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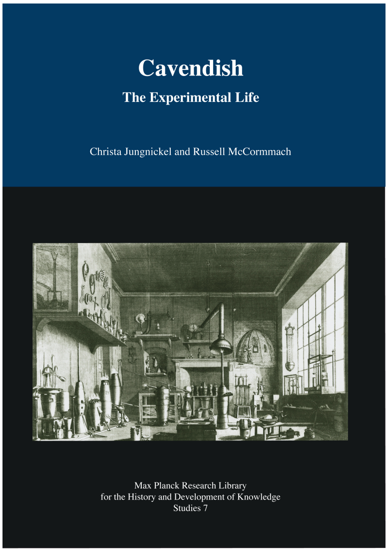
Christa Jungnickel and Russell McCormmach:

Last Years



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Chapter 17
Last Years

Clapham Common

Historians of chemistry may remember Clapham Common in the eighteenth century as the home of a distinguished chemist. Other historians remember it as the home of the "Clapham Sect," a group of prosperous, well-educated Anglican reformers known as evangelicals, who worshiped in the local church, Holy Trinity. Active at the time Cavendish weighed the world, members of the sect were fervently pious, believers in original sin and hellfire, living by the word of God, and working to save themselves, their countrymen, and heathen everywhere. Their goal was to breathe life into the Church of England, which they believed had capitulated to shallow eighteenth-century rationalism, with its external morality and calculus of happiness. They kept spiritual diaries, in which they recorded their sins at the end of each day. Their causes were social as well as religious: corruption in Parliament, barbarity of the criminal code, dueling, bull baiting, cockfighting, and, their most heartfelt, slavery, against which they fought for sixty years. One of their number, William Wilberforce, brought the first bill to outlaw the slave trade in 1789; it and subsequent bills failed until 1807, when persistence was rewarded, the abolition of slavery itself having to wait considerably longer. The meeting place of the Sect was an oval library in a roomy house on the Common belonging to Henry Thornton, a banker, Member of Parliament, president of the Sunday School Society, and chairman of the Sierra Leone Company. Thornton's cousin Wilberforce moved to Clapham Common to share his house. Thornton's somewhat less ardent brothers Samuel and Robert lived across the Common. The rector of Holy Trinity John Venn, founder of the Church Missionary Society, lived in another hospitable house on the Common.[1]

John Venn followed the path of his evangelical father, Henry, who had held the curacy at Clapham for some years. John did well in mathematics at Cambridge, and he was interested in astronomy and natural philosophy, able to explain the principles of the thermometer and compass; he owned a Dolland telescope and other good scientific instruments, and he read the *Philosophical Transactions*. While ministering to souls, he made a scientific contribution to Clapham by giving lectures on science to his own and his neighbors' children, and by introducing Jenner's smallpox vaccination to the whole parish. At Clapham, he often saw Isaac Milner, the capable Jacksonian Professor of Natural Philosophy, who implanted the evangelical movement in Cambridge, and who won over Wilberforce to evangelicalism.[2] As a student at Cambridge, Venn had been a close friend of Francis John Hyde Wollaston, who succeeded Milner as Jacksonian Professor and from whom Cavendish obtained Michell's apparatus for weighing the world. But like all members of the Clapham Sect, Venn preferred

[1] John Pollock (1977, 117–118); Standish Meacham (1964, 27–28); E.M. Forster (1956, 4–9, 26–63); R. de M. Rudolf (1927, 89–90); Michael Hennell (1958, 104–168).
[2] John Gascoigne (1989, 254).

Heaven over Earth, and in a letter of comfort to Wollaston, who had suffered a personal loss, he cautioned him not to immerse himself in science to the detriment of his duty to Christ: "Alas! How little honour it is to be the best chemist in Europe in comparison with being a useful minister of Christ. What comparison can there be between saving a soul and analyzing a salt.... Science and amusement and company are useful in their proper places; you know me too well to think that I would declaim against them in general. It is the abuse of them that prevails at Cambridge—an abuse which renders us careless and insensible upon the verge of eternity."[3] Caring only for his work, Cavendish might well have appeared to Venn guilty of the "abuse" of science, but in their work, Cavendish and Venn were not so far apart, each offering the self in the name of truth. Shy men both, Venn's force of personality derived from his otherworldliness, his faith in eternity; Cavendish's derived from his this-worldliness, which was not without its own form of the eternal, faith in the laws of nature.

Like nature, society was subjected to "experiment" in the eighteenth century. In all good faith, the evangelicals could support a poorly conceived experiment on society: children from central Africa were brought to Clapham, where they were taught to be civilized in the English way. For a time the children roamed the Common, invited into the neighboring houses by their curious owners; unaccustomed to the "rigors of the English climate," most of these children died.[4] The recent French Revolution, Thornton believed, was an "experiment made upon human nature by men insensible of our natural corruption, an experiment by which they expected to show the advantage of a general deliverance from restraint—the superiority of Reason over Revelation. When men are thus left to follow Nature, and are released from their subjection to the laws both of God and of civil society, iniquity will not fail to predominate."[5] The logical outcome of the French Revolution was Napoleon, who was expected to arrive momentarily at Clapham. Evangelicals were not pacifists; Venn published *Reflections in This Season of Danger*, in which he declared that "religion not only permits but enjoins us to defend our property, liberty, and lives against the attacks of violence." The parish was defended by the Clapham militia, commanded by Samuel Thornton.[6] As it turned out, the disturbances of the peace in 1797–98, when Cavendish made his measurements of gravitating matter at his home on the Common, were of the usual kind. The patrol for watching and lighting for the village of Clapham reported that two men were stopped early one Sunday morning in possession of "a bag of cabbages, a pewter pot, and some greenhouse plants."[7]

Benevolence and charity, beloved by the evangelicals, may have meant nothing or little to Cavendish, who reduced them, Wilson said, to a "singular numerical rule." If a person approached Cavendish with a request, he looked over the list for the largest gift, then wrote a check for that amount, no more no less.[8] We have located the lists of Easter offerings from the rector's account book for the years from 1791. In the first year, Cavendish matched the maximum gift on the list, one pound one shilling, but when a neighbor whose gift he had matched raised his gift to five pounds five shillings, Cavendish stayed with his original one pound one shilling; the neighbor's health may have prompted his generosity, for two years

[3]Hennell (1958, 42, 52–53, 143). Forster (1956, 35–36, 53).
[4]Pollock (1977, 183–184). Hennell (1958, 241–242).
[5]Meacham (1964, 65).
[6]Ibid., 80. Hennell (1958, 215).
[7]"Watching and Lighting Notes, Clapham," 138.
[8]George Wilson (1851, 180–182).

later he was dead.[9] If Cavendish had a rule, he did not apply it foolishly. The charities to which he contributed from January 1806 to January 1807 were the African Association, a cause supported by the evangelicals; magdalen, or reformed prostitutes; asylum; poor people; St. George's Hospital; and St. Giles Charity School. In the last seven months of his life, at his Bedford Square address he gave to forty-eight "poor people," whose names are listed in his porter's account book. If Cavendish's giving was not heartfelt, it was not grudging either.[10]

Banks, Blagden, and Cavendish

In 1768 the Council of the Royal Society accepted the request of the youthful Joseph Banks to accompany Captain Cook on his voyage to the South Seas to observe the transit of Venus the next year. Described in the minutes of the Council as a "gentleman of large fortune, who is well-versed in natural history," Banks came from a family of landed gentry in Lincolnshire with a tradition of public service. On Cook's voyage, he brought with him a company of seven persons, paid for by himself, who included Linnaeus's pupil Daniel Solander.[11]

Banks's assertive presence on Cook's voyage foreshadowed his activity as president of the Royal Society. As patron and administrator, he exerted a remarkable personal force on English science over several decades. Georges Cuvier said of him: "The works which this man leaves behind him occupy a few pages only; their importance is not greatly superior to their extent." Meager as his scientific accomplishment was, Cuvier said, Banks had performed "good service to the cause of Science" in other ways, such as using his influence with men of power.[12] No single activity can summarize Banks's way of serving, but he may have shown himself to best advantage as host of a Sunday salon at his house. Cavendish went faithfully to the tea-drinking-only socials held in the civilized setting of Banks's library. Called by Banks "conversaziones," an elegant word for an English at-home, his salons were distinguished for their regularity, intimacy,[13] and diversity; there London men of science mixed with visitors from out of town and abroad, colleagues, world travelers, and men of fortune and rank. Cavendish as an aristocrat and man of science was welcome on both counts.

Cavendish publicly gave his approval of Banks's presidency during the dissensions in the Society, as we have seen, and implicitly he gave it over the thirty-two years he served in the Royal Society under Banks. Long accustomed to working together in the Society, and to meeting socially at the Sunday conversaziones and elsewhere, Cavendish and Banks were friendly, but not close.

By contrast, Cavendish and Blagden were "intimate,"to use Blagden's word. Someone said of their connection that in the end it did not "suit,"[14] but the break, if that is what it was, appears to have begun as a break between Blagden and Banks, with Cavendish the affected third party. In early 1788 Blagden wrote to Banks that he intended to resign as secretary of

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[9]Untitled Clapham rector's account book, 1791–1842, Lambeth Archives, P/C/26, p. 152.

[10]"Bedford Square. James Fuller's Account with the Exec. of Hen: Cavendish … Settled 30 August 1810," Devon. Coll.

[11]9 June 1768, Minutes of Council, Royal Society 5:314. George A. Foote (1970, 434).

[12]David Philip Miller (1981, 9, 14–16, 19, 43–47). Hector Charles Cameron (1952, 209).

[13]Timothy Holmes (1898, 46, 68).

[14]Wilson (1851, 129).

the Royal Society, and on the same day he sent a copy of the letter to Cavendish, explaining that he was taking this step to prevent him and Banks from becoming a "violent mixture."[15] Three days later Blagden wrote to Watson, who may have intervened to make peace, that he bore no "ill will" toward Banks and would continue to serve him but would stop "short of an absolute sacrifice" of himself.[16] In early 1789, Blagden told Banks that his secretaryship of the Royal Society was the "great misfortune" of his life, and he referred to his "reflections" on his "connexion" with Banks, which he said he would send later.[17] Banks replied that he had no idea what Blagden was talking about, whether Blagden's complaints were leveled at him or at the world in general. He had thought they were friends but now he feared they were enemies.[18]

Blagden's unhappiness was multiplied by a task Banks had assigned him, to find a method of determining the correct excise duty on alcoholic beverages. For a time the Swiss chemist Johann Caspar Dollfuss had worked on it, but then Dollfuss left, and his experiments were repeated by George Gilpin, clerk of the Royal Society, who then proposed further experiments for Blagden. In this work Blagden was assisted by Cavendish,[19] but it nevertheless cost him much time and effort.

