, 7th ed. (London, 1673), pp. 320–21, 328. See also Ruth Kelso, *The Doctrine of the English Gentleman in the Sixteenth Century*, University of Illinois Studies in Language and Literature, vol. XIV (Urbana, Ill.: 1929), pp. 1–288, esp. p. 78. For warnings about merchants' secrecy and search for present profit, see Sprat, *History*, pp. 65–67; for the Royal Society's freedom from 'sordid interests', see Joseph Glanvill, *Scepsis Scientifica* (London, 1885; orig. publ. 1665), p. lxiv.

83 For Copley: Chalmers, *Biographical Dictionary* (n. 71), pp. 130 and 132n. and 'Espinasse, *Robert Hooke*, p. 142; for Molyneux: Thomas Molyneux to William Molyneux, 9 June 1683, quoted in K. Theodore Hoppen, 'The Royal Society and Ireland: William Molyneux, F.R.S. (1656–1698)', *NRRS*, 18 (1963), 125–35, on p. 127; for Leibniz: Leibniz to Oldenburg, 26 Feb. 1672–73, in *Oldenburg*, ix, 494; for Moray: Moray to Oldenburg, 8 Jan. 1665–66, in ibid., iii, 9; for Oldenburg: Oldenburg to Boyle, 6 Oct. 1664, in ibid., ii, 248 (the editors suggest [p. 250 note] that Hooke was the person referred to, and other sources make this seem highly probable).

discourse, in actions designed to spread and support right religion, in the social forms of observance, and in his publicly visible moral deportment. The Christian virtuoso was to be a moral paragon. His character vouched for the authenticity of his knowledge. Whether Hooke was perceived by his contemporaries as a moral paragon is highly doubtful. This is not the place to deal with Hooke's erratic, if not erotic, sexual life. In the event, we have the confident assurance of Lawrence Stone that Hooke's 'sexual drive was far below that of the average Western man today. The central interest of his life lay not in women — not even in Nell or Grace — but in his scientific, technological and architectural pursuits.'[84] In fact, it is extremely difficult to establish what about Hooke's private life was known to others, and it is only the public perception of his private life that matters in this connection. On the one hand, I have found no significant or detailed allusion to Hooke's sexual morality by any of his contemporaries. (It would appear that he shared a minor interest in pornography with the Duke of Montagu, since it was he who first showed Hooke the 'Naked [woman picture]', and a week later apparently lent it to Hooke for home consumption. This picture was still in Hooke's cellar when he died.)[85] On the other hand, it is hard to believe that the nature of Hooke's relations with his various housekeepers and his young niece was unknown to those like Boyle who kept such an anxious eye on standards of public morality.

The matter of Hooke's Christian observance and its public display is more straightforward, even though it too presents the historian with difficult problems of evidence and interpretation. While God is a pervasive presence in the scientific texts of Robert Boyle, He is elusive in the published works of Robert Hooke. The invocation of the Deity is most notable in Hooke's early *Micrographia*, and it may be relevant that this was a work submitted by the new Curator for the approval of his corporate masters. Interestingly, a significant number of *Micrographia*'s invocations argue the special case for microscopic (and telescopic) skill in the culture of natural theology. Hooke claimed, for instance, that 'the Wisdom and Providence of the All-wise Creator' are as evident in the minute parts of the fly and the moth, 'which we have branded with a name of ignominy, calling them Vermine', as they are in larger animate bodies visible to the naked eye. Those possessed of mechanical skill in devising instruments which extended the empire of sense were, Hooke said, extremely valuable to the advertised goals of the philosophical enterprise,

84 Lawrence Stone, *The Family, Sex and Marriage in England 1500–1800* (London 1977), pp. 561–63. Remarkably, Stone does not appear to recognise any problems in equating the number of orgasms recorded in Hooke's *Diary* with the number Hooke actually experienced, nor in making judgments on this basis about Hooke's 'sexual drive'.

