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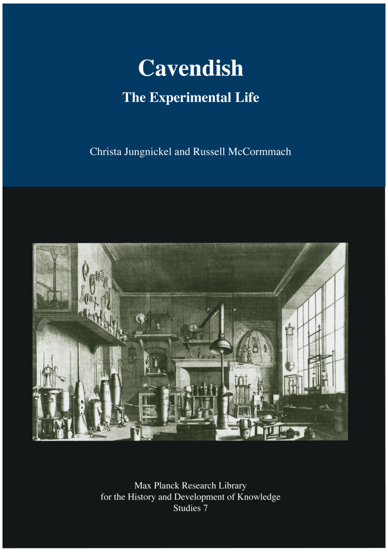
Christa Jungnickel and Russell McCormmach:

Public Activities



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Chapter 5
Public Activities

Public Life

Charles Cavendish's administrative skills were valued in arenas outside of family affairs, politics, and science, in the founding and working of several organizations. Each of the organizations had a technical dimension, and the people he worked with were often the same people he worked with in politics and science. In the first section of this chapter, we briefly consider the organizations, beginning with a hospital.

For twenty years Robert Walpole kept the country in peace and prosperity, during which time several hospitals were established, Westminster in 1720, Guy's in 1724, and others. These were hospitals in the usual sense of the word. In addition there was a new charitable hospice for unwanted children, the Foundling Hospital (Fig. 5.2). Inspired by foundations for this purpose in Amsterdam, Paris, and elsewhere, the Foundling Hospital was the culmination of an arduous and heartfelt campaign by Thomas Coram on behalf of "great numbers of Helpless Infants daily exposed to Destruction." The Hospital was incorporated by royal charter in 1739 in a ceremony attended by bankers and merchants from the city and by six dukes and eleven earls, who set the tone of the endeavor. The charter, which was received by the president of the Hospital, the duke of Bedford, a relative of Cavendish's, named Cavendish's brother, the duke of Devonshire, and his father-in-law, the duke of Kent, as original governors, and Cavendish himself was elected governor later that year.[1] The Hospital was first located in a leased house, but soon it acquired a new building set in the fields, the location of most of the other new institutions of eighteenth century London. The interior of the building was adorned with paintings; elegant concerts were held there.[2]

This fashionable charity needed administrators who were both able and hardened to the task, for conditions of life in an eighteenth century foundling home were depressing. During the first four years the Hospital admitted children indiscriminately, whether or not they were true foundlings—exposed and deserted children who would otherwise die—nearly 100 a week at times. Of the roughly 15,000 children received then, over 10,000 did die, a mortality rate of about seventy percent. From the provinces, infants were transported under desperate conditions to the Hospital, where they were dumped, sparing parish officials the trouble and expense of maintenance. To avoid the cost of burial, parents abandoned children there, more dead than alive. The administrators of the Hospital had to deal with the consequences of their policy and ultimately with the policy itself.

The Hospital could call upon the best medical opinion in London. Hans Sloane, president of the Royal Society, and Richard Mead, both of whom were named in the charter, were among the leading physicians who volunteered their expensive services. William Wat-

[1] R.H. Nichols and F.A. Wray (1935, 16, 19). Roy Porter (1982, 302–303).
[2] John Summerson (1978, 119–120).

son, an expert on infectious childhood diseases, led the Hospital's crusade to prevent the devastations of smallpox, then a disease primarily of children under three.[3]

With the desire to put its children to work, the Foundling Hospital turned for help to the whitefish industry. The Society of Free British Fisheries recommended fitting up the rope yard for spinning twine and making net, agreeing "to take as much Yarmouth Shale as the children could braid." Cavendish was active at both ends of this arrangement, as a governor of the Foundling Hospital and as a member the Society.[4] The inconclusive end of the War of the Austrian Succession in 1748 was the setting of the start of the Society. There was a widespread feeling then that the nation needed to be strengthened, and a natural way of doing this was to encourage its fisheries, by then an old idea. When in 1749 the House of Commons formed a committee on the state of British fisheries, a group of traders and merchants responded by submitting a plan for a fishery company, which resulted in a Parliamentary act. In 1750 the Society was incorporated under a royal charter. Modeled after the great chartered trading companies, the Society was justified by the need for British fisheries to compete successfully with the Dutch, who then dominated the trade in herring. It had three main objectives: to strengthen British commercial power through incentives to build up the fishery, to secure Britain against hostile rivals especially France by ensuring a supply of seamen, and to provide employment for the laboring class. There were anticipated side benefits. It would improve the moral character of the nation by eliminating the uncivilized practice of impressing seamen; rebuild the economy in depressed regions, especially the Highlands, indirectly reconciling the Scottish clans to a United Kingdom; lower the poor rate by putting the unemployed to work; and discourage crime, drink, gaming, irreligion, and other forms of social disorder. The Society was permitted to own ships, build warehouses and wharfs, carry naval staples, regulate trade, and raise capital for these purposes in the form of joint stock paying three percent semi-annually. It was popular at the beginning, fueled by anti-Dutch sentiment and a perceived threat from France, but expectations for it were soon disappointed. By the mid-1750s the Society was in trouble for a number of reasons: the start of the Seven Years War, the rise of the Swedish fishery, the movement of herring away from the west coast of Scotland, poorly thought-out regulations on the conduct of fishing and curing of fish, and more.[5] We need not go into this any further since we do not know what part Cavendish played.

We do know that Cavendish took an active interest in the Society of Free British Fisheries, as we would expect, repeatedly serving on its Council. The industrialist James Lowther of Cumberland, a distant in-law whose estate he would later take charge of, was a moving force behind the fishery from the start. Its first governor was Frederick, prince of Wales whose gentleman of the bedchamber he had once been. His fellow Member of Parliament from Derbyshire Nathaniel Curzon was on the Council of the Society, as was his close friend and colleague William Watson. Possibly Cavendish's interest began with the Society's contract with charities and parishes including the Foundling Hospital to make nets. He must

[3]Ruth K. McClure (1981, 205–218). William Watson (1768). Charles Creighton (1965, 500, 514).

[4]Nichols and Wray (1935, 131, 182).

[5]Francis Grant (1750, 37). Anonym (1750a, 13, 46). Anonym (1750b). Mr. Horsley (1750). Bob Harris (1999, 285, 291, 293, 296, 298, 304, 307).

have thought that the fishery would be good for the country, and in any event it was a venue where he could perform a duty of service.[6]

Closer to Cavendish's scientific and scholarly interests was the British Museum. Readers of books lacked a proper public library in London. The Universities of Oxford and Cambridge had libraries, cathedrals had them, and there were a few specialized libraries, such as the one for law at the Inns of Court and the Royal Society's own library; even a few small public libraries had been established in London, but most readers could not readily lay their hands on a given book. By this yardstick of civilized society, England was decidedly backward. Italy had had important public libraries since the fifteenth century; in Prussia, Berlin had had a great public library since the late seventeenth century; in France the royal library in Paris had been open to the public since 1735, and the Mazarin library was nearly as large; and other great European cities such as Vienna and Munich had major public libraries.[7] With the assistance of Cavendish, London belatedly acquired an important public library as part of a new institution, the British Museum.

In the usual British way of addressing social needs, a public library in London came about through private rather than government initiative. When Hans Sloane stepped down as president of the Royal Society in 1741, the secretary Cromwell Mortimer, in the dedication of a volume of the Society's *Philosophical Transactions,* referred to his "noble and immense Collection" in natural history and to his large library of books on natural history and medicine, inflated to the "most complete in the Universe."[8] When Sloane died in 1753, he left to the nation his natural history collection and his library, for a price. Parliament accepted the offer, raising the necessary money by means of a lottery. Sloane's trustees bought Montagu House to hold his collection and library, to which were added the Cottonian Collection and the Harleian Manuscripts. Open and free to "all studious and curious Persons,"[9] Montagu House was occasionally referred to as Sloane's Museum, but it would be known as the British Museum.

Sloane's will did not name Cavendish as one of the trustees, but it included him in a long list of "visitors," starting with the king and the prince of Wales, who were charged with watching over Sloane's possessions.[10] To get from the dignitaries to the working staff—the librarian and underlibrarians—Parliament approved a complicated plan. A manageable but still large number of persons were selected from the trustees and visitors and given the responsibility of electing fifteen persons. These so-called "elected trustees" were to appoint a standing committee to meet regularly with the staff and take charge of the management of the Museum. Cavendish became a trustee in the first election, in 1753, and he was appointed to the standing committee in its first year, in 1759. The latter included Cavendish's relative Philip Yorke and his close friends and colleagues Watson, Birch, and Macclesfield.

From the start, the British Museum was warmly welcomed by fellows of the Royal Society, who volunteered their services. Most of the first trustees were fellows of the Royal Society or of the Royal Society of Antiquaries or both; eleven of the first elected trustees

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[6]Harris (1999, 286, 291, 305–306, 308, 312). Cavendish was a member of the Council of the Society in 1756, 1763, 1764, and likely in other years too. "The Monthly Chronicler," 30 November, *The London Magazine. For November, 1756*.

[7]Edward Miller (1974, 25).

[8]Dedication on 31 Dec. 1741, a month after Sloane's resignation: *PT*, vol. 41, for 1739–40, published in 1744.