Blagden complained that he should have been paid for this task. Banks replied that he had performed many tasks for the government and never thought of reward, but he would look into it if Blagden would tell him what he expected. Blagden's resentment of Banks had been building. From the time he returned from America, Blagden said, Banks had taken him for granted and deceived him. When he accepted the job of secretary to the Royal Society during the dissensions, Banks made him a "tool of his ambition." Blagden believed that Banks would advance him in society and improve his fortune, but instead he discouraged Blagden from pursuing his profession, medicine, and even from marrying, his only purpose being to keep Blagden dependent on him. Banks defended his character and conduct.[20] Blagden's rancor at Banks continued, as did their correspondence until it became tiresome.[21]

The draft of a letter by Blagden, which was probably written in 1790, gives a clear idea of the extent of his disappointment. The recipient of the letter is Blagden's benefactor, who could be Cavendish though more likely he was Heberden or someone else. To make Banks's "ungenerous, (if not treacherous) conduct the more evident," the letter read, "let me contrast it with your own. You, to whom I had not had any opportunity of being serviceable, seeing how unwisely I neglected my profession, had the goodness not only to advise me to resume it, but likewise to offer that you would bear all the pecuniary risk attending the

[15] Charles Blagden to Joseph Banks, 2 Feb. 1788. Charles Blagden to Henry Cavendish, 2 Feb. 1788; in Jungnickel and McCormmach (1999, 648–649).
[16] Charles Blagden to William Watson, Jr., 5 Feb. 1788, draft, Blagden Letters, Royal Society 7:115.
[17] Charles Blagden to Joseph Banks, 27 Mar. 1789, BL Add Mss 33272, pp. 56–57.
[18] Joseph Banks to Charles Blagden, n.d. [after 28 Mar. 1789], draft, BL Add Mss 33272, p. 58.
[19] "Remarks by Mr.Cavendish," Blagden Collection, Royal Society, Misc. Notes, no. 65. Charles Blagden to Henry Cavendish, 12 and 26 Mar. 1790; in Jungnickel and McCormmach (1999, 675, 677). Among other assistance, Cavendish made available his father's table of the expansion of water with heat. "From the Experiments of Lord Charles Cavendish, Communicated by Mr. Henry Cavendish. March 1790," Blagden Collection, Royal Society, Misc. Notes, no. 99.
[20] Charles Blagden to Joseph Banks, 28 Mar. 1789, BL Add Mss 33272, p. 59. Joseph Banks to Charles Blagden, 15 July 1789, Blagden Letters, Royal Society, B.39. Charles Blagden to Joseph Banks, 25 July 1789, draft, Blagden Collection, Royal Society, Misc. Matter – Unclassified. Joseph Banks to Charles Blagden, 31 July 1789, Blagden Letters, Royal Society, B.40.
[21] Charles Blagden to Joseph Banks, 27, 28, 29 Mar. and 8 Apr. 1790; Joseph Banks to Charles Blagden, n.d., BL Add Mss 33272, pp. 73–74, 80.

pursuit, so that my private fortune should at all events remain unimpaired. I am sensible how imprudently I acted in not following your advice; but at that time I had still the weakness to believe Sir J[oseph] B[ank]'s professions sincere."[22]

When Blagden considered marriage, Cavendish entered into his plans. In 1789 the potential wife was picked out, Ann Osborne, and in November of that year Blagden asked his brother to inform him about her. Would she enjoy Blagden's kind of company and "particularly would so far enter into the pursuits of my friend Mr. C. as not to think some portion of time spent in his company tedious? This would be a matter of the utmost consequence to us both. You will easily suppose I do not mean that she should enter into our studies, but simply that she should not find it disagreeable to be present when such matters were the subject of conversation, or when any experiment which had nothing offensive in it, was going on."[23] Blagden contemplated the three of them together, Blagden, his wife, and Cavendish. He was concerned about her reaction, not about Cavendish's, calling into question Cavendish's severe misogyny, as described by Wilson.[24] In one of his letters of reproach to Banks, referring to his desire to marry, Blagden said that he "had great reason to believe Mr. Cavendish would assist me in making such a settlement as the family could not properly object to."[25] Banks too had taken into account Blagden's expectations; to justify his use of Blagden services on the problem of excise duties, he told Blagden in the stilted third person way they had adopted in their communications with one another that "as the Dr [Blagden] told me on a former occasion, that if he married Miss Bentinck [another prospect], Cavendish would make ample settlement on him, equal to the wishes of her family, I little suspected that his time and trouble were to be valued by the hour."[26] From the letters of 1789 and 1790, we see that Cavendish was a friend and support to Blagden.

Cavendish is said to have accepted Blagden as his associate on the condition that he give up medicine and devote himself to science.[27] The contrary would seem to have been the case. Blagden reminded Banks that in 1784, he told him that "Mr.Cavendish wished me to prosecute seriously the profession of physic."[28] The year 1784 was two years into Blagden's association with Cavendish. Around this time Blagden wrote plaintively to people about "being now quite out of the practice of physic" and unable to advise on remedies,[29] about being as little familiar with inoculation and other topics of medicine "as if I had never been of the profession."[30] Blagden blamed Banks for encouraging him to abandon his profession and then not advancing and compensating him.

It seems clear that in 1789 Blagden was on good terms with Cavendish and not with Banks. That summer Blagden contemplated going abroad with Henry Temple, second Viscount Palmerston, and his wife, Lady Mary, and possibly staying away the coming winter. His only reservation about that plan was Cavendish's desires: if by being away he would

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[22]Draft of a letter in the Blagden Collection, Royal Society, Misc. Notes, no. 224. Because of the similarity of content and wording to a letter from Blagden to Banks on 8 Apr. 1790, it is probably from around that time. Blagden's comment that he "had not had any opportunity of being serviceable" might seem to rule out Cavendish.
[23]Charles Blagden to John Blagden Hale, 13 Nov. 1789, draft, Blagden Papers, Yale, box 5, folder 49.
[24]Wilson (1851, 169–170).
[25]Blagden to Banks, 8 Apr. 1790.
[26]Banks to Blagden, 27 Mar. 1790.
[27]Henry Brougham (1845, 258).
[28]Blagden to Banks, 8 Apr. 1790.
[29]Charles Blagden to William Farr, 14 Nov. 1785, draft, Blagden Letterbook, Yale.
[30]Charles Blagden to Françoise Delarouche, 1 Dec. 1786, draft, ibid.

hold up Cavendish in any of his pursuits, he would stay. Cavendish raised one objection, which did not have to do with his desires but with Blagden's: being abroad would interfere with what Blagden had "much more at heart than any object in life,"[31] his return to medicine. Blagden thought his chances of practicing medicine at the resorts were as good as in London, and with Cavendish's blessing, he left with the Palmerstons. Before he did, he sold his house and its furnishings on Gower Street, with the thought that he would never again have a permanent address in England. Persons with messages for him were to be directed to Cavendish's house on Bedford Square. His bureau containing private papers was left in Cavendish's bedroom, and Cavendish was given the key and instructed to open the bureau and keep or burn the papers in it if Blagden should suffer an accident.[32] Blagden had recently turned forty and his life seemed without direction, as he set out on yet another Continental journey, evidently with gloomy premonitions.

As it turned out Palmerston did not go on to Italy to spend the winter of 1789–90 as planned, and in the late fall Blagden returned to London to resume his job as secretary of the Royal Society. Out of the turmoil, nothing much changed in Blagden's life, and a surface calm was restored. Banks and Blagden settled for a modus vivendi, but there was an edge to it. Blagden confided in his diary that "Sir JB came at length, & behaved with his usual cunning & falseness, for éclat."[33] He found the "perverseness & jobbing of Sir JB's manner worse than ever."[34] Banks's moral sentiments were "debased," his character "odious."[35] People who meet daily over a long time can irritate one another, but Blagden's censures of Banks are severe and persistent. On his side, Banks could be wounding, as he was when Blagden considered stepping down as secretary of the Royal Society. Blagden had been elected to that post for fourteen successive years, during which time he had ruined his eyes and could no longer read papers at the meetings, but he wanted to leave open the possibility of resuming the job later. Banks told him to forget it because Blagden's "enemies" would bring up his absences on his travels and accuse him of "not cultivating science with the same ardor as you have formally done, owing to the habits you have lately adopted of mixing much in the gay circles of the more elevated ranks of society."[36] Blagden replied with indignation that he had "never performed the office so well" as he had last winter.[37] Blagden resigned for good in the winter of 1797.[38]

From what he could learn, Wilson concluded that Cavendish and Blagden's break "did not occur till at least 1789." We agree; as we note above, as late as November 1789 Blagden was concerned about how his potential wife would react to his work with Cavendish. A year later, Blagden excused himself from a trip he had planned with Palmerston because of "some experiments at Clapham." Cavendish and Blagden continued to be much together,

[31] Charles Blagden to Henry Cavendish, Aug. 1789, draft, Blagden Letters, Royal Society 7:794.
[32] Charles Blagden to John Blagden Hale, 17 Sep. 1789; "An Inventory of Furniture. Taken September 3. 1789 at Dr Blagden's House in Gower Street Appraised & Sold to Hill Esq.," Gloucestershire Record Office, D 1086, F 155, 157. Charles Blagden to William Lewis, 15 Sep. 1789, draft, Blagden Letters, Royal Society 7:306. Charles Blagden to John Blagden Hale, 16 Sep. 1789, draft, ibid. 7:309. Charles Blagden to Henry Cavendish, 16 Sep. 1789; in Jungnickel and McCormmach (1999, 668–669).
[33] 25 May 1807, Charles Blagden Diary, Royal Society 5:73.
[34] 20 Nov. 1806, ibid. 5:12.
[35] 2 Feb. 1805, 12 Mar. 1807, ibid. 4:307 and 5:46.
[36] Joseph Banks to Charles Blagden, 27 Apr. 1797, Blagden Letters, Royal Society, B.44.
[37] Charles Blagden to Joseph Banks, 27 Apr. 1797, BL Add Mss 33272, 158–159.
[38] He resigned on 30 Nov. 1797. The draft letter of resignation, undated, with no address, begins: "The inflammation of my eyes …." Blagden Collection, Royal Society, Misc. Matter – Unclassified.

but their relationship was less close than it had been. We can safely assume that Cavendish did not want to quarrel with Banks, but this was unlikely the main reason. Thomson said that Blagden "left him."[39] Blagden wanted to make changes in his life, which first of all had to do with his obligations to Banks, and a reduction in his obligations to Cavendish may have been included. In late 1789, while he still fully intended to continue his association with Cavendish, he described his financial situation to his brother to pass along to his prospective wife: his stocks were worth between 9 and 10,000 pounds, and his income was 250 pounds a year from his half pay in the military and his secretaryship of the Royal Society; he was "not without other expectations, but of these nothing can be said."[40] Cavendish did not contribute to Blagden's income, but Blagden's "expectations" probably had to do with him in the event that he married. As it turned out, Blagden did not marry, and Cavendish consequently would not have entered his subsequent plans. Another consideration was that Cavendish was not as busy as he had been and his having less need for Blagden's help, their separation may have been mutually desired. About the personal side of their association we know little; their natures being very different in some ways, it is possible that their collaboration was trying. If his relationship with Cavendish eventually did not suit, Blagden's regard for Cavendish did not change. Writing to Banks from Paris in 1802, Blagden compared Cavendish with "Laplace, who is as much superior among them here as Mr. Cavendish is with us."[41]

The Duchess and the Philosopher

Through the Devonshire and the Kent dukedoms, Cavendish had an enduring connection with the world independently of Blagden, Banks, and his other scientific colleagues. For most of his adult life, the head of the Cavendish family was William, fifth duke of Devonshire. From Chatsworth, Thomas Knowlton wrote to the naturalist John Ellis, "I wish that our Duke [the fifth duke was twenty-two] would, like his father, who every day improved in knowledge, take a turn that way."[42] The young fifth duke would continue not to be like his father, who had been a self-improving man with a highly developed sense of service, one of the most respected British statesmen of the eighteenth century. The fifth duke was the first of the dukes of Devonshire resolutely to turn his back on politics. He had that much in common with Henry Cavendish, in whom the absence of political desire was clearly an asset in his chosen life. The fifth duke had other traits in common with Henry: he was intelligent, reclusive, awkward, and indifferent to religion, but here the resemblance ends. Since little individual exertion was required of the duke, he made little, preferring to lie in bed until the middle of the afternoon and then to get up only to go to his club. He was dissolute, unfaithful, and, in his dedicated passivity, fascinating. He disapproved of Henry Cavendish, as we have noted, because "*he works*."[43] When Henry Cavendish died, the duke took a passing interest in the inheritance. The duke lived only one year beyond his working relative.