85 Hooke, *Diary, 1672–1680*, pp. 176 (21 Aug. 1675) and 177 (27 Aug. 1675), The manuscript inventory of Hooke's possessions in 1703 records 'a picture of a Naked woman without a frame' in the cellar.

including its theological goals.[86] In later texts, particularly those deriving from the Cutlerian lectures, there is far less invocation of the Deity and little evidence of serious commitment to the natural theological enterprise, though it could plausibly be argued that this might be expected from the nature of these works. Some writers have attempted to make Hooke out as a secularist-before-his-time, particularly with reference to his geological work. This would be over-stating the case. His *Lectures and Discourses of Earthquakes* made repeated reference to the Noachian deluge, and there is no expression of disbelief in the reality of the events described in *Genesis*. Nevertheless, it is noteworthy that many of the allusions to the Flood in this work occurred in the context of arguments against its adequacy as an explanation of the present distribution of fossils. The Flood, in Hooke's view, was too brief an event to account for the finding of fossils on mountain tops; naturalistic processes like earthquakes, which raised the ocean floor into mountains, were more plausible explanations. Given seventeenth-century discriminations between the natural and the supernatural, Hooke clearly preferred to invoke the former.[87]

Waller strove manfully to present Hooke as a pious Christian, though the effort of doing so seems to show. 'He always', Waller said, 'exprest a great Veneration for the eternal and immense Cause of all beings, as may be seen in very many Passages in his Writings . . .' According to Waller, Hooke never made any inventions or solved any philosophical problems without 'setting down his Acknowledgment to the Omnipotent Providence . . .', though whether the pervasive divine expletives in Hooke's *Diary* indicate Christian piety, as Waller claimed, is highly doubtful.[88] Thus, on suffering through a performance of *The Virtuoso*: '*Vindica me Deus*'; when his left nostril 'looked black', or when port made him sick: '*Miserere mei deus*'; when he became exasperated with City bureaucracy: '*Libera me Domine*'.[89] Nor is it certain, despite Waller's testimony that Hooke 'was a frequent studier of the Holy Scriptures in the Originals', that Hooke was, indeed, a regular reader of the Bible. Compared to the work of Robert Boyle, there are few Scriptural allusions in his writings, and, according to Feisenberger, while there were several Bibles in Hooke's personal library, there was 'comparatively little theology' represented, 'usually the largest section in a seventeenth-century library'. Unlike Newton's or Boyle's library, Hooke's contained a number of

86 Hooke, *Micrographia*, p. 198. Other references to God are on pp. 2, 8, 95, 105, 124–25, 133–34, 154, 171–72, 179, 189–90, 193–95, 207, 242. See also Michael Aaron Dennis, 'Graphic Understanding: Instrument and Interpretation in Robert Hooke's *Micrographia*', *Science in Context*, forthcoming, and Harwood, this volume.

87 References to the Deluge in Robert Hooke, 'Lectures and Discourses of Earthquakes . . .', in *Posthumous Works*, pp. 210–450, are on pp. 319–20, 322, 324, 328, 341, 408, 412, 414–16, 422–24. On Hooke's attitude to Biblical authority in his geological work, see esp. Rudwick, *The Meaning of Fossils*, ch. 2.

88 Waller, 'Life of Hooke' (n. 3), p. xxviii.

89 Hooke, *Diary, 1672–1680*, pp. 235 (2 June 1676), 226 (13 April 1676), 232 (13 May 1676), 201 (15 Dec. 1675)

profane works: French plays and works with louche titles like *The Practical Part of Love* and *Merry Drollery or Jovial Poems*.[90]