[9]Arundell Esdaile (1946, 18).

[10]Sloane's printed will: BL Add Mss 36269, ff. 39–54. A handwritten list in 1753 of additional trustees includes Cavendish, f. 57.

were fellows of the Royal Society, and of the thirty-one trustees who were elected from the beginning of the British Museum until the year Cavendish died, twenty-three were fellows of the Royal Society. Of the thirty-seven trustees who were named to of the standing committee during Cavendish's lifetime, twenty-eight were fellows of the Royal Society, including four of its presidents.[11]

Cavendish was involved in every stage of preparation for the opening of the Museum in 1759. As a member of the standing committee, he examined Sloane's insects, birds, and other animals, finding some in good condition and others in a predictable state of decay. He helped to inspect Sloane's books and to compare the contents of Sloane's cabinets with catalogs in forty-nine volumes. By 1755 Cavendish's name sometimes headed the list of trustees at the general meetings, despite the number of peers who could come and whose names would have preceded his if they had. In time attendance at the weekly committee meetings dropped to five or so, but Cavendish always came, and when Macclesfield did not come, Cavendish presided, or at least he headed the list of persons attending: in the six months from May to November 1755, Cavendish attended thirty-four meetings of the standing committee, at twenty of which he presided.[12] Cavendish was a man of public affairs with broad interests and administrative skills, who could be counted on absolutely, not the least of the reasons why his services were valued in the British Museum and generally in the affairs of the learned world of London.

Places of Public Service

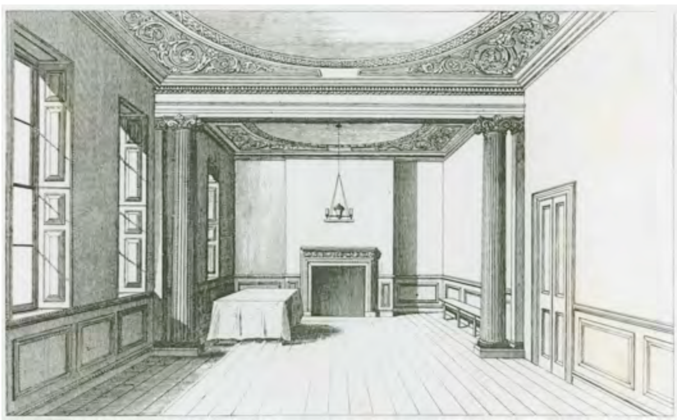

Figure 5.1: Royal Society. Through Charles Cavendish's time, the Royal Society met in this room at Crane Court. It had long departed when this print was made in 1848. Frontispiece to the first volume of Charles Richard Weld, *A History of the Royal Society*, 2 vols. (London, 1848).

[11] Esdaile (1946, 30, 323). A.E. Gunther (1979, 209–210, 214–215).

[12] Thomas Birch's minutes of the meetings of the trustees of the British Museum: BL Add Mss 4450, ff. 1 and following. "Minutes of the General Meetings and the Standing Committee Meetings of the Trustees of the British Museum," ibid., 4451, ff. 3 and following.

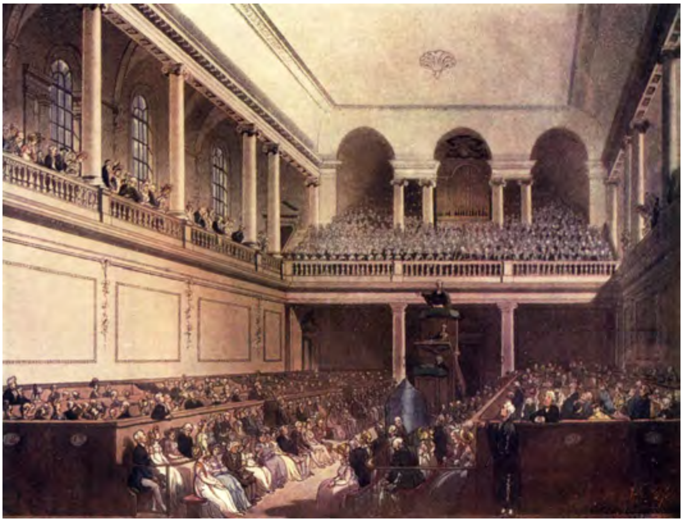

Figure 5.2: Foundling Hospital. The Chapel. By Thomas Rowlandson and Augustus Charles Pugin for Ackermann's *Microcosm of London* (1808–11). Demolished. Lord Charles Cavendish was a governor of this institution from the year of its charter, 1739. Wikimedia Commons.

Figure 5.3: British Museum. Entrance to the Old British Museum, Montagu House. Visitors are seen entering from the left; through the arched gateway on the right visitors are seen on the staircase. The statue inside the room is of Joseph Banks, former president of the Royal Society. Charles Cavendish became a trustee of the Museum at its first election in 1753. Henry Cavendish was elected a trustee in 1773.

Figure 5.4: British Museum. Staircase of the Old British Museum. Visitors are shown on the stairs and on the landing looking at stuffed animals. The giraffes look to be outgrowing the house. This was true in a sense, for by the time of this painting, most of the contents of the overcrowded and dilapidated Montagu House had been removed to the new home of the Museum. Watercolors by George Scharf, the elder, 1845. Reproduced by permission of the Trustees of the British Museum.

Figure 5.5: Building of Westminster Bridge. Painting by Samuel Scott, circa 1742. The bridge is shown in an early stage of construction. Lord Charles Cavendish was an active bridge commissioner from 1736 to 1749, the eve of its opening. Wikimedia Commons.

Figure 5.6: Westminster Bridge. By Giovanni Antonio Canaletto, 1747. The Lord Mayor's procession on the River Thames. This second bridge in London over the river is nearly finished in this painting; final construction can be seen at the far right. Courtesy of the Yale Center for British Art, Paul Mellon Collection.

Montagu House, which earlier had nearly been acquired by the Foundling Hospital, was located at the north end of town on Bloomsbury Square, the fashionable home to rich physicians such as Sloane and Mead (Figs. 5.3–5.4). Designed in the French style for Ralph, later first duke of Montagu, by Robert Hooke, the versatile curator of experiments of the Royal Society, the original house had burned down, replaced by a house resembling a contemporary Parisian *hôtel*. It had an imposing façade with colonnades, an entrance topped by a cupola, wings extending to the front to form a courtyard, an interior of spacious and lofty apartments with paintings on the walls, and, in general, the grandeur befitting a great library and scientific collection in the nation's capital. Given the great load it was to bear, of equal significance was the sober evaluation by the standing committee, to which Cavendish belonged, that the house was a "Substantial, well built Brick Building." Seven and a half acres of garden came with it, to which Cavendish's friend and fellow trustee William Watson devoted loving care.[13]

The collections of the British Museum were dedicated to the "Advancement and Improvement of Natural Philosophy and Other Branches of Speculative Knowledge."[14] The senior staff consisted of a "principal librarian" and three "under-librarians" or "keepers," each with an assistant, corresponding to the three departments: Printed Books, Manuscripts, and Natural Productions and Artificial Curiosities. There was in addition a keeper of the reading room, considered an assistant librarian.[15] The scientific ambition of the Museum was clear from the qualifications of the principal librarian, who was expected to be studious, learned, educated as a physician, versed in mathematics, a judge of inventions, able to carry on conversation with the learned in their fields, and competent to write and speak

[13] Esdaile (1946, 39–40). Miller (1974, 50–54).
[14] "Rules proposed to be Observed in Making the Collections of Proper Use to the Public by Way of Resolutions in a General Meeting of the Trustees," BL Add Mss 4449, f. 115.
[15] Gunther (1979, 210). P.R. Harris (1998, 12).

French and Latin and correspond with foreigners.[16] There were disqualifying criteria too, which were not mentioned.[17] Gowin Knight, the choice for principal librarian, presented himself as a physician who had devoted the greatest part of his life to the "pursuit of natural Knowledge";[18] the evidence, his powerful artificial steel magnets, he brought with him to the British Museum, requesting a passage five feet wide to house them.[19] Matthew Maty, De Moivre's friend, who was appointed underlibrarian for Printed Books and would one day become principal librarian, had accomplishments equally impressive: he had received an M.D. under Boerhaave at the University of Leiden, he had studied natural philosophy and mathematics, he had wide-ranging foreign connections as editor of the *Journal Britannique*, and he spoke French and Dutch;[20] soon after joining the staff of the British Museum, Maty was elected secretary of the Royal Society. Another underlibrarian was Charles Morton, physician to the Middlesex and Foundling Hospitals, who like Maty had received an M.D. at the University of Leiden; he would become secretary of the Royal Society, and he too would one day become principal librarian.[21] A third underlibrarian was the naturalist James Empson, charged with overseeing Sloane's natural history collection. As each underlibrarian had an assistant, the staff was sizable and, in William Watson's opinion, "unexceptionable." Its "disposition," however, was a different matter, as librarians and assistants were not on speaking terms, and insubordination was rampant. The poet Thomas Gray, one of the first users of the library of the British Museum, said that "the whole society, trustees and all, are caught up in arms," and he compared the rebellious factions to "fellows of a college."[22] Watson analyzed the conflict in terms of turf and abilities.[23]

At first, a two-month reservation was required to secure a seat in a dark space in the basement used as the reading room, but after the novelty wore off the room proved ample; a few months after the Museum had opened, Thomas Gray found himself one of only five readers, the others being the antiquarian William Stukeley and three hacks copying manuscripts for hire.[24] In its first year, alongside Gray, several scientific readers visited the

[16]"Qualifications and Duty Required in the Principal Librarian," BL Add Mss 4449, f. 108. "Rules Proposed to be Observed in Making the Collections of Proper Use to the Publick by Way of Resolutions in a General Meeting of the Trustees," ibid., f. 115.