The fifth duke and his (first) wife, Lady Georgiana Spencer, had this in common: like their great friend Charles James Fox, they were both prodigal gamblers.[44] Otherwise the

[39]Thomas Thomson (1830–1831, 1:338). Wilson (1851, 129). Charles Blagden to Henry Temple, Lord Palmerston, 8 Oct. 1790, draft, Blagden Papers, Yale, box 63/43.
[40]Charles Blagden to John Blagden Hale, 13 Nov. 1789.
[41]Charles Blagden to Joseph Banks, 1 Apr. 1802, BL Add Mss 33272, 172–173.
[42]Thomas Knowlton to John Ellis, Oct. 1770, in James Edward Smith (1821, 2:79).
[43]John Pearson (1983, 122–123). Francis Bickley (1911, 202).
[44]Hugh Stokes (1917, 283–288).

duchess was the duke's temperamental opposite, vivacious, enthusiastic, charming, "her animal spirits were excessive," whereas the duke, by contrast, was said to be a simile for winter.[45] Like the Cavendishes, the Spencers had sided with the victorious party in the Revolution of 1688–89 and with greater interest in politics than her husband, the duchess actively supported Fox and his followers. Known as the queen of London fashion, she also had an avid if unfocused interest in music, literature, history, and science. With Giardini, she studied music;[46] with a "Philosopher," she studied the globes, buying two for herself from the instrument maker George Adams;[47] with a "German," she studied chemistry and mineralogy;[48] with Blagden she exchanged scientific news; and she took a keen interest in her cousin-in-law Henry Cavendish. When writing to the duchess, Blagden referred to "our friend Mr. Cavendish."[49]

Figure 17.1: Georgiana (Spencer), Duchess of Devonshire. By Joshusa Reynolds. Reproduced by permission of the Chatsworth Settlement Trustees.

[45]Mary Robinson (n.d. 301).
[46]Bickley (1911, 241).
[47]Georgiana Cavendish, duchess of Devonshire to Countess Spencer, 11 Jan. 1783, Devon. Coll.
[48]Charles Blagden to Henry Temple, Lord Palmerston, 21 Feb. 1794, draft, Osborn Collection, Yale, box 63/43.
[49]Charles Blagden to Georgiana Cavendish, duchess of Devonshire, 4 Jan. and 6 Mar. 1794, Devon. Coll.

From abroad, the duchess asked Blagden to tell her about "any chemical, mineralogical, or philosophical novelty" and to give her compliments to Cavendish,[50] and when she and Blagden happened to meet abroad, they spent an evening with "much talk about chemistry & mineralogy." Blagden noted in his diary: "Dss of Devonshire said she was quite wild with studies of that nature: asked much about Mr. Cavendish & his pursuits"; "much talk with the Dss about Sir Jos. Banks's meetings, Mr. Cavendish."[51] The duchess called on Cavendish at his house,[52] and Cavendish called on her, often, it is said. Once when Blagden came to see her at Devonshire House, he found Cavendish there engaged in scientific talk.[53] In wanting to be informed about scientific advances and about Henry Cavendish's activities, the duchess overcame his shyness and his alleged misogyny. To have his company she had only to keep to his subject, science, her lively curiosity no doubt doing the rest.

Unpublished Work

In his later years, Cavendish worked on nearly all of the subjects he had in his early years, though the proportions changed. Astronomy was now prominent. Part observational and larger part mathematical, his astronomical papers make up a large share of his scientific manuscripts. The papers sometimes begin as carefully drafted studies with a clear objective but then trail off into calculations of unclear significance, and other times they have a finished quality, meant to be shown to someone. Cavendish did not make systematic observations of the sky as Maskelyne and Herschel did—he did not have that kind of observatory and he did not spend his time that way—but he made observations from time to time to test techniques such as taking transits, and he looked at things that other astronomers looked at, a planet, a comet, a variable star, and volcanoes on the moon.[54] As in other areas of science, in astronomy he took a sustained interest in instruments, methods, and errors of observation. In this section, we look at three examples of unpublished work from, or bearing on, astronomy: an astronomical instrument, orbits of comets, and refraction and dispersion of light.

Around London there was a series of observatories roughly following the course of the River Thames. Cavendish's Observatory at Clapham Common was directly south of London, and on a line with it to the east were Aubert's observatory at Loam Pit and just beyond that Maskelyne's Royal Observatory at Greenwich. Considerably to the west of this

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[50] Georgiana Cavendish, duchess of Devonshire to Charles Blagden, 4 Mar. 1794, Blagden Letters, Royal Society, D.61.

[51] G. De Beer (1950, 76, 80, 83).

[52] Once when she called on Cavendish, his servant told her he was unwell, and she asked Blagden to find out how he was. Charles Blagden to Joseph Banks, 11 Aug. 1795, BL Add Mss 33272, 143. It was not an excuse: Blagden called on Cavendish later that month and found him "decaying: his forehead healing not kindly." 27 Aug. 1795, Charles Blagden Diary, Royal Society 3:67.

[53] 1 Sep. 1794, Charles Blagden Diary, Royal Society 3:14. Cavendish may have acted as a tutor to the duchess: when Blagden arrived at her house, he found "Mr. Cav. there; saw none had notes." The duchess proposed that Cavendish "shew extracts from Js de Physique." On 27 Nov. 1794, Blagden again came across Cavendish at the duchess's: "Met Mr. Cav. there: pleasant talk." Ibid., 33(back).

[54] Herschel observed what he regarded as a volvanic eruption on the moon, shining with a fiery light, and he observed two "extinct" volcanoes as well; he came to his conclusion about what he saw "by analogy, or with the eye of reason." With a telescope, Cavendish and Blagden observed the unusual light in the dark area of the moon where Herschel thought he had located a big volcano. William Herschel (1787). Charles Blagden to Mrs. Grey, 14 June 1787, draft, Blagden Letterbook, Royal Society 7:324.

group was Herschel's observatory. Cavendish knew these observers well, as he did another astronomer Michell, who did not live in London. We should get to know them.

In 1781 William Herschel discovered a new major planet, the first to have done so since antiquity, naming it after George III (it was renamed Uranus), who rewarded him with a royal pension, freeing him from his original profession, music; the same year he was elected to the Royal Society. (Fig. 12.6). He settled near Windsor Castle, where he made observations at night and telescopes by day, which he sold to supplement his pension or used himself. The biggest of his telescopes was a reflector of (for that time) unprecedented proportions, four feet across and forty feet in length—Blagden walked through the iron tube of this telescope hardly having to stoop[55]–its dimensions being a proper measure of his ambition, which was to see to the ends of the universe and to survey its contents. From his systematic sweeps of the sky, he identified over 800 double stars and 2500 nebulas of all kinds. He published sixty-nine papers in the *Philosophical Transactions*, laying the foundations of stellar astronomy. His achievement was the result of patient application, excellent instruments, masterly observation, and imaginative theorizing, a rare combination in any science.[56] Seven years younger than Cavendish, he interacted with Cavendish, though probably not often.

At the Royal Society Club, John Playfair found that members paid little attention to guests, of whom he was one. The exception was Alexander Aubert, whom Playfair found "a very polite man, and a great consolation to a stranger."[57] (Fig. 12.3). This detail captures a truth about Aubert: he was observant and helpful. He seemed to have had no personal ambition in astronomy, only a passion for it and a standard of excellence. Equipping his observatories with instruments by the leading instrument makers, Jesse Ramsden, Peter Dolland, John Bird, and James Short, he had "the best set of astronomical instruments that belongs, perhaps, to any private man."[58] Because of the quality of his instruments, Herschel asked him to confirm his own observations so that they would be taken seriously by other astronomers.[59] He was a director and from 1787 governor of the London Assurance Company, administrative experience which he brought to his learned side pursuits. A fellow of the Royal Society since 1772, he was elected to the Council and appointed to committees for astronomy and meteorology, on which he served regularly with, and almost as often as, Cavendish. In 1778, the Council considered two members to replace the outgoing president, Aubert and Banks, and after long deliberation they made their fateful choice of Banks.[60] Afterwards it was asked "what Mr. Aubert had done."[61] He published very little.[62] He and

[55]Charles Blagden to John Michell, 31 Oct. 1786, draft; in McCormmach (2012, 413).
[56]Michael A. Hoskin (1963, 17–18, 62–64). "Herschel, Sir William (1738–1822)," *DNB*, 1st ed. 9:719–725.
[57]Playfair quoted in Geikie (1917, 160).
[58]Playfair, quoted ibid., 159. In the 1780s Aubert's astronomical establishment was "except that of Count Brűhl [...] the only well-equipped private establishment of the kind in England." "Aubert, Alexander (1730–1805)," *DNB*, 1st ed. 1:715. "Brűhl, John Maurice, Count of (1736–1809)," ibid. 3:141.
[59]William Herschel to Alexander Aubert, 9 Jan. 1782, copy, Royal Astronomical Society, Herschel W1/1, 21–24; published in Constance A. Lubbock (1933, 102–103).
[60]Henry Lyons (1944, 197).
[61]Ibid. Edward Smith (1911, 56–57).
[62]Over the course of his long activity in astronomy, he published three papers on the transit of Venus in 1769, a new method of finding time by equal altitudes in 1776, and meteors in 1783, all brief and all appearing in the *Philosophical Transactions*.

Cavendish were the same age and saw each other regularly at their clubs. Cavendish brought Aubert into his financial affairs as a trustee of his property at Clapham Common.[63]

Cavendish saw Nevil Maskelyne often and in the same places he saw Aubert, at the Royal Society and at their clubs (Fig. 12.5). Maskelyne offered Cavendish what Herschel and Aubert could not; not only was he a fine observer and skilled with instruments, he was highly competent in mathematics, evident from memoranda that passed between him and Cavendish. He probably met Cavendish while a student in Cambridge. After graduation, he was ordained to a curacy, and about the same time he was elected fellow of his college, Trinity. Two years before Cavendish, he was elected to the Royal Society, where most of their collaboration took place. Early on he assisted the astronomer royal James Bradley in computations, and with Bradley's help he was sent abroad by the Royal Society to observe the transit of Venus in 1761. In 1765 he became the fifth astronomer royal, replacing Nathaniel Bliss, who died after only two years. Under the first three astronomers royal, John Flamsteed, Edmond Halley, and Bradley, the Royal Observatory at Greenwich held a leading position among European observatories. That no longer could be said, but Maskelyne oversaw an important change in the way the Observatory was used: whereas past astronomers royal kept their observations more or less to themselves, beginning with Maskelyne, observations made at the Observatory became public property. From the Royal Society he received a fund to publish his observations, which appeared in four volumes between 1776 and 1811. In 1766 he brought out the first number of the *Nautical Almanac* (for 1767), which he continued for forty-four years until his death, thought to be his most important work. He championed the lunar method of determining longitude at sea, which used tables and a sextant for measuring the distances of certain stars from the moon. He published frequently in the *Philosophical Transactions*, always on subjects related to astronomy. Playfair said that Maskelyne was "slow in apprehending new truths, but his mind takes a very firm hold of them at last." According to a French visitor at the Observatory, Maskelyne had a "politeness and a *complaissance* that scholars of his rank don't always have *pour des Passans*." His methodic exactness and his devotion to astronomy suited Cavendish, and their two temperaments were compatible.[64]