Hooke's *Diary* gives no evidence that he was either a notable church-goer or Sabbatarian. His Sunday routine was, to be sure, somewhat different from weekdays, though these changes might have been substantially dictated by structural patterns in Hooke's society. Hooke typically spent most of the Sabbath at home, doing his *Diary*, writing notes from the Royal Society's meetings, 'rectifying' proofs, and working in his operatory. It tended to be a day he received visits from his mechanic friends, rather than paying visits to his philosophical colleagues, who were, certainly in Boyle's case, more observant than Hooke. Nor was Sunday a day to miss the coffee-house, where Hooke would go in the late afternoon or evening. There are only a handful of notes in Hooke's early *Diary* which unambiguously establish his presence at places of Christian worship. In 1677 Boyle apparently dragged him to chapel when Hooke called on a Friday; in 1680 Hooke was visiting Lord Conway in Oxford and heard a sermon from a parson whom, he decided, was 'a Sycophant or worse'; in April 1678 he recorded that he 'heard Dr. [Gilbert] Burnet about providence', in December on 'spirits and against the Pope', and in February 1680 on 'peace'. In 1676 he noted that the 'St. Helens parson rayld against Philosophers &c.' So far as the conventional social forms of Christian worship are concerned, that is about all the evidence we have which certainly establishes Hooke's attendance through the 1670s.[91] There are periodical allusions to Hooke's participation in theological discourse, but little to establish what his views were. He condemned *The Virtuoso* as an 'Atheistical' play as well as a 'wicked' one; and he deprecated a Royal Society colleague as an 'enthusiastick quaker', while there are occasional inconclusive hints that Hooke may have had heretical inclinations. There is apparent interest in Caballa and Mosaic philosophy; there is a reference to Hooke's private philosophical group as a 'Rosicrucian' society (though the allusion is most probably to alchemy). His encomium to John Wilkins in *Micrographia* suggests an attachment to a theory of pure and primitive Christianity; and even Waller was unwilling to hold up his orthodoxy to close scrutiny: 'If he

90 Waller, 'Life of Hooke' (n. 3), p. xxviii. For a reference to Hooke's purchase of a Welsh Bible: Hooke, *Diary, 1672–1680*, p. 411 (8 and 10 May 1679). For Hooke's library: Feisenberger, 'The Libraries of Newton, Hooke and Boyle', esp. p. 50.

91 Hooke, *Diary, 1672–1680*, pp. 335 (21 Dec. 1677), 447 (27 June 1680 [Sunday], when Hooke also recorded 'Not at church in the afternoon.'), 387 (8 Dec. 1678 [Sunday]), 241 (9 July 1676 [Sunday]), for the St. Helen's parson. For Burnet's sermons: pp. 354 (21 April 1678 [Sunday]), 387 (8 Dec. 1678 [Sunday]), 439 (22 Feb. 1679–80 [Sunday]). See also ibid., p. 353 (14 April 1678 [Sunday]): 'at Temple church with Mr. Godfrey'. Sunday entries in Hooke's *Diary 1688–93* periodically record parish names (St. Peter's, St. Helen's) which may indicate church attendance. (St. Peter's and St. Helen's were both parish churches within short walks of Gresham College, and Hooke was buried in the latter.) These references are not common before 1692. See, for example, Hooke, *Diary, 1688–93*, pp. 196, 222, 229, 242, 244, 253.

was particular in some Matters, let us leave him to the searcher of Hearts.'[92] If Hooke's virtuosity was Christian in inspiration, it was a very private Christianity. There is little work deriving from the core of the Royal Society whose public presentation was as disengaged from theological aims as Hooke's.

Integrity, Independence and Experimental Testimony

There were no qualities more important for the Christian virtuoso to possess than integrity and independence. He had to have the integrity to wish to be a truth-teller, and he had to have the independence reliably to tell the truth. The experimental philosopher told the truth because there were no forces acting upon him which might make him want to tell an untruth and because there were no considerations which could compromise or damage him if he told the truth. It was said that this integrity and independence distinguished the new experimental philosopher from existing practitioners. The Peripatetics were said to be slavish followers of the word of the ancients; those bred up in Schools and accepting the moral economy of Schools were said to follow their masters' authority and to live in fear of them; and the alchemists were said to keep secret whatever legitimate knowledge they possessed because they wished to gain advantage from it.