[17]Emanuel Mendes da Costa applied to be an underlibrarian at the British Museum with these credentials: he was a longtime fellow of the Royal Society, an expert on fossils, and fluent in the all of the main languages. Letter to Lord Hardwicke, 4 Feb. 1756, BL Add Mss 36269, ff. 100–101. William Watson considered Da Costa to be eminently qualified, but his "religion is an unsurmountable object." Letters to the archbishop of Canterbury, 21 June 1756, and Lord Hardwicke, 22 June 1756, BL 36269, ff. 139–142, 144–145. A few years later Da Costa asked Thomas Birch if it was "obnoxious to the Society that I (as by Profession a Jew) can put up for Hawksbee's place" in the Royal Society. Letter of 17 Jan. 1763, BL Add Mss 4317, f. 113.

[18]Gowin Knight to Lord Hardwicke, and 22 Sep. 1754, BL 36269, ff. 29–30.

[19]BL Add Mss 36269, f. 134.

[20]J. Jortin to Lord Hardwicke, n.d. and 12 Feb. 1756, BL Add Mss 36269, ff. 104–106.

[21]"Morton, Charles," *DNB,* 1st ed. 13:1047–48,

[22]Edmond William Gosse (1906, 142).

[23]The underlibrarians were naturalists, and their assistants were antiquarians, an unworkable combination, it turned out. The different parts of the British Museum required different talents, which had to be properly assigned, Watson explained: "We have an extensive collection of the productions of nature & of art; a very large medical & philosophical library; as well as one relating to antiquities, & a vast collection of coins." The friction among the staff was rooted in this fact: "it must require a great length of time for any person to have a competent knowledge of any one branch of the Museum & unless he be acquainted with it, he will be but little qualified to instruct others." The proper persons had to be matched up with the proper subjects. Typical good sense from William Watson to the archbishop of Canterbury, 21 June 1756.

[24]Gosse (1906, 141–142).

room, Watson, Heberden, and John Hadley among them.[25] Readers were admitted for six months at a time upon recommendation; members of the Royal Society and other learned bodies were admitted without recommendation. From its modest beginnings, the library eventually became the national library, and the natural history collection grew into a major research center. This successful institution had no more assiduous early administrator than Charles Cavendish.

Cavendish's own researches were directed to questions of basic science, but he was interested in the uses of science too. On 8 June 1757, he was elected a member of the Society of Arts, founded three years earlier to encourage hopeful applications of knowledge by awarding prizes from money donated by public-spirited supporters of progress. Given the aims of the new society, its membership naturally overlapped that of the Royal Society: of the eleven founding members of the Society of Arts, four were fellows of the Royal Society, and twenty years later the president and all ten vice presidents of the Society were fellows of the Royal Society. Macclesfield, Franklin, Knight, Heberden, and Watson, to name several of Cavendish's friends, were members; it was Watson who proposed Cavendish. The Society attracted a strong aristocratic patronage as well; relatives of Cavendish's belonging to it included the dukes of Devonshire and Bedford, the earls of Bessborough and Ashburnham, Viscount Royston, and Lord George Cavendish. Cavendish was not active in the Society of Arts as he was in the Royal Society and the British Museum, but it is indicative of the breadth of his public interests that in 1760 he was appointed to special committees for judging competitions in the fine arts, technology, and agriculture.[26] He kept up his membership to the end of his life.

The bridging of the River Thames at Westminster was a highly visible application of knowledge of materials, structures, and machines. The early eighteenth century saw both the rapid improvement of roads through turnpiking and the beginning of bridge building on a large scale. A major impetus was the growth of London, by then the largest city in the world, the demands of which on the still largely agricultural nation were vast and insatiable. Herds of cattle were driven down turnpikes and over bridges to feed the concentrated mass of humanity on the banks of the Thames. Here and there streets of the city led to stairs down to the river, where cursing boatman ferried paying passengers to the opposite bank. London Bridge, the only bridge in the city, was medieval, dangerous, congested, and built up with houses. Ideas for improving transportation by a second bridge, discussed since Elizabethan times, had been successfully resisted by impecunious monarchs, water men defending their livelihood from ruin, and parties expressing fears such as commercial competition, armed rebellion, and the falling down of London Bridge once it was neglected for a rival.[27]

Renewed interest in a new bridge took the form of two petitions to Parliament in 1721, leading to a committee and a bridge bill. The House of Commons did not act, probably for political reasons, since Walpole, who favored the bridge and was on the committee, was well hated by then.[28] When in 1736 another petition for a bridge was submitted to the Commons, the resulting committee, which could hear testimony of any kind, chose to hear technical testimony, undoubtedly hoping in this way to avoid the commercial controversy that had

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[25] "Persons Admitted to Reading Room Jan. 12. 1759 to May 11. 1763," BL Add Mss 45867.
[26] 26 Mar., 9 and 30 Apr. 1760, Minutes of the Society, Royal Society of Arts, 5. Derek Hudson and Kenneth W. Luckhurst (1954, 6). Royal Society of Arts (1768). Henry Trueman Wood (1913, 28–46).
[27] R.J.B. Walker (1979, 12–32).
[28] Walker (1979, 44–49).

upset bridge plans in the past. J.T. Desaguliers, the curator of experiments for the Royal Society, addressed the committee on the "proper Instruments for boring the Soil under the River Thames."[29]

The Westminster Bridge Bill of 1736 set up a commission, with about 175 members, a good proportion of whom were members of Parliament. They also included such an obviously useful person as the director of the Bank of England as well as dukes, bishops, and admirals, who were useful in other, more or less obvious ways. The first meeting was held in June 1736, at which time the commissioners viewed models of the bridge that had been exhibited in the House of Commons, and they set up a lottery with the Bank of England to finance the construction.[30]

A good many of the commissioners were fellows of the Royal Society, Charles Cavendish one of them, and the Royal Society was kept informed on the project. Thomas Innys exhibited before them a model of a machine he invented for laying the foundation of the piers of the bridge. To decide on technical matters of this sort, in June 1737 the bridge commissioners formed a committee of thirteen, the so-called committee of works. Cavendish was appointed to it, as were several other fellows of the Royal Society, though William Kent, a well-known architect, was perhaps the only member of the committee with obvious qualifications.[31] Now both a commissioner and a committeeman for the bridge, Cavendish took his duties with his usual seriousness.

Although at the beginning, the committee of works resolved to consider only wooden bridges for reasons of cost,[32] nevertheless it and the commissioners heard the stone-bridge advocate Charles Labelye, whose method of laying the foundations of the piers worked for either a stone or a timber superstructure. Labelye's credentials differed from those of his competitors, the best-known of whom came from a background in architecture and seem to have had no engineering experience. Not an architect, he was evidently experienced in surveying and construction, for the House of Commons treated him as an expert "engineer," calling on him to testify on the bridge before its own petition committee. Like Desaguliers, who claimed him as his "disciple" and "assistant,"[33] Labelye was of Huguenot origins. Educated in Geneva, he settled in England, where he became involved in such projects as draining the fens and improving harbors.[34] In due course, the "foreigner" Labelye was hired by the commissioners to build stone foundations for a bridge that still could be made of wood or stone.[35] Eventually the commissioners decided that a bridge made partly of wood was unequal to the dignity of Westminster and London and ordered it to be built entirely of stone.