If Cavendish did not meet Michell in Cambridge, where Michell was a fellow of Queens' College when he was a student at Peterhouse, he met him in London no later than 1760, the year both of them were elected to the Royal Society. That same year, at Cavendish's first dinner as a member of the Royal Society Club, Michell was present as a guest,[65] and in later years Cavendish brought Michell as his own guest. Like Cavendish, Michell was a natural philosopher, though his main publications were in geology and astronomy. In theoretical inventiveness, he was Herschel's equal, and he had mathematical skills comparable to Cavendish's and Maskelyne's. In mid-life he resigned his fellowship in Cambridge to become a country pastor. To keep up contact with men of science, he regularly made the long journey from his parish in Yorkshire to London. His one known

[63] In a bundle of papers dealing with Cavendish's Clapham Common property are extracts from Aubert's and Aubert's heirs' wills. They were assembled to transfer the property to the duke of Devonshire. Devon. Coll., L/38/78.
[64] Maskelyne's obituary, *Gentleman's Magazine* 81:1 (1811): 197, 672. Playfair (1822, 1:lxxix; Appendix, No. 1, "Journal"). "Maskelyne, Nevil (1732–1811)," *DNB*, 1st ed. 12:1299–1301.
[65] 14 Aug. 1760, Minute Book of the Royal Society Club, Royal Society, 4.

sustained correspondence was with Cavendish, a continuation of a conversation from his last visit to London.[66]

Hardly had Cavendish settled into his new house on Clapham Common than he took the first step toward erecting a telescope of 123-foot focal length made by Constantine Huygens, brother of Christiaan, who also made telescopes. Constantine, who was then secretary to King William III, presented the telescope to the Royal Society in 1691.[67] Besides this telescope, the Royal Society later acquired two more object-glasses made by Constantine of even greater focal length, 170 feet and 210 feet. Evidently borrowing all three, Cavendish definitely tried the 123-foot telescope and probably the 210-foot one.[68] The incentive to build telescopes of such long focal lengths was to reduce aberrations and to achieve high magnification.[69] Christiaan Huygens is usually given credit for introducing the so-called "aerial" telescopes, which dispensed with unwieldy rigid tubes for mounting the object-and eye-glasses, making possible telescopes with much longer focal lengths. Not until John Hadley built a Newtonian reflecting telescope with a parabolic mirror in 1721 did astronomers know of any practical way to minimize aberrations other than by lengthening their telescopes, ultimately a dead end.[70]

Christiaan Huygens's account of an aerial telescope was published in the *Philosophical Transactions* in 1684. To dispense with the "heaviness and disproportion" of the telescope tube, Huygens cut out "almost the whole tube, saving only a small part of it near the objective glass, and somewhat towards the Eye glass, ordering these two extremities in such a manner, that they may do the same service, as if the whole tube of one piece should be employed." He described a fifty-foot mast for erecting an aerial telescope of seventy-foot focal length, a stand for steadying the observer's arms, a lantern for illuminating the object-glass so that it could be found at night, and a cord for aligning the eye-glass and the object-glass.[71] Never

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[66]Material on Michell's life, in McCormmach (2012).

[67]The focal length has been stated variously as 120, 122, 123, and 126 feet, as has its aperture, $6, 7\frac{1}{2}, 7\frac{7}{8}$ inches. R.A. Sampson and A.E. Conrady (1928–1929, 289, 291).

[68]The Journal Book of the Royal Society said that Christiaan Huygens made the telescopes: 7 Jan. 1742, JB 13:4334. Sampson and Conrady give the reason for attributing them instead to the brother, Constatine. "Three Huygens Lenses" (Sampson and Conrady 1928–1929, 292). When Cavendish returned the telescopes he included his apparatus. Ibid., 289.

[69]Any increase in magnification comes at a high price, for the length of a telescope increases faster than the magnification: to double the magnification, the length has to be quadrupled; to triple it, the length has to be increased ninefold. The 123-foot Huygens telescope has a magnification of 218. William Kitchener (1825, 22). The very slight curvature of the long focal length lens greatly reduces spherical aberration, and chromatic aberration is practically eliminated for the following reason. The telescope consists of two lenses, neither of which is achromatic, but if the two lenses are made of glass of the same dispersion and the telescope is focused at infinitely distant objects such as stars, the angular magnification for any given color depends only on the curvature of the lenses and not on the refractive index. The workmanship on the Huygens lenses was of high quality, but not the glass, which compares poorly with the cheapest bottle or window glass. The tangle of fine veins in the glass made the refraction irregular. The glass available to Huygens resulted in a poor definition of images, as Cavendish no doubt determined. Sampson and Conrady (1928–1929, 298–299).

[70]Newton's other early reflecting telescopes had spherical mirrors, which were subject to spherical aberration. Astronomers knew that to achieve sharp images, the mirrors needed to be parabolic, but they were hard to make. Hadley's first telescope with a mirror of 6 inches diameter and a length of 6 feet worked almost as well as Huygens's 123-foot aerial telescope.

[71]Huygens explained the working of the aerial telescope. The observer stood resting his arms on a light frame or hurdle and holding the eyepiece (concentric, adjustable metal tubes containing the eye-glass) by the handle. A cord connected it to a short board on which the object glass was mounted at one end and a counterpoise at the other. By tension on the cord the observer could bring the two lenses into parallel. Christiaan Huygens (1684). Smith (1952, 354). Sampson and Conrady (1928–1929, 298).

very popular in Britain, the aerial telescope was hard to manage, and on dark nights the object-glass was difficult to see without artificial light, alllowing stray light to enter the eye-glass. The alternative, a telescope of long focal length that came with sliding tubes, was also hard to use, affected by wind and vibration.[72] The Royal Society considered fixing the Huygens telescope to a tall, solid building, but they could not settle on any tall or solid enough. Halley was ordered to consider the scaffolding of St. Paul's Cathedral. James Pound mounted the telescope on a maypole removed from the Strand and relocated in Wanstead Park, where he and Bradley made successful use of it. Pound made improvements on its "furniture and Apparatus," the most important of which was a micrometer, which gave the Huygens telescope its one advantage over the Newtonian: the longer the telescope, the larger the image, and the micrometer measures a large image more accurately than a small one. The telescope was borrowed again by William Derham, who returned it in 1741, having made no observations: "The chief inconvenience is the want of a long pole of 100 or more feet, to raise my long glass to such a height as to see the heavenly bodies above the thick vapours," and he was told that this would cost him eighty or ninety pounds, which were beyond his means. In 1748 Charles Cavendish together with Jones, Folkes, and Graham brought the Huygens lenses from the Royal Society to Macclesfield's Shirburn Castle to try it.[73] The telescope worked fine: a visitor who went to Shirburn Castle to look at Jupiter through it saw "that bright planet in perfection."[74] In 1778 Maskelyne borrowed the longer 210-foot Huygens telescope.[75]

At this juncture, Henry Cavendish enters the history of Huygens's telescopes. In November 1785 the Council of the Royal Society gave him permission to borrow the 123-foot telescope and also the other Huygens object-glasses, which he kept for three years. Among Cavendish's manuscripts is a study by him of a ship's mast, which we take to be the mount for the Huygens telescope. It begins with fundamentals: "According to Newton the resistance of wind to a globe is equal to […] and therefore if wind is 60 miles per hour…." To judge from his calculations—he determined the pressure of wind on two cylinders of unequal diameters each 40 feet in length—the Huygens telescope was erected on a wooden mast 80 feet high, supported by 20-foot struts planted 11 feet from the base. A horizontal piece was fixed to the mast.[76] Well secured, the mast remained in place long after Cavendish died, identified in a description of his property this way: "In a padlock at the back of the house is a mast of a ship, erected for the purpose of making philosophical experiments."[77] The mast towered above Cavendish's house as if it were the home of a nostalgic man of the sea.

In March 1786 Aubert told Herschel that after half a year, Cavendish still had not tried the Huygens lenses on objects on land, but he was busy preparing the apparatus for trying them on celestial objects.[78] In June Blagden told Berthollet that Cavendish was ready to "make a trial of the old aerial telescopes," and that Herschel looked forward to the trial for

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[72] A.J. Meadows (1970, 307).

[73] Smith (1738, 2:354, 440). R.S. Rigaud (1832, ix, lx, lxxxiv). 20 June 1728, JB, Royal Society 13:237. 10 and 29 Aug. 1748, Minutes of Council, Royal Society 4:5–8. King (1955, 63). Charles Yorke to Philip Yorke, 23 Aug. 1748, BL Add Mss 35360, f. 185. Thomas Birch to Philip Yorke, 18 Aug. 1748, BL Add Mss 35, 397.

[74] Catherine Talbot to Elizabeth Carter, 10 Oct. 1748, in Carter (1809, 1:293–294).

[75] 10 Dec. 1778, Minutes of Council, Royal Society 5:369.

[76] The computations for the mast are in Cavendish Mss, Misc. Robert Smith (1738, 2:355).

[77] Burgess (1929, 57).

[78] Alexander Aubert to William Herschel, 23 Mar. 1786, Royal Astronomical Society, Mss Herschel W 1/13, A23.

"comparing the effect with that of his large reflectors."[79] Blagden thought that the 200-plus-foot telescope would probably be found inferior to Herschel's big reflectors, but still it was "desirable to form a just estimate of the tools with which our ancestors worked."[80] Herschel came to Clapham Common to participate in the trial, as did the instrument maker Peter Dolland, whose father, John, had shown how to eliminate one of the major aberrations (chromatic) of telescopes. They found that the "Dwarf," a forty-six-inch triple-lens achromatic refractor (either Dolland's or Cavendish's), was "fairly a match for the [123-foot] Giant."[81] Cavendish evidently was the last person to mount Huygens's telescopes for making observations, though the lenses continued to draw interest.[82]

From the 1780s Cavendish devoted a large body of work to the orbits of comets, beginning with the "comet" discovered by Herschel in 1781. Cavendish made computations from observations by Maskelyne and the Oxford astronomer Thomas Hornsby, who resisted calling it a "planet" (it was, in fact, Uranus).[83] Cavendish's study of comets proper began with observations by Caroline Herschel, who assisted her brother William at the observatory. When he was away she made sweeps of the sky herself, in the course of which she became a proficient discoverer of comets, eight in all. Blagden at the Royal Society was informed directly by her and indirectly by Aubert of her first comet, in 1786. Blagden used the occasion of an inspection of the Greenwich Observatory to announce her discovery to the assembled astronomers. Banks with some friends planned to visit Caroline Herschel and see the comet for themselves.[84] When she discovered her next comet, Cavendish made observations of it.[85] His interest in comets was directed to two problems, which were connected: one was methods of computing their paths, the other was computing deviations of their paths from perfect conic sections, analogous to computing errors, a regular activity of Cavendish's.