The qualities of integrity and independence were shared between the ideal experimental philosopher, the ideal English Christian and the ideal English gentleman. The pious Protestant went on the authority of no other man, no priest and no Pope. He inspected the evidence of God's Books for himself, and he inspected his conscience. Scripture enjoined him to tell the truth, and Protestantism encouraged him to give active witness to what he conceived to be the truth. The English gentleman was also characterised by his independence and integrity. The capacity for free action was, indeed, a defining feature of an English gentleman in the sixteenth and seventeenth centuries: he was a man so bred and so positioned in the economic and social orders that he was free to do and to speak as he wished, subject to civil law and the law of God. By contrast, the merchant and the tradesman might neither be free to tell the truth nor might they desire to do so. Insofar as anyone in a

92 For theological discourse, see, for example, Hooke, *Diary, 1672 – 1680*, pp. 163 (8 June 1675) [for theological conversation with Sydenham], 250 (20 Sept. 1676) [for conversation with Hoskins regarding Tillotson's theology], 387 (5 Dec. 1678) [again with Hoskins 'about Creeds, Spirits, Antichrist, &c.'], 368 (24 July 1678) ['much discourse about Spinosa quakers'], 376 (9 Sept. 1678) [visited Tillotson; 'Discoursd much of Criticall Learning of the French Bible'], 382 (27 Oct. 1678 [Sunday]) [at Jonathan's coffee-house: 'Chaff about Religion']; for Mosaic philosophy and Caballa: p. 292 (24 and 26 May 1677); for the 'Rosicrucian' Society: p. 242 (14 July 1676); for *The Virtuoso*: p. 166 (25 June 1675); for Oliver Hill as 'quaker': p. 338 (3 Jan. 1677 – 78). In *Micrographia*, 'The Preface', sig. g2r, Hooke wrote that in the Rev. John Wilkins 'we have an evident Instance, what the true and the *primitive unpassionate Religion* was, before it was *sowred* by particular *Factions*', though the allusion was a fairly routine Latitudinarian formula in the early Restoration. For Waller's suggestion of unorthodoxy, see 'Life of Hooke' (n. 3), p. xxviii.

position of economic and social dependence was subject to the will of his master, he was not able to give his own free opinion. The way in which dependence compromised free action was importantly discussed in the debates over the franchise during the Civil War and Interregnum. Both sides to the Putney Debates, for example, assumed that those who sold their labour to another had so compromised their integrity and independence that they could not legitimately participate in voting. Whatever was said by those who sold their labour could not reliably be ascribed to them. They might speak as they did because it was their master's will.[93] In addition, the merchant and the tradesman might not tell the truth because they might not wish to do so in certain circumstances. Considerations of gain and advantage might decide the tradesman knowingly to say what was not true or to keep silent about what was true. Edward Chamberlayne (a Fellow of the Royal Society) identified the reason that tradesmen 'in all Ages and Nations have been reputed ignoble'; it was 'the doubleness of their Tongue, without which they hardly grow rich . . .' And even Daniel Defoe wrote at length on the prevalence and necessity of the 'trading lie' among those engaged in selling goods and services.[94]

For the gentleman, however, truth-telling was not only the result of his capacity for free action; it was an obligation, freely assumed, that was acknowledged to lie heavily upon him. A popular seventeenth-century guide to gentility specified that nothing could 'disparage or lay a deeper aspersion upon the face of *Gentrie*, than to be taxed for fabulous relations'.[95] Francis Bacon acknowledged the differences among men in their tendencies to tell truth. Poets lied for 'pleasure' and merchants lied for 'advantage'. The gentleman was a truth-teller because he was bound by a code of honour which enjoined him not to lie to other gentlemen. The violation of this code was a source of 'shame': 'There is no vice that doth so cover a man with shame as to be found false and perfidious . . .' In the end, for a gentleman to tell an untruth was a sign of irreligion and a blot on his honour: '. . . Montaigne saith prettily, when he inquired the reason why the word of the lie should be such a disgrace, and such an odious charge, saith he, "If it be well weighed, to say that a man lieth, is as much as to say that he is brave towards God and a coward towards men. For a lie faces God, and shrinks from man . . ." ' A gentleman, by contrast, was brave towards men and humble towards God.[96]