Labelye was not a fellow of the Royal Society, but he was friends with a good number of men who were. In the middle of building the bridge, he sent the president of the Royal Society Folkes a calculation about the card game whist.[36] The prospect of a gambling bridge-

[29] 16 Feb. 1735/36, Great Britain, Parliament, *House of Commons Journals* 22:569. Hereafter *HCJ.*
[30] Walker (1979, 63–67).
[31] Besides Cavendish, three other members of the committee had been fellows of the Royal Society since the 1720s: the chairman of the committee, Joseph Danvers, M.P., a lawyer by training and now a landowner; David Papillon, M.P., practicing lawyer; Thomas Viscount Gage, M.P., from 1743 master of the household to the prince of Wales. Walker (1979, 79, 86 n.7.)
[32] 5 Aug. 1737, Minutes of the Committee of Works, vol. 1: Aug. 1737–Sept. 1744, Public Record Office, Kew, Work 6/39.
[33] 16 Feb. 1735/36, *HCJ* 22:569. J.T. Desaguliers (1744, 2:506).
[34] Walker (1979, 83–86).
[35] Walker (1979, 82).
[36] Charles Labelye to Martin Folkes, 22 Mar. 1741/42, Folkes Correspondence, Royal Society.

builder could be unnerving, but Labelye was only carrying out an exercise in De Moivre's subject, the doctrine of chances. Labelye was a good enough mathematician for Desaguliers to publish his investigation of the vis viva controversy in mechanics.[37]

At a meeting of the commissioners in August 1738, Cavendish heard a report about a violent opposition to the bridge. Angered by the threat of losing their trade to the bridge, watermen ran their barges into the boats moored beside the pile-driving engine. After the commissioners decided to advertise that part of the bridge act that legislated the death penalty for anyone found guilty of sabotaging the bridge works, the engine was tried without incident. The designer of the engine brought a model to a meeting of the Royal Society, and Desaguliers published a description and drawing of it in his *Course of Experimental Philosophy.* When in January 1739, the foundation for the first pier was finished, the earl of Pembroke laid the first stone "with great Formality, Guns firing, Flags displaying."[38]

Technical problems dogged construction all the way, the most damaging of which was the gradual sinking of the bridge. It was supposed to bear 1200 tons, but when it was loaded with 250 tons of cannon as a test, it began to fail. "Westminster-Bridge continues in a most declining Way," Thomas Birch wrote to Philip Yorke. People stayed up late to be able to say "What kind of a Night the Bridge has had." The formerly unhappy watermen burst into cheers as they watched the bridge settle as much as four inches in a night.[39] Possibly it was sabotaged, but whatever the cause the subsiding pier had to be rebuilt, requiring extra years. The wait was worth it. Spanning 1200 feet, built of Portland and Purbeck stone, Westminster Bridge was a monument to engineering and architectural grace (Figs. 5.5–5.6).[40]

The first Westminster Bridge lasted only about a century, a brief life compared with the six hundred years of London Bridge, but that was not owing to faulty construction. Once Westminster Bridge was built, the rickety condition of London Bridge gave rise to alarm. On Labelye's advice, some of its piers were removed, but the piers had acted as a dam, and when they were removed the tide eroded the riverbed and ground away at the piers of Westminster Bridge. Labelye's beautiful bridge had to be replaced.[41]

Halfway into the construction, Labelye wrote that the bridge commissioners "have nothing, and can expect nothing, but Trouble for their Pains," and that he admired their selfless "publick Spirit" and "Patience."[42] Labelye was right about Cavendish, who devoted a large effort to the bridge while at the same time carrying out his parliamentary duties. In 1739, in the third year of the bridge, for example, Cavendish served on twenty-four committees of Parliament, and he also went to nineteen meetings of the Westminster Bridge commissioners. In the middle years of the construction, he rarely missed a meeting of the commissioners or of the works committee. In addition he came fairly regularly to a third kind of meeting, that of a small commitee of accounts for the bridge, often chairing the meeting.[43] In 1744, he attended twenty-five out of twenty-six meetings of the commissioners and eighteen out of nineteen meetings of the works committee. He was involved in much of the quiet work in the building of Westminster Bridge, exhibiting the combination of political,

[37]Charles Labelye to J.T. Desaguliers, 15 Apr. 1735, published in Desaguliers (1744, 2:77, 89–91).
[38]Walker (1979, 91–95). Desaguliers (1744, 2:417–418).
[39]Thomas Birch to Philip Yorke, 12, 19 Sep. 1747, 11, 18, June 1748, BL Add Mss 35397, ff. 72–76, 114–116.
[40]Summerson (1978, 113–116).
[41]Samuel Smiles (1874, 70–71, 140–142).
[42]Charles Labelye (1743, 24–25).
[43]Minutes of the Committee of Accounts, vol. 1:1738–1744, Public Record Office, Kew, Work 6/41.

administrative, technical, and accounting skills he brought to his organizational work for the Royal Society.

Scientific Administration

We begin this discussion by recalling some basic facts about the running of the Royal Society. By a royal charter of 1663, the Society was constituted a self-governing corporation. Every St. Andrew's Day, November 30, the members elected a Council of twenty-one and a number of officers: president, treasurer, and two secretaries. The president chose one or more vice presidents to sit in for him when he was absent. To ensure that the Council did not become fixed and at the same time to ensure a measure of continuity, ten of its members were newly elected each year while eleven were kept on from the old Council. The government of the Society was invested in the Council and president, who were assisted by a person responsible for foreign correspondence and translations of foreign papers. The election of officers was by simple majority.[44]

After being a member for eight years, Cavendish was elected to its Council for the first time in November 1735. He was elected again in November 1741, and for the next twenty-one years he was on the Council every year with the exception of 1753, when family business called him away. He served four more nonconsecutive terms on the Council, his last in 1769, when he served together with his son Henry. Henry would have an even longer record of service; combined, their membership on the Council would span seventy-three years, with some interruptions. For many years, Charles was also a vice president.

The Royal Society was now in its third home, a quiet, central location in Crane Court (Fig. 5.1). The front of the house faced a garden, the back a long, narrow court. Up one flight of stairs and fronting the garden was the small room where the Society as a whole met weekly, except during Christmas and Easter and the long recess in late summer, about thirty times a year in all. How often the Council met depended on how busy the Society was and on the energy of the current officers. Ordinarily it met six or fewer times a year toward the end of Folkes's presidency in the late 1740s, and eight to ten times under Macclesfield's in the 1750s, but it met twenty-two times in 1760 during preparations for observing the transit of Venus the following year. Presidents before Newton rarely came to Council, but Newton came all the time, changing the day of the meetings of the Council to accommodate his schedule. His precedent was followed, with decreasing rigor, by his successors: Sloane missed only eight out of 105 Council meetings in his fifteen years as president; his successor, Folkes, missed one quarter of his; and Folkes's successor, Macclesfield, missed about one third of his. Cavendish's first term on the Council was under Sloane's presidency, and he missed a good many meetings, perhaps because he found that the Council conflicted with his political duties. His attendance picked up in the year he returned to the Council, which was the year he stepped down from Parliament; for the next six years he came to two out of three meetings, and after that he was almost never to miss a meeting. Frequently only a half dozen members attended, a meager number considering that it included the two secretaries and usually the president, and ten or so constituted a fair turnout. To give an idea of his steadfastness, in the five years from January 1748 through November 1752, he attended all twenty-seven meetings, and in the eight-years from December 1753 through November

[44] 20 Aug. 1730, Minutes of Council, Royal Society 3:50–61.

1761, out of eighty-seven meetings, he attended seventy-eight. Only two fellows came oftener, the secretaries of the Society, who had no choice short of neglecting their duties, Peter Davall from 1747 and Thomas Birch from 1752. One other councilor came regularly over a long period, the barrister James Burrow, who like Charles Cavendish sometimes acted as temporary president of the Society during a vacancy.[45]

The minutes of the Council listed Lord Charles Cavendish first after the president, except when Lord Macclesfield (before he was president) was there, and later Lord Morton; this protocol ceased after 1760 when councilors were listed alphabetically. At this time about one seventh of the membership of the Royal Society was aristocratic,[46] a proportion which was increasing.[47] As an aristocrat who supported science, Cavendish was not unusual. What set him apart from most was his solicitous attention to the affairs of the Society.

Meetings of the Council typically dealt with money: payment of bills from printers, bookbinders, solicitors, and instrument makers; payment of debts; payment of insurance on the houses owned by the Society; and payment of salaries. Besides handling these matters routinely as they came up in Council, Cavendish usually went over them all again, since nearly every year he was appointed to a committee of auditors of the treasurer's account. Cavendish was an all-purpose, responsible, and accurate servant of the Society, as his son Henry would be after him.

Recently the *Philosophical Transactions* had been criticized for publishing thin material. The critic John Hill, a writer on natural history and on various subjects outside of science, stepped up his criticisms after having failed in his bid to become a member of the Royal Society. Singling out for ridicule papers on natural history appearing in the journal, he proposed that the Society form a committee to decide on papers to be read or published. There were influential members of the Society such as William Watson who agreed with Hill that the standard of papers could be improved.[48] Early in 1752 Macclesfield asked the Council to consider the way papers were chosen for publication in the *Philosophical Transactions*. One of the secretaries had run the journal, making decisions on his own though probably taking into consideration requests by individual members. At this time the secretary was the physician Cromwell Mortimer, under whose oversight the journal emphasized antiquarian interests.[49] For the "credit and honour of this society," Macclesfield said, from now on, decisions about publication would be made by a committee. The president, the vice presidents, and the two secretaries were to be included in the committee, and no decisions on papers could be made without a quorum of five. For advice on particular papers, authorities from outside the committee could be brought in by a request of a majority of the committee. At meetings of the committee, at the request of a member, a paper would be read in full without "debate or altercation." Then a vote would be taken by ballot, so as to "leave every member more at liberty to fully declare his opinion." Since the decision to publish a paper was a recognition not every author received, the new committee had a sensitive assignment. Macclesfield (correcting himself) said that the Society in the past had not "usually meddled" in the selection of papers to be published. That it had meddled at various

[45] Information from the Royal Society, Minutes of Council.
[46] Bound with the minutes of the committee of papers is a printed membership list for the Royal Society in 1749. The total British membership then was around 340, and of these around 45 were aristocrats, counting bishops and persons like Cavendish with the courtesy title "Lord."
[47] Richard Sorrenson (1996, 36).
[48] Kevin J. Fraser (1994, 44, 48–51). John Hill (1751).
[49] Charles Bazerman (1988, 137).

times in various ways he conceded; what was going to change was that it would meddle in a systematic and accountable way. Cavendish joined Macclesfield in proposing amendments, and on 26 March 1752 the new statutes were passed by the Council.[50] With Cavendish in the chair, Philip Yorke proposed that for the time being the Council would be the "committee of papers."[51] Readers of the journal were informed that the *Philosophical Transactions* was now for the "sole use and benefit of the society, and the Fellows thereof."[52] In the middle of the eighteenth century, in a variety of ways the Royal Society rationalized its procedures,[53] and the papers committee could be seen as an example.