Newton showed that a comet moves on a parabolic path, which in the case of a returning comet coincides with a highly eccentric ellipse. In principle three observations determine the elements of the path, but in practice it was a difficult problem for astronomers. A forty-year-old method by Boscovich had recently been rejected by Laplace, leading to an acrimonious dispute, and capturing the attention of calculators. As a test of their methods, and of their skill, astronomers looked forward to the return in late 1788 or early 1789 of the great comet observed in 1532 and 1661.[86] The mathematical problem was to find the distortion of the

[79] Charles Blagden to C.L. Berthollet, draft, 5 June 1786, Blagden Letterbook, Royal Society 7:2.
[80] Charles Blagden to Benjamin Thompson, draft, 7 July 1786, Blagden Letterbook, Royal Society 7.
[81] This is what Dolland told Kitchener (1825, 22).
[82] Out of historical curiosity, the astronomer W.H. Smyth considered setting up the telescope again, around 1835: "I was so puzzled to know how they contrived to get the eye and object-glasses of these unwieldy machines *married*, or brought parallel to each other for perfect vision, and so desirous of comparing the performance of one of them, that I was about to ask the Royal Society's permission to erect the aerial 123-foot telescope in their possession. The trouble, however, promised to be so much greater than the object appeared to justify, that I laid the project aside." Quoted in Weld (1848, 1:331). In 1929 Sampson and Conrady examined the two Huygens lenses of longer focal lengths. They used an interferometer to determine the focal lengths and again to determine the radii of curvature, since the extreme shallowness of curvature of the long-focal-length lenses precluded the use of a spherometer. Sampson and Conrady (1928–1929, 294–297).
[83] Supported by Cavendish's computations, Hornsby thought that Herschel's observations were in error. Herschel thought otherwise. Thomas Hornsby to William Herschel, 26 Feb. 1782; William Herschel, "Memorandum for Mr.Cavendish," in Lubbock (1933, 106–107).
[84] Charles Blagden to Claude Louis Berthollet and to Benjamin Thompson, 4 Aug. 1786, draft, and to Caroline Herschel, 5 Aug. 1786, draft, Blagden Letters, Royal Society 7:18–20. Caroline Herschel (1786).
[85] Henry Cavendish, "Miss Herschels Comet," Cavendish Mss VIII, 37. This was the 1788 comet.
[86] Charles C. Gillispie (1978, 309–310).

path of the comet when it passed the large planets Jupiter and Saturn on its way out of the solar system, affecting the timing of its return. The Royal Academy of Sciences at Paris announced a prize for the best solution. Maskelyne published a paper "to assist astronomers in looking out for this comet." Cavendish corresponded with Maskelyne about it, made computations on the comet of 1532, and wrote a paper on how to compute the return of a comet whose path is altered by the attraction of planets.[87]

In December 1788, while looking for the expected return of the great comet (it failed to return), Caroline Herschel discovered a faint comet, her second. Evidently with this in mind, Cavendish wrote a substantial paper laying out his method for computing the orbits of comets, both parabolic and an elliptical, from three observations. His method made use of a globe covered in white paper on which the ecliptic and various circles and points were drawn. He gave his study of comets' orbits to Maskelyne, who suggested a planisphere made by Adams in place of Cavendish's globe. Along with this and other comments on Cavendish's paper, Maskelyne sent him the observations he had requested, those for Caroline Herschel's recent comet, the orbit of which he wanted to compute using his method.[88] (Fig. 17.2). In due course Cavendish wrote to Maskelyne that he had been "so much taken up about this & other matters" that he had not been able to study his comments on his method. He said that up to this point the method caused "rather more trouble than I imagined it would be before I tried it but on the whole seems as if it would prove an useful method especially if proper tables were made which if I knew of any one that I could employ to compute them I would get done." He wrote a paper on the disturbance of a comet's orbit in passing planets,[89] a variation of the problem of the alteration of the orbit of a planet by another planet, which he also worked on.[90]

Years later, Cavendish returned to comets to make lengthy studies of methods of computing their orbits[91] and to compute the path of the first of two comets discovered by the French astronomer Pierre Méchain in 1799.[92] After pointing out a small error in a logarithm, Cavendish told Maskelyne that if the correction were made, he believed that his orbit "would be found to agree very nearly with observation." He thought that it might seem extraordinary that the results came out so accurate, but he explained how that must happen.

[87] Henry Cavendish, "Comet, 1532"; "In Order to Compute the Return of a Comet," Cavendish Mss VIII, 38, 39. Nevil Maskelyne (1786, 429). Charles Blagden to Mrs. Grey, 5 Oct. 1786, draft, Blagden Letters, Royal Society 7:39.

[88] Nevil Maskelyne, "Remarks on Mr. Cavendish Paper on Finding the Orbit of a Comet," 16 Apr. 1789, enclosed in Henry Cavendish, "Method of Finding Comets Orbit Fair," Cavendish Mss VIII, 43; in Jungnickel and McCormmach (1999, 662).

[89] Henry Cavendish to Nevil Maskelyne, [after 16 to April 1789], in Jungnickel and McCormmach (1999, 664). Henry Cavendish, "On the Alteration Produced in Comets Orbit by Attraction of ⊕," Cavendish Mss VIII, 52; "Written for Person Thought of for Calculating Perturbation of Expected Comet," ibid., 53.

[90] Henry Cavendish, "To Find the Alterat. Produced in the Elements of a Planetary Orbit by a Small Alteration in Its Velocity & Direction," Cavendish Mss, Misc.

[91] Henry Cavendish, "To Find Whether 2 Parabolic Orbits Can Be Drawn So as to Agree with Observation." This concerns the question whether or not more than one parabolic orbit can be drawn through three points and other matters pertaining to comets. It is written partly on paper carrying the watermark 1797, which he was still using in 1799. Cavendish Mss VIII, 40. Another paper written partly on paper carrying the watermark 1797, but also partly on paper with watermarks 1802 and 1804, which may mean that it was written at different times, is Henry Cavendish, "Boscovics Method of Finding the Orbit of a Comet," Cavendish Mss VIII, 50. The next paper is undated, but since Cavendish drew on Boscovich for his study of the comet of 1799, it may belong to that time: "Example of Computing Orbit on Bosc. Principle without Graphical Operat.," Ibid. VIII, 42.

[92] Henry Cavendish, "Comet of 1799 Computed by the Table for Boscovic's Sagitta"; "Comet of 1799"; "Computation of Comet of 1799 by Fluxional Process," Cavendish Mss VIII, 44, 46, 47.

He used Boscovich's graphical method, which he thought had little error in it. (He found Laplace's method wanting.) "But I have tired myself too much with the former comp. to do any more," he said.[93]

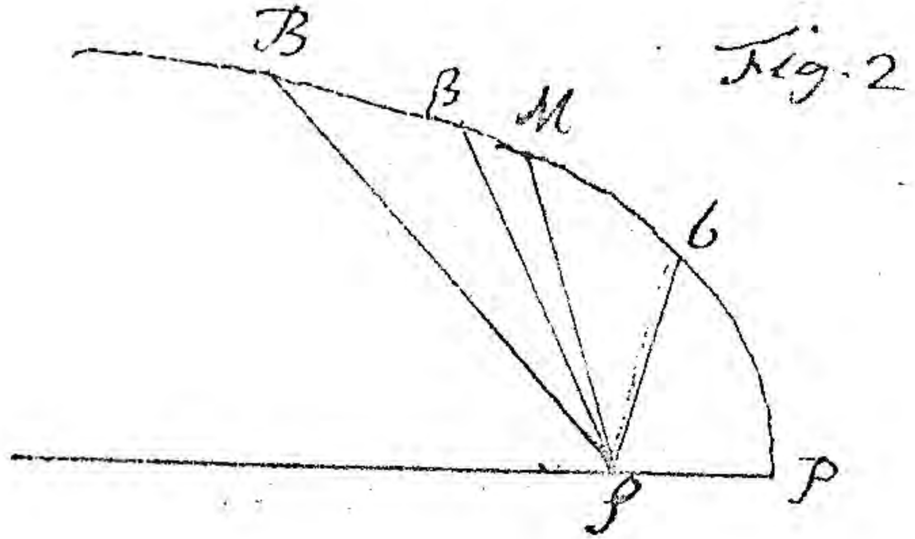

Figure 17.2: Comets Orbit. BbP is the orbit of a comet, S is the Sun, P is the perihelion, and B and b are the locations of the comet at the two extreme observations. "Method of Finding, Orbits Fair," Cavendish Mss VIII, 43. Reproduced by permission of the Chatsworth Settlement Trustees.

The very considerable labor Cavendish devoted to the paths of comets can be understood as a response to problems astronomers addressed at the time. There may have been an additional incentive too. Once regarded as transient phenomena of the atmosphere, comets were one of the triumphs of the Newtonian world. These seemingly capriciously appearing objects were found to be subject to the force of gravitation and therefore to theoretical calculation and prediction.[94] They recall the earliest record we have of Cavendish's thoughts, the poem from his Cambridge years: nature may mock us, but "She does lay bare hidden causes/ And the wandering paths of the stars." Cavendish's study of comets' paths in his later years may be seen as a vindication of that thought (and, perhaps, of his calling).

The final unpublished work of Cavendish's we consider belongs to optics. Among his papers we find a copy of a letter written by the astronomer William Ludlam about a manuscript of a text on optics, which he was critical of. The author left out Dolland's dis-

[93]Henry Cavendish, "La Places Method," Cavendish Mss VIII, 41. Henry Cavendish to Nevil Maskelyne, [Oct. 1799], draft, Cavendish Mss VIII, 46; partially reproduced in Jungnickel and McCormmach (1999, 720).
[94]A. Wolf (1961, 159–160).

covery and the related doctrine of aberrations, “the most difficult as well as the most important part of optics.” Ludlam cited Experiment 8 in Newton’s *Opticks*, on which Newton based a dispersion law implying that all further improvement in refracting telescopes other than for increase in length was impossible. Ludlam attributed the over-fifty-years’ delay before John Dolland discovered the error to the indolence of man or to the difficulty of experiments. No experiments had been made after Dolland’s, and there needed to be, Ludlam said, setting bounds to the further improvement of Dolland’s lenses.[95] Cavendish and Ludlam were acquainted, Cavendish having brought him as his guest to the Royal Society and the Royal Society Club. Cavendish must have considered Ludlam’s letter sensible, since he kept it among his papers. It would seem that Cavendish agreed with him, as his researches in optics were mainly about aberration.[96]

Dolland repeated Newton’s experiment, finding both the experiment and Newton’s dispersion law wrong. With a double prism of glass and water, and with an adjustment of the angle of the water prism, he was able to achieve refraction without dispersion into prismatic colors. With further experiments with prisms, he found that by combining two kinds of glass with different powers of dispersion in the right proportion, he could again obtain refraction without dispersion. The success with prisms carried over to lenses, enabling Dolland to build an achromatic telescope using a compound lens of flint glass and crown glass, or ordinary window glass. A significant advance in astronomy was implicit in Dolland’s telescope, though its realization waited for improvements in glass, especially in flint glass. Through the last half of the eighteenth century, achromatic telescopes with lenses over five inches in diameter were unknown owing to the poor quality of the glass. The defect was overcome by the Swiss watchmaker and optician Pierre Louis Guinard, who for twenty years experimented with casting methods with the goal of freeing glass from defects. He had only limited success until 1805 when he joined the firm of Fraunhofer and Utschneider in Munich, where his method was perfected. Fraunhofer improved achromatic telescopes to where they rivaled the best reflecting telescopes.[97]

On a tour in Switzerland, Blagden met Guinard, who gave him a small piece of his flint glass, which he said had much greater refractive and dispersive power than common flint glass, and which moreover was free from veins. When Blagden returned, the fragment of glass was ground into a prism and given to Cavendish, who weighed it, finding its specific gravity larger than that of common flint glass.[98] He evidently followed this up with a series of experimental and mathematical researches in optics, begun in February 1789 and continuing into October. Because he did not write up a paper for publication or for a colleague, we have only his laboratory record, to which someone other than Cavendish gave the title “On Rays of Different Colours Transmitted through Prisms of Different Materials.”

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[95]“Mr. Ludlam’s Acct of Mr. Harris Ms.,” Cavendish Mss V, 3.

[96]Examples are: Henry Cavendish, “On the Aberration in Reflecting Telescope Used in Herschels Manner”; “On the Aberration of Rays Passing through Spherical Lens,” Cavendish Mss V, 10, 11.