93 C. B. Macpherson, *The Political Theory of Possessive Individualism: Hobbes to Locke* (Oxford, 1970), esp. ch. 3; Christopher Hill, 'Pottage for Freeborn Englishmen: Attitudes towards Wage-Labour', in idem, *Change and Continuity in Seventeenth-Century England* (London, 1975), pp. 219 – 38.
94 Chamberlayne, *Angliae Notitia* (n. 82), pp. 320 – 21; [Daniel Defoe], *Complete English Tradesman* (London, 1726), pp. 275 – 92. For Defoe 'trading lies', for example asking more for an item than one knew one would actually accept, were normal and permissible departures from literal truth-telling for the tradesman: 'the tradesman should indeed not be understood strictly and literally to his words . . .' Tradesmen's promises, similarly, ought to be taken 'with a contingent dependence upon the circumstances of trade . . .' (pp. 276, 281).
95 Richard Brathwait, *The English Gentleman* (London, 1630), p. 84.
96 Francis Bacon, 'Of Truth', in idem, *The Moral and Historical Works of Lord Bacon*, ed. Joseph Devey (London, 1852), pp. 1 – 4.

The importance in science of a code which allows practitioners to discern who is and who might not be a reliable truth-teller is rarely appreciated. This is partly an inheritance of seventeenth-century empiricist rhetoric which stressed direct engagement between an individual and natural reality. If direct experience is the paradigm of knowledge-making, the role of testimony and trust would seem to be negligible. Yet the experimental programme of the seventeenth century, like empiricist practice generally, was inescapably founded upon the social relations which constituted trust. While the ultimate justification for a claim to empirical knowledge was said to be an act of direct witnessing, it was widely understood in the seventeenth century that one could not, as a practical matter, insist upon direct experience in order to constitute one's factual knowledge. Testimony was essential, and its quality had to be assessed. The testimony of credible witnesses was to be preferred to that of less credible witnesses. The maxim seems banal, but it was a potent resource. In general, everyone in a local society understood who was creditworthy and who might not be. The imputation was structural; it did not depend upon detailed knowledge of individuals' characteristics. Hooke himself tried intermittently to codify the rules for assessing testimony, but in doing so he achieved little more than a transliteration of the informal code.[97]

The Incredible Robert Hooke

I want to conclude by displaying some philosophical consequences of attention to the social identity of practitioners. Why certain knowledge-claims and testimony are credited is partly a function of who makes the claims and who gives the testimony. I will show some relations between Hooke's perceived position on the social map and problems he encountered in making scientific knowledge. I argue that these problems grew out of ambiguity in Hooke's identity. That ambiguity can be conceived as the gap between who Hooke was understood to be and the identity of a Christian gentleman. Insofar as Hooke was seen as a mechanic, as a dependent instrument of others, and as engaged in selling services and goods, certain characteristics were attributed to him which constituted troubles for his role in the community of experimental philosophers. The most significant of those troubles were encountered in the reception of his scientific testimony.[98]

97 See, for example, Robert Hooke, 'A General Scheme, or Idea of the Present State of Natural Philosophy . . .', in *Posthumous Works*, p. 63.

98 I will not treat the handling of Hooke's mechanic testimony, though there is evidence that portions of this were disbelieved by his colleagues. It is possible that this behaviour had a bearing upon the evaluation of his experimental testimony. For example, Copley discussed Hooke's persistent claim that 'he knew a certain and infallible method of discovering the longitude at sea; yet it is evident that his friends distrusted his asseveration of this discovery; and . . . little credit was then given to it in general . . .' (Copley letter, quoted in Chalmers, *Biographical Dictionary* (n. 71), p. 133n.) It is not clear what Hooke's associates thought of his continued claims that he could 'fly', nor, indeed, what Hooke was thinking when he made such claims!

Throughout his career as Curator of Experiments and even after he stopped serving in that formal capacity, Hooke was the Royal Society's major experimental performer. He was the person, far more than Boyle, who actually possessed manipulative skill. Without him (and such other skilled personnel as Richard Shortgrave and Henry Hunt), the experimental work of the Royal Society would have collapsed. He knew how to build the machines and how to make them work. In this respect, no Fellow was his equal. Despite that, Hooke's masters and colleagues in the Royal Society reserved the right publicly to withhold trust from his experimental testimony. Occasionally, they did actually decline in public to credit it; more commonly they laid conditions upon the acceptance of Hooke's testimony not imposed on Fellows generally.