Although a committee would decide on which papers were to be published, a secretary continued to screen papers presented to the Society. The role of a secretary in controlling access to the Society can be seen in the exchange of letters between Thomas Birch and Samuel Bamfield, who had written a paper on a theory of astronomy that disagreed with Newton's. Bamfield wanted to have it read to the Society; Birch refused. Bamfield suggested that another member might see the truth of his theory; Birch recommended that he read a standard book on Newtonian astronomy. Bamfield then tried to dedicate his work to Macclesfield and have Macclesfield look at it; Birch denied him.[54]

In April 1752, the committee of papers convened for the first time, Cavendish presiding. Macclesfield came to the first three meetings, but then dropped out, returning at the end of the year when he became the new president of the Royal Society. Cavendish chaired all of the meetings but one through November 1752. In 1753 Cavendish was not on the Council and the committee. When he returned to the Council in 1754, he attended every meeting of the committee, and this remained his habit in the years following; after him, Burrow came most often, Watson and Bradley came occasionally, and other members came and went. The committee met four to six times a year, usually attended by about four members in addition to the two secretaries, who were required to be there, and the president, when he came. Cavendish's attention to this important responsibility of the Society set a precedent for his son Henry, who would be a steady presence on this committee in his time.[55]

The work of the committee of papers was demanding. In the years before 1740, the number of papers reached a peak of well over 100 per annum on the average. After that, the number fell off, but slowly, and the load remained considerable through Cavendish's years on the committee. At the time the committee was formed, there was a backlog of papers, which the committee went through chronologically, beginning with January 1751, taking several meetings to get through that year: at its first meeting, the committee approved sixteen papers for publication, at its second meeting fifteen, and at its third twenty-four. Daniel Wray, who began coming at the second meeting, wrote to Philip Yorke of their "diligence, as members

[50] 20 Feb., 19 and 26 Mar. 1752, Minutes of Council, Royal Society 4:55, 64, 71–75, 83.
[51] 27 Feb. 1752, ibid. 4:64–65.
[52] 19 Mar. 1752, ibid. 4:76.
[53] Measures were taken to eliminate unnecessary duplication of records, and to make progress in "methodizing" the orders of the Council "relative to the offices of Clerk, Librarian, Keeper of the Repository, Housekeeper, Macebearer and Porter." "Proposal Concerning the Papers of the Royal Society," presumably by Macclesfield, BL Add Mss 4441. It was found that papers presented before the Society ended up in two kinds of books, while only one, the minutes of ordinary meetings, was needed. 12 July 1742, Minutes of Council 3:285; 1 Feb. 1763, ibid. 5:1.
[54] Letters between Samuel Bamfield and Thomas Birch c. 1761–64, BL Add Mss 4300.
[55] Rough notes of the meetings of the committee of papers taken by Thomas Birch, one of the secretaries, in "Minutes of the Royal Society," vols. 1 and 2, Birch Collection, BL Add Mss 4445–46.

of the Committee of Papers."[56] Over time, the number of papers was an inadequate measure of the committee's work, since papers became longer.[57]

To evaluate critically every paper that came before the Royal Society was a good way to keep abreast of what went on in science, though we think that Cavendish's primary motivation was service to the Society. Procedures applying to the *Philosophical Transactions* were considered important, since its contents were the public record of the Society, on which its external authority largely rested. Decisions arrived at by men who were active in science and in the Society were likely to be competent and fair. Cavendish helped get the committee off to a conscientious start in its first year.

Cavendish was also active in the administration of the Royal Observatory. In 1765, by warrant from the king, the president together with other fellows of the Royal Society was charged with making tours of inspection of the instruments of the Observatory. Cavendish was one of several fellows who regularly made these tours, or "visitations," to Greenwich to determine what repairs were needed and to estimate the expense. In 1781, two years before his death, Charles Cavendish was still discharging the Royal Society's obligations, reminding the president that the publication of the Greenwich observations was long overdue.[58] In this capacity again, his son Henry would follow his precedent.

As in the British Museum, Cavendish's interest in books and manuscripts together with his accounting skills was put to use in the Royal Society, where he served as one of the inspectors of the library. The clerk of the Society said that "at present the books weigh less than the filth that covers them" a measure of the neglect of the library at the time. Cavendish and his fellow inspectors delivered a damning report on it: the catalog of the the great Norfolk collection of books and manuscripts is faulty in titles and dates, "there is a deficiency of several whole centuries of numbers" in the catalog, numbers on books do not agree with numbers in the catalog, "different volumes of the same work stand on different shelves, and have very different numbers," "different books have the same number," "many of the books are so ill arranged, as to the sizes of them, that they cannot be placed upright on the shelves," many have spoiled bindings or broken wooden covers, and many more are "very much worm-eaten." As for the rest of the books in the library, their cataloging had stopped over twenty-five years before, whereas since that time nearly 1000 books and pamphlets had been donated to the library, the record of which was found in the journals of the Society. The problems were so severe that the inspectors recommended making an entirely new catalog for the Norfolk collection, updating the catalog of the rest by going through the journals, altering the shelves or rearranging the books, and rebinding those books that were not so far deteriorated as to be beyond repair. Owing to the inspections, some of the defects were corrected. The library was worth the attention and the expense. In size

[56]Daniel Wray to Philip Yorke, 5 July 1752, Hardwicke Papers, BL Add Mss 35401, f. 157.

[57]Raymond Phineas Stearns (1970, 97–98). Bazerman (1988, 81).

[58]Upon the death of the astronomer royal James Bradley in 1762, his executors removed his observation books from the Royal Observatory, claiming them as private property. In 1763, Maskelyne addressed the Royal Society on the subject of their recovery. To reimpose its authority, the Royal Society requested a new warrant from the king, which he granted in 1765, appointing the president and Council of the Society to be visitors of the Royal Observatory. "Visitations of Greenwich Observatory, 1763 to 1815," Royal Society, Ms. 600, XIV.d.11, ff. 6 passim. Cavendish to Banks, 19 May 1781.

it compared with an excellent private library, around 10,000 volumes, roughly the size of Henry Cavendish's private library later in the century.[59]

Elected during Sloane's presidency, Cavendish served through Folke's, Macclesfield's, and Morton's. In 1768, while the Council was absorbed in preparations for a second transit of Venus the following year, Morton died. Ten days latger, Daniel Wray wrote to Philip Yorke that "*Lord Charles* is deaf to all our prayers; and will not *preside* over us."[60] Cavendish was in his early sixties, in good health, and on the Council, but he did not want to be president; his feelings on the subject were the same as when Folkes had stepped down nearly fifteen years earlier.

Science

We begin with Charles Cavendish's earliest recorded scientific observations, which took place soon after his election to the Royal Society. In June 1728 at James Bradley's observatory at Wansted, Cavendish made observations at using a zenith telescope for detecting the parallax of the fixed stars (Fig. 5.7).[61] The instrument had been in place for less than a year, and after Bradley and Halley, Cavendish was the next person to observe with it. Later that year, in the course of looking for parallax, Bradley discovered the aberration of light from the stars, which greatly improved the accuracy of observational astronomy.

With his new instrument Bradley observed small motions of stars passing nearly through the zenith, motions which he knew were too large and in the wrong direction to be caused by the parallax of the fixed stars. His explanation was that the motion of the zenith stars was the resultant of two motions, the orbital motion of the Earth and the motion of light. In his announcement of Bradley's discovery of the aberration of light to the Royal Society, Halley observed that the "three Grand Doctrines in Modern Astronomy do receive a Great Light and Confirmation from this one Single Motion of the Stars Vizt. The Motion of the Earth, The Motion of Light and the immense distance of the Stars."[62] Bradley had, in fact, provided the first direct evidence of the Copernican theory, and the twenty-four-year-old Charles Cavendish had had a brush with this grand work of observation and reasoning in astronomy.