[97]C.S. Hastings (1891, 344–345). H.C. King (1948).

[98]Charles Blagden to M.A. Pictet, 9 Apr. 1789, Blagden Letters, Royal Society 7:223. We assume that Cavendish weighed the glass after it was ground into a prism, but it could have been before. See next footnote.

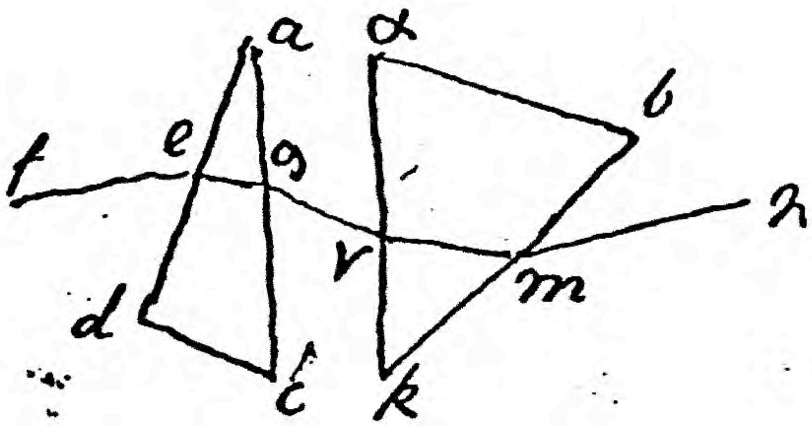

Figure 17.3: Compound Prism. The prism S is made of Swiss glass, the prism F of flint glass. Cavendish compared the refractions of the two prisms using colored light, red and blue. Cavendish Mss V, 4. Reproduced by permission of the Chatsworth Settlement Trustees.

Cavendish's first experiment was a comparison of a prism of "glass from Switzerland" with a prism of ordinary flint glass (Fig. 17.3). Given the timing we suppose that the glass from Switzerland is the one Blagden received from Guinard.[99] In the experiment, rays from the two extremes of the spectrum, red and blue, were directed through the two prisms, which were pressed together, and projected on a board, where one inch corresponded to seventy minutes of arc. Repeating the trial using flint glass and crown glass, Cavendish found the dispersion—the separation of the red and blue rays—of the flint prism by itself to be 91.7 minutes, of the crown prism by itself to be 58.1 minutes, and of the compound prism to be 4.9 minutes, a very considerable reduction in the spread of colors, as expected after Dolland. The refractions of the red and blue rays in passing through the compound prism were about eighteen degrees, the bending responsible for magnifying and focusing in telescope lenses. Cavendish developed rules for computing the difference in the refrangibility of red and blue rays by compound prisms. He experimented with prisms made of white glass and crystals and also with hollow prisms filled with water, spirit (alcohol), solution of Glauber's salt (sodium sulfate), and sugar of lead in water (lead acetate). He was interested in the breadth of images of colored light, for which he derived a formula, and also in their brightness and dilution. For this investigation, his experimental arrangement consisted of two separated prisms and two slits and a hole, each about 1/8 of an inch across. The Sun was usually the

[99]Another reason for thinking the glass is the same as the one Blagden brought home is that Cavendish's drawing of a compound prism made up of a prism of Swiss glass and a prism of flint glass shows the former as the smaller of the two prisms, in agreement with the smallness of the prism made from Blagden's glass.

source of light, occasionally candles. As customary, he compared theory with experiment, computed values with observed values.[100]

Cavendish's experiments with light and prisms were probably connected with his interest in astronomy, as they took place around the same time as his mounting of Huygens's aerial refractors. If his experiments began with Blagden's interesting piece of glass from Switzerland, they turned into a study of the optical properties of various substances, paralleling his earlier studies of the chemical, thermal, and electrical properties of various substances. Experimental optics had not been a major field when he began his work in natural philosophy, a likely reason why he turned to it only after completing his main work. The part of experimental optics that interested him was the one most closely identified with Newton's optics: experiments on the refrangibilities of the colored rays of sunlight carried out with prisms, slits, holes, and screens. Newton had not solved all the problems of colors, as Dolland showed, nor had Dolland solved all of them, as Ludlam pointed out. Cavendish's late optical researches were both an acknowledgment of Newton's master experimental work and an expression of curiosity about where Newton's lapse led.

Published Work

Cavendish's last five papers published in the *Philosophical Transactions* all had to do directly or indirectly with astronomy, though only one of them, his paper on weighing the world, discussed above, was a major work. In one paper, he calculated the height of an aurora observed from three locations several years before, in 1784. The letters from the observers of the aurora were read to the Royal Society in 1786, and Cavendish's paper was published in 1790. Different from the common aurora borealis, which was seen towards the north low down in the sky in the form of a circle, this aurora was thought to be of the one kind whose height was measurable. Halley had proposed triangulation as a method of finding the height of auroras, and Cavendish was the first to use the method successfully. From the reported observations of the position of the aurora in question among the stars and from the distance between the observers, Cavendish found its height to lie between 52 and 71 miles, an "astonishingly exact result" for a measurement of this kind. It was not until the twentieth century that his result could be confirmed, and as was frequently the case with his work, his result was "not generally recognized" in his time.[101]

Cavendish's interest in the aurora extended beyond the calculation of its height. By analogy with the aurora borealis, he suspected that auroras of this kind consist of parallel rays of light shooting skyward, and he encouraged "people to attend to these arches" to help decide if his hypothesis was "true." His hypothesis had "some probability in it," but it was not yet a "theory of which I am convinced."[102] His paper was one of six papers, including the three letters, on auroras appearing in part 1 of the *Philosophical Transactions* for 1790; it can be seen as a contribution to an effort by the Royal Society to draw attention to auroras.

In 1792 Cavendish published a paper on the Hindu civil year.[103] We see his interest in the subject in the information he sought out at the time. He brought as a guest to the Royal

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[100] Henry Cavendish, "On Rays of Different Colours Transmitted through Prisms of Different Materials," Cavendish Mss V, 4.
[101] Harold Falck-Ytter (1983, 57, 60).
[102] Henry Cavendish (1790); Thorpe (1921, 67–68).
[103] Henry Cavendish (1792).

Society Club William Marsden, a fellow of the Royal Society and an orientalist and linguist, who published a paper on Hindu chronology in the *Philosophical Transactions*.[104] Cavendish commented on a paper on Hindu astronomy by Samuel Davis, another orientalist;[105] Davis was subsequently elected to the Royal Society on the recommendation of Cavendish, who appeared first on Davis's certificate.[106] Around this time, Cavendish added to his library a number of books on India and a subscription to the *Asiatick Researches*, the journal of the Asiatic Society of Calcutta, modeled after the Royal Society of London.

Cavendish began his paper by pointing out that much was known about Hindu astronomy but little about the Hindu civil year, and what was known varied, in part, because different methods were used in different parts of India. To clear up this uncertainty, Cavendish asked the Sanskrit scholar Charles Wilkins, a fellow of the Royal Society, to lend him three almanacs from different parts of the country. Before analyzing the almanacs, Cavendish discussed the Hindu astronomical, or "solar," year, which begins when the Sun comes to the first point on the Hindu zodiac. It is a little longer than the Julian year, by several minutes, so that it begins continually later than the Julian. The year is divided into twelve months; the length of each month is the time the Sun remains in some sign of the zodiac, so that the months are of unequal length. The day, which begins at sunrise, is divided into sixty parts, which again are divided into sixty parts. The civil year in the parts of India that use the Benares almanac is "lunisolar," divided into twelve months, with an intercalcary month inserted occasionally. The lunar month is divided into thirty parts called teethees, each equal to the time it takes for the moon to travel twelve degrees from the Sun. The teethee is sometimes longer than a day and sometimes shorter, two teethees ending on the same day. The counting of days, Cavendish said, is "sufficiently intricate; but that of counting the months, is still more so." We will not go through it here. Because the Hindu civil month, both solar and lunar, does not have a determinate number of days and is not fixed to a regular cycle, an ordinary Hindu has no way of knowing the day of the month other than by consulting the almanac, and at different locations the month might begin on different days. In answer to Cavendish's question if there was a way to avoid the ambiguity, Davis said that there was not, that months can begin on different days at different locations, but that in practice this did not matter much. The Brahmin in charge of the temple had an almanac, which he used to announce times of observances, and if he was an astronomer, he could make the corrections for location. It was otherwise with teethees, lunar days which regulated most religious festivals, which caused considerable perplexity.[107]

Cavendish described the almanacs beginning with Benares. He characterized its preface as a man of the Enlightenment might: it "begins with an invocation to the Deity, and then gives a whimsical account of the four Yoogas, or ages, and of the inferiority of each succeeding age to that preceding it, and concludes with astrological remarks." The almanac contains eleven columns, without titles or explanations, "but by a careful examination of the numbers, a person acquainted with astronomical computations may, without much difficulty, find out their meaning." Cavendish went through the columns one by one, giving his

[104]William Marsden (1790). 17 May 1787, Minute Book of the Royal Society Club, Royal Society, 8. In that year Marsden was elected member of the Club.

[105]Davis asked Banks to show a paper of his to Cavendish, initiating the connection. Samuel Davis to Joseph Banks, 10 Mar. 1791, Banks Correspondence, Royal Botanical Gardens, Kew, l.38.

[106]28 June 1792, Certificates, Royal Society 5.

[107]Cavendish (1792, 237, 242).

interpretation. The almanac contained other information such as tables of diurnal motion, places of the Sun and planets in the Hindu zodiac for each week, lunar and solar eclipses, times when the moon and planets come to certain situations, about which, Cavendish said, "there is not a great deal which I understand, and what I do, is not worth taking notice of." There were some tables and figures that he thought "relate only to astrology," falling outside his area of interest and competence.[108]

Another brief publication by Cavendish, in 1797, came about the following way: Mendoza y Rios was given permission by Cavendish to publish as an addition to a paper on nautical astronomy an extract from a letter by him on a method for computing the distance between the moon and a star. In nautical tables published several years later, Mendoza did not use Cavendish's method, which involved a series of corrections and was more complex than the one he chose.[109]

Cavendish's last publication was about a method for dividing astronomical instruments. The success of instrument makers depended on their ability to divide circles and straight lines accurately into equal parts. George Graham's eight-foot mural quadrant at the Royal Observatory was examined by James Bradley, who concluded that it was in error by over fifteen seconds of arc. The instrument maker John Bird replaced it with a quadrant that was accurate to within one second of arc.[110] In a class by himself, Bird never let more than one person into the room when he was working, since the heat could spoil his divisions. For his method of dividing astronomical instruments, Bird needed two kinds of equipment. One was a scale for measuring the radius to 1/1000 of an inch, the other a set of five beam compasses with magnifying glasses. The longest beam was for drawing the circles to be divided, and the others of different lengths were for measuring chords of the circle, the finer divisions of the circle being made by bisection. Beam compasses made scratches at the edge of the circle; points were made with a punch not exceeding 1/1000 of an inch across. In describing a mural quadrant divided by his method, Bird quoted from the *Nautical Almanac* for 1767 in what could be considered the joint faith of an instrument maker and a user of instruments: "a mean of several observations, made by good observers with accurate instruments, properly adjusted, will always lead us either to the truth itself, or extremely near to it."[111]

As was the practice up to his time, Bird made his divisions by hand, the accuracy of which depended critically on his skill. An alternative to his method was that of the dividing engine, which made graduations of instruments largely independent of the skill of the maker. In 1766, Jesse Ramsden built his first dividing engine, which was accurate enough for surveying but not for nautical instruments; he improved on it in 1775. Called his outstanding invention,"[112] his dividing engine consisted of a large horizontal metal circle, the circumference of which was divided into 2160 teeth, in which an endless screw turned, six revolutions of the screw turning the wheel through one degree of arc. The brass astronomical circle to be divided was screwed down on the wheel. A frame above the wheel held the dividing point, which could mark any angle on the limb of the circle "with great exactness."[113] Regarded as a versatile expert on instruments, Cavendish was appointed to a committee of

[108] Ibid., 238, 242–243, 245.
[109] The extract from Cavendish's letter was published at the end of Mendoza y Rios (1797): "Addition. Contenant une methode pour reduire les distances lunaires," 119–22; Henry Cavendish (1797, 246–248).
[110] Allan Chapman (1993, 209).
[111] John Bird (1767, 2, 11, 13).
[112] E.G.R. Taylor (1966, 244).
[113] Jesse Ramsden (1777, 1).

the Royal Society in 1783 to find out why Ramsden was behind schedule in delivering a seven-foot equatorial circle to the Royal Observatory; at Ramsden's house, the committee found the "Circle ready for dividing."[114] When Ramsden completed a mural quadrant for Milan in 1790, he invited Cavendish along with others to see and try the instrument, which was "true much within a second." Ramsden told his visitors that "any common man in his workshop, with good eyes and hands, could, on the same principles, have divided it to equal perfection."[115] Such was the advantage of a dividing engine over the old method of dividing circles by hand.