In the early 1660s Christiaan Huygens claimed to have observed the so-called anomalous suspension of water, the failure of a column of water, when purged of air, to descend in the Torricellian apparatus when moved into the receiver of an air-pump. This was a finding which, if genuine, appeared to threaten the conceptual basis of Boyle's pneumatics. Boyle reckoned that the water should descend; if it did not, this was probably because the receiver of the air-pump in which the tube had been placed was leaking. Late in 1662 and early in 1663 the newly appointed Curator was ordered to replicate the experiments described by Huygens. Through 1663 Hooke appears constantly to have disappointed and irritated his masters by producing what they took to be experimental 'failures'.[99] The judgment of whether or not anomalous suspension existed as an authentic matter of fact was informed by judgments of Hooke's skill in constructing and operating the pump, in particular his skill in making the pump tight.[100] Those who rendered judgments of Hooke's skill generally lacked the relevant skill themselves. They proceeded on the basis of their *knowledge* of what phenomena a well-working pump ought to produce, and they asserted the right of knowledgeable agents to define the meaning of skilled agents' work.

It was not uncommon for Hooke's testimony about the outcomes of experimental trials performed in his own operatory to be contested when this conflicted with the expectation of knowledgeable colleagues. Early in 1663, for instance, the *Journal-Book* records that 'Mr. Hooke made the experiment of condensing air by the pressure of water; but the trial not agreeing with the hypothesis, it was ordered to be repeated at the next meeting'.[101] In 1672 the Royal Society was considering the question whether air was generated or consumed by burning. Success or failure in these experiments had to be defined in relation to some theory or expectation about the resulting

99 There are many references to these 'failures' in the *Journal-Book* for the period between ca. December 1662 and ca. October 1663; see, e.g., Birch, *History*, i, 139, 212, 268. See also Hooke to Boyle, [ca. July 1663], in Boyle, *Works*, (n.7) vi, 484–85, on p. 484.

100 The career of anomalous suspension in the 1660s and 1670s is described in Shapin and Schaffer, *Leviathan and the Air-Pump*, ch. 6, esp. pp. 248–50. Hooke continued to theorise about the cause of anomalous suspension into the mid-1680s; see Hooke, 'Lectures and Discourses of Earthquakes' (n. 87), pp. 365–70.

101 Birch, *History*, i, 177 (14 Jan. 1662–63).

measurement. Hooke's colleagues reserved the right to define whether or not his experimental work had succeeded. Indeed, when he eventually reported 'success' the *Journal-Book* referred cautiously to the experiment 'he said, he had made', and members of the Society were delegated to act as witnesses.[102] Repeatedly, Hooke's masters and philosophical colleagues simply assumed the right to identify when Hooke had or had not performed a competent experiment. On failure, Hooke was instructed to take the experiment away until it worked properly, and only then to show it in public. Moreover, Hooke was frequently obliged to make good his testimony about experimental trials by displaylng the operations in public. In the 1680s, as Pumfrey has recently shown, Hooke was being taken to task 'for not performing his experiments publicly'. Martin Lister referred to a set of magnetic experiments

> which I recommend to farther trial, because Mr. Hooke owned he could not make them succeed in private trial, accusing the too soft temper of the drill; and therefore he is desired to order better (if it can be) to be made that we may not break off in uncertainties, but have the experiments tried before us.[103]

As with all directions he received from those he recognised as his superiors, Hooke generally tended to accept his orders without significant demurral. There are, for all that, occasional indications that he resented the liberty with which his testimony was doubted. In 1667 Hooke was one of the major experimenters in the Society's vivisectional work on respiration. He was clearly irritated that his report of experimental success had not been credited by his philosophical colleagues:

> I did heretofore give this *Illustrious Society* an account of an Experiment I formerly tryed of keeping a Dog alive after his *Thorax* was all display'd by the cutting away of the *Ribs* and *Diaphragme*; and after the *Pericardium* of the Heart also was taken off. But divers persons seeming to doubt of the certainty of the Experiment (by reason that some Tryals of this matter, made by some other hands, failed of success) I caus'd at the last Meeting the same Experiment to be shewn in the presence of this *Noble Company*, and that with the same success, as it had been made by me at first . . . This I say, having been done . . . the Judicious Spectators [were] fully satisfied of the reality of the former Experiment . . .[104]