We assume that Cavendish learned about instruments from Bradley. Cavendish was able to return the favor several years later after Bradley had moved from Wansted to Oxford, a few miles from Macclesfield's Shirburne Castle, where Bradley regularly made observations. When Bradley became a candidate to succeed Halley as astronomer royal, Macclesfield exerted his influence, but because his voting had put him out of favor at court, he had

[59]Andrew Coltee Ducarel to Thomas Birch, 13 Oct. 1763, Birch Correspondence, BL Add Mss 4305, 4:57. "I compute about 1000 vol to whit the Norfork 500 MSS & 3000 printed. The Society Library about 6000 printed books only." Emanuel Mendes da Costa to William Borlase, 9 July 1763, E. da Costa Correspondence, BL Add Mss 28535, 2:150. Reports of the inspectors of the libraries of the Royal Society, 6 June 1768, 6 April 1769, and 25 July 1770, Minutes of Council, Royal Society 5:308, 6:25–26, 62–65.
[60]Daniel Wray to Lord Hardwicke, 22 Oct. 1768, in George Hardinge (1815, 137). Next month, James West presided over them.
[61]S.P. Rigaud (1832, 237).
[62]14 Nov. 1728, JB, Royal Society 13:260–262, on 261–262. Together with Samuel Molyneux, Bradley looked for the parallax of the star Gamma Draconis, which would appear as a small annual cyclical motion of the apparent position of the star. They observed a small annual cyclical motion, but not the one they expected, for which they had no explanation. After Molyneux died in 1728, Bradley found the explanation in the "aberration of light."

to proceed indirectly; to build scientific support for Bradley, he wrote to William Jones to ask him to enlist Folkes and Charles Cavendish.[63]

We learn of Cavendish's next recorded observations from a passing remark by his friend William Watson: in the severe cold of 1739, the thermometer in Cavendish's room sank to twenty-five degrees; Cavendish, Watson said, then placed his thermometer outside the window and some distance from it, observing a low one night of thirteen degrees.[64] It is possible that in 1739 Cavendish had a self-registering thermometer for low temperatures, though he did not make public such an instrument until nearly twenty years later.

Figure 5.7: James Bradley. Painting by Thomas Hudson, around 1742–47. Wikimedia Commons.

[63] Lord Macclesfield to William Jones, 13 Jan. 1741/42; Lord Macclesfield to Lord Hardwicke, 13 Jan. 1741/42, in Rigaud (1832, xlvi).
[64] William Watson (1767, 444).

Unlike his own work, which he kept to himself or communicated privately or, at most, allowed a colleague to mention publicly, Cavendish's work for the Royal Society was public. His first scientific assignment concerned longitude at sea. The Greenwich Observatory was founded in 1675 to perfect astronomical tables for finding longitude, but the tables did not work for ships. To secure their safety and to promote trade, in 1714 Parliament passed an act that provided rewards for improvements in taking longitude at sea proportional to their accuracy, the ultimate award, £20,000, to be paid to the discoverer of a method that on a six-week journey to the West Indies gave the longitude upon arrival within an accuracy of thirty miles. To evaluate proposals, the Board of Longitude was established, a body of twenty-two members, who were quickly inundated with proposals; before a parliamentary committee, Newton, a member of the Board, rejected them all. A well-known alternative to the lunar method of finding longitude at sea was a seaworthy and accurate clock. John Harrison, at first with his brother James, built a series of clocks, the first one proving capable of overcoming variations of heat, moisture, friction, and fluidity of oil so perfectly that its error was less than one second a month for ten years running, only this wonderfully accurate machine was a delicate pendulum unsuited for taking to sea. The second clock was practical, keeping good time while undergoing violent motions simulating storms at sea. The Board of Longitude rewarded Harrison with modest sums of money, and in 1741 Cavendish was one of committee of twelve fellows of the Royal Society called in as a source of expert opinion, who recommended that Harrison continue to be encouraged.[65] In 1763, on the eve of a second trial run of Harrison's latest clock, Cavendish was appointed to another committee on the project. From what had become a life work and prolonged legal battle, and with the support of Cavendish and other fellows of the Royal Society, in the end Harrison received most of the money he deserved, and in addition he was awarded a Copley Medal. British ships in return received a reliable instrument for determining longitude; Captain Cook used Harrison's clock on his voyage to the South Seas in 1772, justifying the claims of precision made for it.[66]

In 1742, Cavendish accepted another assignment having to do with accuracy of measurement. The project was to compare the Royal Society's weights and measures with those kept by the Academy of Sciences in Paris and also with other standards in England. Measurements were decisive in some experimental work, and depending upon the country in which they were made, they were expressed in the English foot or the French toise, lengths marked off on metal standards and deposited in various archives. The project was expanded to include a comparison of the Royal Society's standards with other standards in England. The instrument-maker George Graham carried out the necessary experiments in the presence of a delegation of witnesses from the Royal Society, who other than being fewer were

[65]The persons Cavendish came together with on the committee were known for their accuracy: mathematicians De Moivre and his circle, Folkes, Jones, and Macclesfield; astronomers Bradley and Halley (and Macclesfield); instrument makers John Hadley and George Graham; the versatile James Jurin; and Cambridge professors of natural philosophy and mathematics Robert Smith and John Colson.

[66]The act of 1763 altered the original act of 1714. The other members of the new committee were Lord Morton, Lord Willoughby, George Lewis Scott, James Short, John Michell, Alexander Cumming, Thomas Mudge, William Frodsham, and James Green. Only the instrument maker Short and the watchmakers Frodsham and Green were satisfied with Harrison's explanation of his clock. Cavendish was appointed by the Board of Longitude to another committee; John Bird deputized for him this time. E.G.R. Taylor (1966, 126, 170, 172). "Some Account of Mr. Harrison's Invention for Determining the Longitude at Sea, and for Correcting the Charts of the Coasts. Delivered to the Commissioners of the Longitude, January 16th, 1741–2"; in John Harrison (1763, 7–8, 19, 21). Humphry Quill (1966, 5–6, 120–122, 139–146, 186, 221).

almost the same as the committee that had investigated Harrison's clock. In this company, Cavendish was in his element, accuracy.[67]

In 1747 William Watson invited members of the Royal Society to join him in an experiment on electrical conduction, the scale of which, miles literally, was a measure of his enthusiasm for the subject. The experiment was made possible by the recent discovery of the Leiden jar, the "explosion" of which could communicate shocks over considerable distances. Watson thought that a powerful Leiden jar might send a shock clear across the River Thames, and to test the idea Watson with "many others" assembled at the new Westminster Bridge (to which Cavendish had recently devoted so much work) across which they laid a wire connected to a Leiden jar, the river and the bodies of the experimenters completing an electrical circuit. Upon discharging the Leiden jar, Watson and his associates felt shocks in their wrists and elbows, confirming his hypothesis. The circuit was progressively lengthened until finally the experimenters moved from the river onto dry land, at Shooters' Hill, where using signals and watches they concluded that electrical conduction is "nearly instantaneous." In the experiments, which lasted for weeks, twenty-five fellows of the Royal Society took part, including Cavendish and other members of the De Moivre circle, Folkes, Stanhope, Davall, Jones, and Scott. Bradley was there, and so were many of the leading instrument makers. For this "Body of Philosophers," the outdoor experiments in the middle of summer were an outing as well as an inquiry into nature, Stanhope supplying venison pastry and French wine.[68] The experiments were financed by and "made by the order and for the service of the [Royal] Society."[69] Watson published an account of them in the *Philosophical Transactions*.[70]

More important was Cavendish's assistance to Watson in his private researches on electricity. To discover if the vacuum transmits electricity, Watson relied on the imperfect vacuum achieved by an air pump until Cavendish solved the problem with an ingenious and very simple apparatus, which achieved a Torricellian vacuum and an electrical circuit at once. Bending a narrow glass tube seven and a half feet long into a parabolic shape, Cavendish filled it with mercury and placed its ends in basins of mercury; the mercury in the two arms of the parabola descended until the level stood about thirty inches above the basins, leaving a vacuum at the top of the parabola. By bringing up a wire from an electrical machine, Cavendish caused electricity to pass through the vacuum in a "continued arch of lambent flame." "This noble Lord," Watson said in appreciation, joined a "very complete knowledge" of science with that of making apparatus; his "zeal for the promotion of true philosophy is exceeded by none."[71]

"It were to be wished, that this noble philosopher would communicate more of his experiments to the world, as he makes many, and with great accuracy," Benjamin Franklin

[67]"An Account of the Proportions of the English and French Measures and Weights, from the Standards of the Same, Kept at the Royal Society," *PT* 42 (1742, 185–88). "An Account of the Comparison Lately Made by Some Gentlemen of the Royal Society, of the Standard of a Yard, and the Several Weights Lately Made for Their Use; with the Original Standards of Measures and Weights in the Exchequer, and Others Kept for Public Use, at Guild-Hall, the Tower, &c.," *PT* 42:541–556. H. Hall and F.J. Nicholas (1929, 40). Of the seven witnesses, five we have met in connection with De Moivre: Folkes, who was then president, Macclesfield, Jones, Peter Davall, and Cavendish. The other two were the instrument-maker Hadley and the secretary Cromwell Mortimer.
[68]Thomas Birch to Philip Yorke, 15 Aug. 1747, BL Add Mss 35397, ff. 70–71.
[69]17 Oct. 1748, Minutes of Council, Royal Society 4:15.
[70]William Watson (1748a).
[71]William Watson (1752c, 370–371).

wrote in 1762, expressing his admiration for an experiment Cavendish made on the conduction of electricity by heated glass.[72] The study of electrical conduction had been advanced by the discovery of the Leiden jar, which delivered far greater quantities of electricity than did the unaided electrical machine. The Leiden jar was able to do this because the glass of the jar did not conduct electricity. By his experiment, Cavendish showed that when glass is heated to four hundred degrees or higher, it becomes a conductor of electricity.