In 1785, Cavendish communicated to the Royal Society a paper on dividing circles by John Smeaton. The paper contained two letters by Smeaton's friend the clockmaker John Hindley, who around 1739 "was the first to construct an engine for cutting the teeth in clock wheels and for dividing instruments," making use of the "roller method for the original division of the dividing plate, which was actuated by an endless screw."[116] Hindley's method depended on contact not sight, an advantage in an astronomical circle, the certainty of contact being fifteen times greater than that of vision. Smeaton's pyrometer, for example, which relied on contact, was accurate to 1/24,000 part of an inch, and he thought that 1/60,000 part of an inch was possible. Smeaton summed up the importance of the method of dividing circles: "Perhaps no part of the science of mechanics has been cultivated by the ingenious with more assiduity, or more deservedly so, than the art of dividing circles for the purposes of astronomy and navigation."[117]

Between 1775 and 1778, John Troughton built a dividing engine of Ramsden's construction, thought to be superior in accuracy.[118] He and his younger brother Edward were known for their dividing instruments, which were used by other instrument makers, the ultimate compliment. By the beginning of the nineteenth century, Edward Troughton, who then conducted the business alone, had succeeded Ramsden as the foremost instrument maker in England. In 1807 Cavendish was part of a visitation committee from the Royal Society who agreed with the astronomer royal that observations at the Royal Observatory would have greater accuracy if they were made with a circular instrument as well as with the existing mural quadrant. On the committee's invitation, Troughton recommended a circle six feet in diameter.[119]

In 1804, Troughton had perfected a new method of dividing circles, which he used in graduating the Goombridge Transit Circle, a four-foot transit instrument he made for the astronomer Stephen Goombridge; the instrument was to plague Troughton for years.[120] In the visitation committee, Cavendish spoke against Troughton's "proposed instrument" for the Royal Observatory,[121] his objection to Troughton being partly based on the Goombridge instrument. Cavendish, in Blagden's words, "thought Troughton deficient in judgment, con-

[114] 31 July and 25 Sep. 1783, Minutes of Council, Royal Society 7:143, 146.
[115] These were Charles Blagden's words, reporting what Ramsden said. Letter to Joseph Banks, 23 Sep. 1790, BL Add Mss 33272, pp. 89–90.
[116] David Baxandall (1923–1924, 135).
[117] John Smeaton (1814, 170, 186).
[118] Baxandall (1923–1924, 136).
[119] Meeting of the committee on 22 Jan. and report of the meeting of the Council on 28 May 1807, "Visitations of Greenwich Observatory 1763 to 1815," Royal Society, Ms. 600, XIV.d.11, ff. 59–62.
[120] A.W. Skempton and Joyce Brown (1973, 246). In 1823 the instrument was examined for accuracy to "correct rumours harmful to Mr. Troughton." Taylor (1966, 289).
[121] 14 May 1807, Charles Blagden Diary, Royal Society 5:69.

trived some things very ill."[122] The committee reported to the Council of the Society that the "instrument recommended by Mr. Troughton is the best they are likely to procure under the present circumstances."[123] The less than wholehearted wording may have expressed Cavendish's reservations.

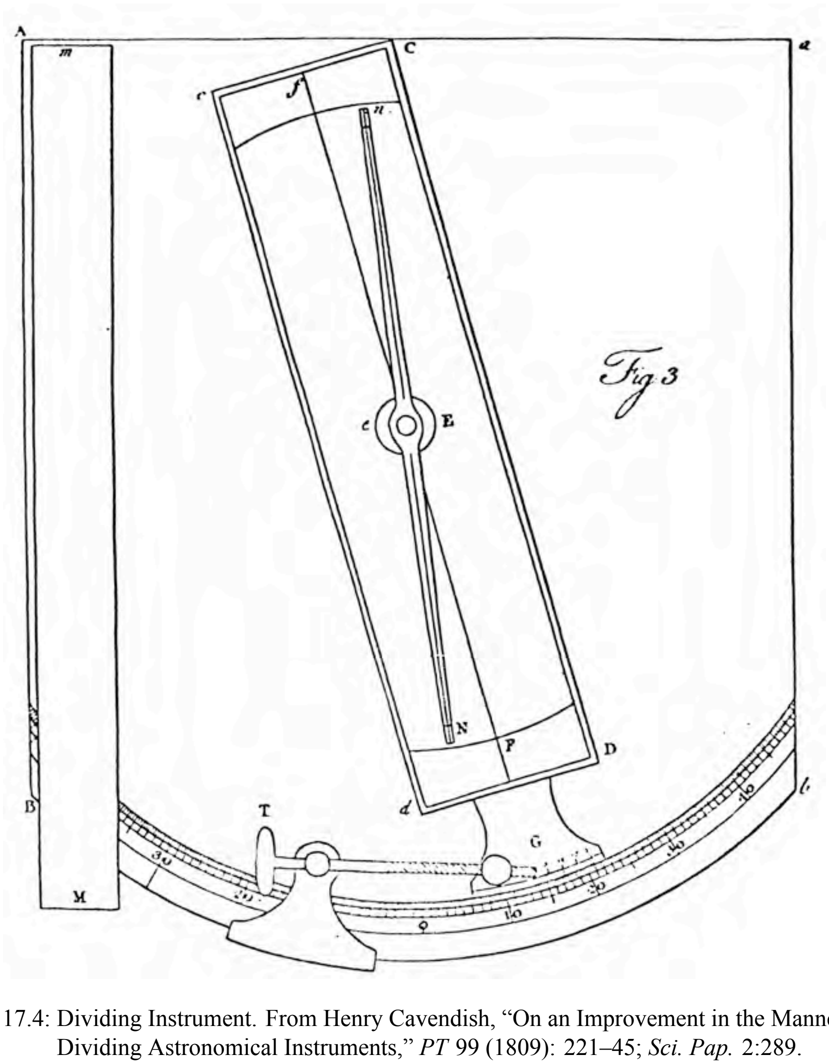

Figure 17.4: Dividing Instrument. From Henry Cavendish, "On an Improvement in the Manner of Dividing Astronomical Instruments," *PT* 99 (1809): 221–45; *Sci. Pap.* 2:289.

Troughton submitted a paper containing his new method of dividing circles to the Royal Society in 1808, and the next year it was published in the *Philosophical Transactions*.[124] He said that Bird was the greatest divider of his time, and after him came Ramsden, Smeaton,

[122] 22, 23 Jan. 1807, Charles Blagden Diary, ibid. 5:29.
[123] 28 May 1807, Minutes of Council, Royal Society 7:503.
[124] Skempton and Brown (1973, 246).

and his brother John. For his part, he said, he had quickly come to reject beam compasses, finding that he could not bisect two points "without enlarging, displacing, or deforming them" with the tools then in use. Recognizing that only "turning" led to perfection, he used rollers to divide a circle, marking off the revolutions. In the paper Troughton mentioned the six-foot circle he was making for the Royal Observatory.[125]

Troughton's paper is mainly about reducing errors. Two other papers at the time dealt with the same subject. The astronomer John Pond wrote that it is "one of the many advantages of circular instruments, that from the observations made with them, we may infer with great precision not only the mean probable error, but likewise the greatest possible error to which they are liable." For his astronomical circle, he calculated the greatest possible error as 2.5 seconds and the mean error as 1 second.[126] The Lowndean Professor of Astronomy at Cambridge William Lax said that it was unsatisfactory to make observations of "extreme accuracy" with an instrument whose "exactness" cannot be judged. In his paper, he showed how to achieve high accuracy from an instrument that is not very exactly divided.[127] Cavendish's paper, "On an Improvement in the Manner of Dividing Astronomical Instruments," appeared the same year as Troughton's and Lax's papers, and like them it was concerned with reducing error.

Cavendish pointed out the great difficulty in the common method of dividing beam compasses, which required placing a point halfway between two nearby scratches on the limb of the circle, an action that was hard to achieve without the point slipping toward one or the other scratch. He supposed that this was why Troughton invented an alternative "ingenious method of dividing," which induced him to see if the older method of beam compasses could be modified to avoid the objection. His change was to use a beam compass with one point instead of two, replacing the second point with a microscope, in this way eliminating the need to set the point of the compass into any division, and the objection to the "old method" was "entirely removed."[128]

In Cavendish's apparatus, a movable frame rests on the circle to be divided, and there is a single beam compass with a retractable point near one end and a pivot at the other, fitted with a microscope that slides from one end of the beam to the other (Fig. 17.4).[129] Horace Darwin describes his method concisely: "the circle was first divided into 6 parts by setting a beam compass with the points apart at a distance equal to the radius. These spaces were divided again by the beam compass, sometimes into two equal parts, and sometimes into three and five equal parts, and so on till quite small spaces were left. Errors have to be calculated and allowed for, and the process is most laborious and slow."[130] Both his and Troughton's methods were free of the inaccuracy of setting a point of a compass in the center of a division, but his required "much less apparatus" than Troughton's and was "free from any danger of error" from irregularity and slippage of motion of a roller, and it had an additional "considerable advantage" in being free of mistakes in "computing a table of errors."[131] His method had "much advantage" over the common beam compasses

[125]Troughton (1809, 105–106).
[126]John Pond (1806, 421).
[127]William Lax (1809, 232–233).
[128]Henry Cavendish (1809, 287)
[129]The auction catalog of Cavendish's instruments lists five beam compasses, items 22–24. *Catalogue of Sundry Very Curious and Valuable Mathematical, Philosophical, and Optical Instruments*.
[130]Horace Darwin, in Thorpe (1921, 74).
[131]Cavendish (1809, 293).

in accuracy, but whether or not it had an advantage over Troughton's method was left for instrument makers to decide.