It would be incorrect to claim that refusal to credit Hooke's experimental testimony, or even its public qualification, was a routine occurrence. It was

102 Ibid., iii, 61, 77-78 (20 Nov. 1672, 5 and 19 March 1672 – 73).
103 Ibid., iv, 261 – 62 (27 Feb. 1683 – 84); Stephen Pumfrey, 'Mechanizing Magnetism in Restoration England — The Decline of Magnetic Philosophy', *Ann. Sci.*, 44 (1987), 1 – 22, on p. 13; cf. Michael Hunter, 'Reconstructing Restoration Science', pp. 458 – 59, for the Royal Society's discontent with Hooke's performance of his duties in the late 1670s and early 1680s.
104 'An Account of an Experiment made by Mr. *Hook*, of Preserving Animals alive by Blowing through their Lungs with Bellows', *Phil. Trans.*, 3 (1667), 539 – 40.

not, and one can hardly imagine how the Royal Society could have arranged its affairs if Hooke's testimony had not been generally accepted. The point is that the withholding of trust was acknowledged to be a very serious act. This trust was withheld only exceptionally. Typically this occurred when the testifying individual was not known to the Fellowship or when he was known, but known to have suspect credentials. A relevant contrast is with the fate of Boyle's experimental testimony. So far as I can discover, there is only ambiguous evidence that an English Fellow of the Royal Society ever withheld trust from Boyle's experimental testimony concerning matters of fact, or even required public replication for his factual narrations to be credited.[105]

Who, then, was Robert Hooke? At the end of the exercise there is still no satisfying simple answer to the question of Hooke's identity. The easy answer — that he was a scientist — becomes even more implausible and historically insupportable. His identity was complex and ambiguous. Some of his associates, some of the time, evidently thought of, and dealt with, Hooke as a mechanic, as a tradesman, as a servant. Insofar as they did so, Hooke's contemporary entitlement to the role and attributes of the experimental philosopher was problematic. Hooke was probably not considered to have the attributes proper to the pattern of Christian virtuosity that was being created and exemplified by his patron Robert Boyle and endorsed by leading figures of the Royal Society. Hooke's experience therefore helps us understand some of the seventeenth-century connections between the emerging role of the experimental philosopher and the existing codes of English gentility and Christian morality. There are massive problems of trust and authority that lie largely unacknowledged at the core of empirical science. They are unacknowledged because these problems were practically, not philosophically, solved in the seventeenth century. The word of the Christian gentleman was part of that practical solution. I have endeavoured to show that Hooke's entitlement to the standing of Christian gentleman was problematic. This had enormous consequences for his life and work in the experimental community.

105 This evidence involves Henry More's controversies with Boyle which largely concerned the proper interpretation of pneumatic experiments and the relationship between experimental natural philosophy and theology. Although Boyle wrote in 1672 that More 'did indeed deny the matter of fact [which Boyle narrated] to be true', he noted that his adversary was 'too civil, to give me *in terminus* the lye', and it is possible to see the disputed point as interpretative in nature: Robert Boyle, 'Hydrostatical Discourse', in Boyle, *Works* (n. 7), iii, 615; also Shapin and Schaffer, *Leviathan and the Air-Pump*, pp. 217 – 18. (Henry More was an inactive member of the Royal Society.) Of course, some of Boyle's experiments were replicated for reasons other than seeking assurance that they had been faithfully delivered. On the literary and social techniques for securing assent to experimental testimony, see Steven Shapin, 'Pump and Circumstance: Robert Boyle's Literary Technology', *Social Studies of Science*, 14 (1984), 481 – 520; also idem, 'Closure and Credibility in Seventeenth-Century Science' paper presented to Joint Meeting of the History of Science Society/British Society for the History of Science, Manchester, 11 – 15 July 1988 (typescript printed in programme proceedings, pp. 147 – 54).