From the summer of 1760 to early 1763, the Council of the Society was almost exclusively occupied with observations of the transit of Venus in 1761, energized by the complexity of this project. In anticipation of the transit, Halley had recommended observing it as a means of measuring the distance of the Earth from the Sun, the standard by which the distances of other bodies of the solar system were measured. To obtain the necessary observations of Venus crossing the solar disk, the Royal Society sent Nevil Maskelyne and Robert Waddington to St. Helena, and Charles Mason and Jeremia to Bencoolen, though they were forced to stop at the Cape of Good Hope. Sixty-two observing stations in a number of countries participated in this project of unprecedented size, and the Royal Society was to receive their reports of the transit and to publish them in its *Philosophical Transactions*.[73] Cavendish was involved in the scientific work at various levels, from the examination of a faulty instrument to the writing of a synopsis of the completed observations of the transit.[74] Soon after the transit of Venus, two of its observers Charles Mason and Jeremiah Dixon were commissioned by the Royal Society to measure a degree of latitude between Maryland and Pennsylvania, and Cavendish played a part in this too.[75] In general, there was little of scientific significance done officially at the Royal Society in the middle of the eighteenth century in which Cavendish was not involved.

The best-documented example of Charles Cavendish's scientific work at the Royal Society is his repetitions of experiments on the compressibility of water made by John Canton, a London schoolmaster. Canton's apparatus was simple, a glass tube with a very small bore two feet long, open at one end and closed at the other by a hollow glass ball an inch and a quarter across. In a preliminary experiment, the ball and a few inches of the tube were filled with mercury and placed in a water bath, which was heated until the mercury rose to the top of the tube, at which time the tube was hermetically sealed. When the mercury had cooled to its original temperature, it stood 32/100th of an inch higher than it had originally, before the mercury had been heated and the tube sealed. The only difference before and after the expansion of the mercury was that the pressure of the atmosphere over it had been removed. Canton found the same when water was used in place of mercury, only the water rose a little higher than the mercury, 43/100th of an inch. The only difference before and after the expansion of the water again was that the pressure of the atmosphere over it had been removed. In a paper in the *Philosophical Transactions* in 1762, Canton concluded that water is compressible. Two years later he published a sequel in which he extended his experiments to other liquids.[76]

[72] Benjamin Franklin to Ebenezer Kinnersley, 20 Feb. 1762, ed. L.W. Larabee (1966, 10:42).

[73] Weld (1848, 2:11–19). A. Pannekoek (1961, 284–287). J.D. North (1995, 352–354).

[74] 27 May 1762, Minutes of Council, Royal Society 4:333–34. Thomas Birch to Philip Yorke, 6 Sep. 1760, 20 June 1761, BL Add Mss 35399, ff. 153, 207.

[75] 25 June 1761, 25 Oct. 1764, Minutes of Council, Royal Society 4:45.

[76] John Canton (1762; 1764). John Canton to Benjamin Franklin, 29 June 1764, in ed. L.W. Larabee (1967, 11:245).

Doubts were raised about Canton's experiments in the *Monthly Review*, which although it was not a scientific journal nevertheless reviewed critically the contents of the *Philosophical Transactions*. When the Royal Society decided to honor Canton with his second Copley Medal—his first was for experiments on magnetism—for his proof of the compressibility of water, the journal hinted that it was to the Society's dishonor.[77] The new president of the Royal Society, Lord Morton, asked the secretary Thomas Birch if it was "necessary every year to give the Medal," and he also asked for an account of the "Experiment, by the [Florentine] Accademia del Cimento which pretends to establish the opinion that water is incompressible."[78] Because in conversation, some fellows made objections, in concern for the "honour of the Society" the Council appointed a committee to repeat Canton's experiments at the Society's expense and to report back to the Council.[79] Any objections to Canton's experiments had to be submitted in writing if they were to be considered by the committee. In June 1765 the Council ordered instruments for the committee, who were assisted in its experiments by several instrument-makers.[80] The Society was in recess for the summer, and some of the committee members were out of town. Those who remained—Cavendish, Franklin, Watson, Heberden, and Ellicott—met four times in July to perform experiments in the Museum of the Society. At the beginning of August, the clerk of the Society informed the president that the attending members of the committee were convinced of Canton's conclusion, but since they were "all friends to the experiments," he anticipated a "contest," especially since the experiments were of such "nicety." In November, after the Society had resumed its meetings, certain experiments were performed a second time before a larger committee.

The larger committee contained a principal skeptic of Canton's claims. Francis Blake, an Oxford mathematician who was active in the Society, raised various questions about Canton's experiments, but his main concern was what seemed to be a violation of common sense: in the Florentine experiment, water was subjected to great pressure without, evidently, causing any change in its bulk, whereas in Canton's experiment, an observable change was alleged to have resulted from a very slight pressure. Which account was Blake to credit? As requested, he put his questions to the Council in writing.[81]

In a paper drawn up for the Council, Cavendish stated and answered the objections to Canton's experiments.[82] The first objection went to the heart of the matter, the conflict with the Florentine experiment: experiment is authority, Cavendish said, and experiment can overrule experiment. In response to Blake's objections, Cavendish wrote a separate paper, which he began by making the same point: "The authority of the most able experimenters is of no weight, when it appears that their experiments were made in such a way, as could not

[77] *The Monthly Review* 29 (1763): 142–144, and 33 (1765): 455–456, on 456.

[78] Lord Morton to Thomas Birch, 6 and 17 Nov. 1764, BL Add Mss 4315, ff. 13, 16.

[79] Besides Cavendish, the committee consisted of the president Lord Morton, Matthew Raper, John Ellicott, James Short, William Watson, Israel Mauduit, and Charles Morton. 28 Nov. 1764, Minutes of Council, Royal Society 5:57. Francis Blake, Edward Delaval, Benjamin Franklin, and George Lewis Scott were added to the committee: 21 Feb., 17 June 1765, ibid. 5:62–63, 109.

[80] They were John Bird, James Ferguson, and Edward Nairne. John Bird is referred to in Cavendish's memoranda on the experiments. James Ferguson was paid for his work: 10 July 1766, Royal Society, Minutes of Council 5:161. Edward Nairne was also appointed according to Lord Morton: 30 Nov. 1765, JB, Royal Society 25:655.

[81] Francis Blake, "Remarks and Queries Recommended to the Consideration of the Right Honourable the Earl of Morton," Canton Papers, Royal Society, 3.

[82] Canton Papers, Royal Society, 3. These objections are contained also in a much longer (11-page) paper, which would also seem to have been written by Cavendish, though the copy in the Canton Papers is not in his handwriting.

possibly show so small a degree of compressibility as Mr. Canton has discovered."[83] There had been progress in the art of experiment in the century since the Florentine experiments, Cavendish said, evidence of which was Canton's skillful demonstration of "so small a degree of compressibility."

We are indebted to the Canton controversy for the only surviving direct record of Cavendish's experimental work, preserved in Canton's papers at the Royal Society. Cavendish sent his measurements and computations to Canton to review, having annotated them throughout with "by my measure" and signing the bottom of every sheet. This example of his practice shows thoroughness and attention to accuracy, characteristics equally of his son Henry's work, of which we have ampler record.

In November 1765, the Council resolved that the hypothesis of the compressibility of water accounts for Canton's experiments and that no other appears to do so as satisfactorily, on which basis it voted to award Canton the Copley Medal for 1764.[84] Two days later, at the anniversary meeting of the Society when the award was announced, the president Morton referred to the work on Canton's experiments by that "Noble Member of the Society," Lord Charles Cavendish, who was "eminent for his great Abilities, and deep knowledge in all the branches of science that come before him."[85] He did not describe the ensuing experiments carried out at the Society, since Cavendish had written a "full and accurate Account" of them and of the "Theory deducible from them."[86] Cavendish's paper was read at the next general meeting of the Society.[87]

Cavendish described several self-registering thermometers he had contrived in his one publication in the *Philosophical Transactions*, in 1757, by which time he had been active in science for thirty years. The idea of maximum and minimum thermometers goes back to the end of the seventeenth century, but Cavendish's were the first maximum and minimum liquid thermometers.[88] Fig. 5.8 shows them: two maximum thermometers, one using mercury and the other alcohol, and one minimum thermometer. Macclesfield, who was then president of the Royal Society, proposed Cavendish as the Copley Medalist for that year, a choice which the Council unanimously approved. In his address to the Society on the occasion, Macclesfield brought together the Copley Medalist's scientific and social eminences: Lord Charles Cavendish was as conspicuous for "his earnest desire to promote natural Knowledge, and his Skill and abilities together with his continual Study and endeavor to accomplish … his desire" as he was for his "high Birth and eminent Station in life." The Medal was a small part of the recognition that was due him, Macclesfield said; because of his "excess of Modesty," the public had been deprived "of many important discoveries as well as considerable improvements made and contrived by his Lordship, in Several Instruments and Machines necessary for trying Experiments and deducing proper consequences from the Same; and

83 Charles Cavendish "Observations on Mr. Blake's Objections to Mr Canton's Experiments," Canton Papers, Royal Society.
84 21 and 28 Nov. 1765, Minutes of Council, Royal Society 5:131–132.
85 30 Nov. 1765, JB, Royal Society 25:656.
86 Morton's address, 30 Nov. 1765, JB, Royal Society 25:647–664, on 656. The award of the Copley Medal did not bring the work of the committee to an end; two and a half weeks later, the Council resolved that an experiment on the compressibility of water proposed by Morton be resumed. 19 Dec. 1765, Minutes of Council, Royal Society 5:148.
87 Charles Cavendish, "A Paper Delivered to Mr da Costa for the Use of the Committee on Mr Canton's Experiments," 21 Oct. 1765, and "Appendix to the Paper on Mr Canton's Experiments," 5 Dec. 1765, JB, Royal Society 25:668–679. The material is also in the Canton Papers, Royal Society, 3.
88 William E. Knowles Middleton (1966, 150).

also of the results of various usefull and instructive Experiments that he has been pleased to make in private, with that accuracy and exactness which are peculiar to his Lordship, and which few besides himself have a just right to boast of."[89]

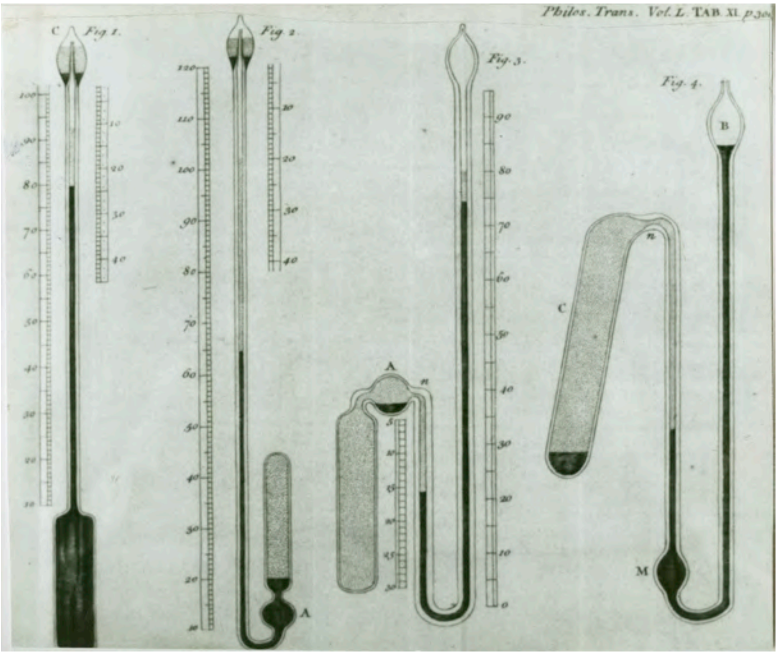

Figure 5.8: Charles Cavendish's Thermometers. The thermometer in Figure 1 shows the greatest degree of heat. It differs from ordinary thermometers in that the top of the stem is drawn into a capillary tube, which ends in a glass ball C. The cylinder at the bottom and part of the stem are filled with mercury (dark part of the figure), showing the ordinary degree of heat. Above the mercury is spirit of wine (alcohol, dotted part of the figure), which also fills the ball C almost to the top of the capillary tube. When the mercury rises with temperature, some spirit of wine is forced out of the capillary tube into the ball. When the mercury falls with a falling temperature, a space at the top of the capillary tube is emptied of spirit of wine. A scale laid beside the capillary tube measures the empty length, which is proportional to the greatest degree of heat that has been registered. Figure 2 is an alternative construction. Figure 3 shows a thermometer for giving the greatest degree of cold. Figure 4 shows how the instrument can be made more compact, an advantage if it is sunk to the bottom of the sea or raised to the upper atmosphere by a kite. The drawing is from a paper that Cavendish communicated to the Royal Society, for which he was awarded the Copley Medal that year. Charles Cavendish (1757).

[89]The Copley Medal was awarded to Cavendish "on account of his very curious and useful invention of making Thermometers shewing the greatest degrees of heat and cold during the absence of the observer." 17 and 31 Mar. 1757, JB, Royal Society 22:506, 520; 30 Nov. 1757, ibid. 23:638–648, on 638–639. It has been suggested that the Royal Society may have been influenced by Cavendish's social standing as well as by the scientific merits of his work. It could be, though it is not clear that in the year 1757 a more deserving work was passed over. William Lewis continued to bring his important experiments on platinum the before the Society, but he had received the Copley Medal in 1754 for earlier experiments in this series. Yakup Bektas and Maurice Crosland (1992, 52).

Apart from their lofty phrasing, Macclesfield's observations were factual. Cavendish made experiments in various branches of natural philosophy, with careful regard for "accuracy and exactness." What Macclesfield called Cavendish's "modesty" could with equal rights be called his "confidence." Given his rank and his competence, he did not need to (anymore than Macclesfield needed to) publish his researches to gain recognition; indeed if he had published them, he might have betrayed an *im*modesty. It was enough that at times he made his results available to his colleagues in the Royal Society. With a naturalness not easily attained by those who had to advance themselves, Cavendish could live an approximation to the cooperative scientific life envisioned by the utopians of the previous century.

Information about Cavendish's researches away from the Royal Society is fragmentary. His electrical experiments were brought up earlier, referred to by Watson and Franklin. His son Henry's manuscripts record his measurements of the pressure of water vapor over a wide range of temperatures.[90] From the same source, we know that he performed experiments on the bulk of water over a range of temperatures,[91] measured the depression of mercury in glass tubes of different sizes,[92] measured the expansion of mercury with heat,[93] probably did chemical experiments,[94] and made astronomical observations together with Henry.[95] From other sources, we know that he computed tables of errors of time for William Ludlam, an astronomer at Cambridge,[96] made meteorological observations with Heberden,[97] kept a meteorological journal,[98] and took Earth-magnetic readings in his garden.[99]

Cavendish converted water to vapor and back with an ingenious and very simple apparatus, similar to Canton's. He filled a barometer enlarged into a ball on top with mercury

[90]Charles Cavendish's values for aqueous vapor tension, given in inches of mercury, are reproduced in an editor's note, in *Sci. Pap.* 2:355.

[91]In connection with government taxes on spirits, Henry Cavendish supplied a table of the bulk of water at degrees of heat from 25 to 210°. "From the Experiments of Lord Charles Cavendish, Communicated by Mr. Henry Cavendish. March 1790," Blagden Collection, Royal Society, Misc. Notes. In the same connection, he communicated the weight of a cubic foot of water, "the result of my father's experiment." Henry Cavendish to Charles Blagden, [probably 1790]; in Jungnickel and McCormmach (1999, 673–674).

[92]Henry Cavendish included his father's table of the depression of mercury in his report on the meteorological instruments of the Royal Society in 1776. Cavendish, (1776b, 116). The table was cited for a long time. Pierre Simon Laplace (1839, 1004).

[93]Thomas Young (1807, 2:391).

[94]Henry Cavendish referred to his father's chemicals. He mixed dephlogisticated air in a bottle with "a bit of my father's phosphorus." 16 June 1781, "Experiments on Air," Cavendish Mss II, 5:56.

[95]Packet of astronomical observations from 1774, in Charles Cavendish's hand, with Henry Cavendish's observations added. Cavendish Mss Misc. We know of Charles Cavendish's interest in astronomy from other sources; for example, William Ponsonby to duke of Devonshire, 24 Jan. 1744/43, Devon. Coll.: "I have not had an opportunity lately of seeing Lord Charles, but I make no doubt of his Lordship having made proper observations on the Comet, which appears here in great Splendor."

[96]Charles Cavendish, "Difference to Be Subtracted from Sidereal Time to Reduce It to Mean Time." This and two other tables of calculations on errors of time by him, in William Ludlam (1769, 145–148).

[97]In 1769 Charles Cavendish's good friend the physician William Heberden published a paper in the *Philosophical Transactions* comparing the rainfall at the bottom of a tall building with that at the top. Benjamin Franklin had an explanation, which he put in a letter where he referred to the experiments of Heberden and Charles Cavendish, both "very accurate experimenters." Benjamin Franklin to Thomas Percival, [probably June 1771], in ed. W.B. Wilcox (1969/1974, 155).

[98]Letters from William Borlase to Thomas Hornsby in 1766 and to Charles Lyttleton in 1767, quoted in J. Oliver (1969, 293). William Heberden included Charles Cavendish's readings of the greatest cold at night for twenty years, as he recorded them at his house on Great Marlborough Street, in Heberden (1788, 66).

[99]In his report on the Royal Society's meteorological instruments, Henry Cavendish said that the variation compass had a contrivance "taken from an instrument of Lord Charles Cavendish." Henry Cavendish (1776b, 120).

and then introduced a small quantity of water above the mercury. The level of the mercury immediately lowered because of the pressure of the water vapor above it, the degree of lowering depending on the temperature. In a memorandum, Henry Cavendish wrote, “My father’s experiments [with the apparatus] on which what I said concerning the turning of water into vapour are founded seem so convincing as to leave no doubt of the truth of it.”[100] With this tribute to Charles Cavendish by Henry Cavendish, we conclude Part I. In Part II, we move from the life of the father to the life of the son.

[100]This two-sheet memorandum concerns the simple additivity of air pressure and the pressure of water vapor. Cavendish Mss IV, 4.