Cavendish's method does not seem to have been adopted. It was for making original divisions, whereas later instruments were graduated using dividing engines, which copied existing divided circles. What is important here is the kind of instrument he was concerned with. His final contribution to science was about a tool for making instruments capable of measuring with more exactness. We close this section with a table from Troughton's paper in the same volume of the *Philosophical Transactions* as Cavendish's. In parts of an inch, the greatest error of six standards were, in order of accuracy:

- .000165 G. Shuckburgh's 5-foot standard
- .000240 W. Roy's scale of 42 inches
- .000273 G. Shuckburgh's equatorial of 2-foot radius
- .000465 Greenwich quadrant of 8-foot radius
- .000700 A. Aubert's standard of 5-foot length
- .000795 Royal Society's standard of 92 inches

Such accuracies had practical as well as scientific and technical significance. Troughton called attention to the place in the ranking of General Roy's scale, which was important because Roy used it to measure the baseline of the national trigonometrical survey.[132] For his paper in 1808 on a method of dividing instruments, Troughton was awarded a Copley Medal. This was not the first time the Royal Society rewarded exactness; earlier instances have come up in this book such as Roy's measurement of a baseline and Harrison's chronometer. Cavendish, who was seventy-seven when his paper on a method of dividing instruments was read before the Royal Society, was interested in furthering this direction of science, to which his earlier work had given impetus. His final contribution rounded out a lifetime's work.

Reasons for Not Publishing

It has been suggested that Cavendish's reluctance to publish more of his work was a consequence of his class and wealth, which isolated him from the scientists of the industrial age, who otherwise could have encouraged him. From a social and material standpoint, he was fortunate in the class he was born into, but from the standpoint of his avocation, scientific research, the argument goes, he was unfortunate. If he had had to earn a living, he would have had different associates and probably a different attitude toward his scientific work. As a scientist of the old school, he might have held Newton's chair in Cambridge or Halley's in Oxford, or as a scientist of the industrial age he might have found work in Birmingham or Glasgow, but being an aristocrat he could do neither. Instead he lived in London and associated with the old ruling class, which in the Royal Society formed a circle around its president Joseph Banks. At Cambridge he studied the science of the previous age, typified by Newtonian mathematics and the mechanics of the solar system, which remained his preference even as his researches led him to heat and chemistry, sciences associated with the rising industrial classes. With a foot planted in each world, the old and the new, he had difficulty in finding a means to communicate his researches.[133] In a general sense, there

[132] Troughton (1809, 140).
[133] James Gerald Crowther (1962). His discussion of Cavendish is on 272–275.

may be considerable truth in this analysis, only it is hard to know how to apply it to specific cases. He developed furthest the science he modeled after Newton's, electricity, but he left unpublished half of his electrical researches needed to complete the work, even though he was in London in association with Banks's circle. Electricity was not yet a science of practical importance in industry, and it is uncertain that he would have received any more encouragement if he had been in Manchester.

We agree that Cavendish's social origins probably did affect his publishing, though isolation was not the most important way it worked. In the previous century the aristocrat Robert Boyle published his scientific writings, and in Cavendish's time Lord Mahon published a good book on electricity and Edward Delaval received a Copley Medal, but it is noteworthy that in the middle of the eighteenth century, very capable men of science who were aristocrats—Lord Charles Cavendish, Lord Morton, and Lord Macclesfield—published almost nothing on science, their stronger motivation being to perform a public service as scientific administrators. Like his father, Henry Cavendish received recognition for his work in the Royal Society, for which he did not need to publish any more than his father did. Able contemporaries of Cavendish's achieved prominence in scientific society by different routes: Herschel's was mainly through publication, Cullen's was by teaching science, Banks's by promoting it, and Aubert's by serving it. The desire of individuals to achieve recognition through published research could be strong, as priority disputes showed, but the understanding that published research was a uniform measure of an individual's scientific contribution was still in the future.

A number of general explanations of Cavendish's practice of publication have been suggested. One of them is Blagden's, mentioned earlier: Cavendish published everything he was satisfied with, and if he did not publish, it was because he was not satisfied. Another reason is that he carried out researches only or mainly to satisfy his curiosity and was indifferent to their publication. A problem with this is that he was committed to the advancement of science, which depends on publication as well as on curiosity. Another explanation is that he disliked controversy and priority disputes. This may have been the explanation at times, but rarely is there scientific work that does not overlap other work, and Cavendish sometimes did publish. It is said that he was ambivalent about publishing because he was shy and disliked attention directed at himself. He exhibited shyness in social situations, but he was not shy about expressing his scientific opinion, only cautious. Cautiousness is distinct from shyness. It is said that he may have found writing for publication irksome, and perhaps he did, but we know that he liked writing. Still other general explanations have been proposed.[134] The causes of Cavendish's reluctance to publish some of his work are no doubt

[134] Hugo Lidbetter offers a psychological explanation for why Cavendish held back from publication. He thinks that Cavendish was autistic, for which reason he did not spontaneously share his interests and achievements with others. If Cavendish was autistic, this is a credible general reason for Cavendish's relative indifference to publication. Lidbetter misreads what Christa Jungnickel and I say in our Cavendish biography, where he says that we explain why Cavendish held back from publication by his "views on the inadequacy of language." That is not what we say, as he should know, since he quotes the relevant passage from our book earlier in his article. In a discussion of Cavendish's taciturnity we say that words, as used in normal speech, do not adequately represent Cavendish's world; for that mathematics and quantities are needed. Publications are, of course, exactly where mathematics and quantities are proper and necessary. We offer a suggestion arising from his work that refers to his habits of *speech*, not of *publication.* Jungnickel and McCormmach (1999, 370). Hugo Lidbetter (2009, 784). I thank Steve Silberman for the reference to Lidbetter's article.

complex and probably depend on the work and its timing, and because he said nothing about his reasons they will probably never be fully known.

Cavendish's laying aside researches after initially intending them for publication may not have had entirely to do with the work at hand. William Heberden, who drafted the certificate for Cavendish's membership in the Royal Society, wrote a paper (which he did not publish) on the advantages of writing but not publishing. Writing, he said, "enlarges the mind and improves the taste," a sufficient reason for going to the trouble. The writer, however, if he "has already established a reputation, loses it as soon as he ventures to give anything to the public." The happiest writer, Heberden thought, was one who wrote "always with a view to publishing, though without ever doing so."[135] For a person who relished his privacy as Cavendish did his, Heberden's advice might have seemed not only clever but wise. There were other ways of contributing to science that did not require publishing.

Coinage of the Realm

If Cavendish had been born one hundred years later, or two hundred, he might have directed a scientific institute, and there is reason to think that he would have been good at it. His publications on heat were commentaries on experiments carried out under his direction. He directed meteorological observations at the house of the Royal Society and for a meteorological station he set up on Dartmoor. He instructed travelers to make observations of the heat of wells and springs for determining average climates of the world. He drafted scientific instructions for voyages of discovery. He did basic planning for two major Royal Society projects, observing a transit of Venus and measuring the density of the Earth. His house at Clapham Common was a live-in forerunner of a research institute. Because of a combination of traits—intelligence, dexterity, knowledge, and a sense of fairness—he had an authority he did not have to assert. We recall these facts about him to provide the background for certain experiments he devised for the public good in his later years.

In his *Sentimental Journey through France and Italy*, Laurence Sterne wrote that he had in his pocket "a few King William's shillings as smooth as glass," explaining that "by jingling and rubbing one against another for seventy years together in one body's pocket or another's, they are become so much alike you can scarce distinguish one shilling from another."[136] That description of coinage was given in 1768, five years before a large recall of the smooth gold coins.

In 1787 Charles Jenkinson, Lord Liverpool, president of the board of trade, directed a committee of the privy council to look into the state of the coinage of the kingdom. It called on the mint to review its gold, silver, and copper coins and collected information for years. In 1796 the one man of science on the committee Joseph Banks gave Jenkinson a long list of questions about the "extravagant waste" of gold owing to the wear of coins and defects in their manufacture.[137] The next year the war with France strained the finances of Britain, and the stock of gold being uncertain Parliament ordered the Bank of England to cease payments of its notes in gold. At the same time the minting of gold coins was cut back, and in 1798 the

[135] William Heberden, "Upon Composition, Authors, and Their Works in General, Either of Genius or Science," quoted in Humphry Rolleston (1933, 417–418).
[136] Laurence Sterne (1951, 165–166).
[137] Unsigned memorandum by Joseph Banks to Charles Jenkinson, Lord Liverpool, [1796], in Liverpool Papers, BL Add Mss 38422, vol. 233, ff. 320–324, on 321–322.

minting of silver coins was stopped completely.[138] That year the privy council committee on coins was reconstituted. Jenkinson opened the proceedings with a speech on the principles and history of coinage, pointing out that for eighty years gold coinage had been the de facto standard replacing silver. Gold was as plentiful as silver had once been, and he advocated adopting gold as the legal standard, replacing silver.[139]

The industrialist Boulton and the chemist Charles Hatchett were asked to write reports on the coinage, which were given to John Rennie, an engineer for Boulton & Watt, who undertook a complete study of the machinery at the mint. The reports were also given to Banks and Cavendish, who addressed the related problems of the wear of gold coins and the most durable alloy of gold for coins.[140] For the person to carry out experiments to decide if the loss of gold was due to defects in the quality of the gold or in the figure and impression of the coins, Cavendish recommended Hatchett, "whose accuracy can be relied on" (Fig. 17.5).[141] Cavendish was asked to assist Hatchett, and if it would help to persuade him (it was not needed) the king would appoint him a privy counselor.[142]

Cavendish planned the experiments to determine what kind of gold coin would best resist wear. To replicate the wearing of coins in Laurence Sterne's pocket, and any other kind of wear arising from their circulation, he designed machines for punishing coins, which were built by the instrument maker John Cuthbertson in whose house the experiments were carried out. One machine was a rotating cubic box in which batches of 200 pieces of gold of different ductility were agitated.[143] Another machine compared the effect of friction produced by various abrasive materials such as sand and metal filings when variously alloyed gold was rubbed against them. Another machine pressed pairs of coins together, moving them laterally across one another. In this machine, twenty-eight coins were placed in an upper horizontal frame and the same number in a lower horizontal frame, and with a weight placed on top, the two frames were moved independently at different rates back and forth by a person turning a wheel (Fig. 17.9). In a typical experiment with this machine, 573,380 cycles were run under a load of $3\frac{1}{2}$ pounds. The experiments were varied, using embossed coins and coin blanks and like and unlike paired metal coins.[144]

The two main questions were: first, whether soft or hard gold experiences the most loss to friction in the circulation of coins; second, whether a smooth coin or an embossed coin wears least. The experiments showed that when coins of the same qualities are rubbed together, the most ductile coins wear least, and that when dissimilar coins are rubbed together, the reverse is the case.

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[138] John Craig (1953, 260–262).
[139] Ibid., 267–268.
[140] Ibid., 268–269. Charles Jenkinson, Lord Liverpool to Joseph Banks, 10 May 1798, BM(NH), DTC 3:279–280.
[141] Henry Cavendish to Joseph Banks, 23 July and 6 Aug. 1798; in Jungnickel and McCormmach (1999, 708–709). Charles Jenkinson, Lord Liverpool to Joseph Banks, 13 Feb. 1799, BM(NH), DTC 3:195–196. On Cavendish's urging, a report was also given by A. Robertson, an Oxford mathematician who did research on coinage; Robertson's report was delivered and read by Cavendish, to whom Liverpool gave his thanks on 12 Apr. 1799; in Jungnickel and McCormmach (1999, 714).
[142] Charles Jenkinson, Lord Liverpool to Joseph Banks, 7 July 1798, BM(NH), DTC 3:19–20.
[143] Charles Hatchett to Joseph Banks, 14 Mar. 1800, BL Add Mss 33980, f. 225.
[144] J.C. Chaston (1974, 111).

Young Colleagues

Figure 17.5: Charles Hatchett. Engraving by F.C. Lewis from the painting by T. Phillips. Collaborator of Cavendish's. Wikimedia Commons.

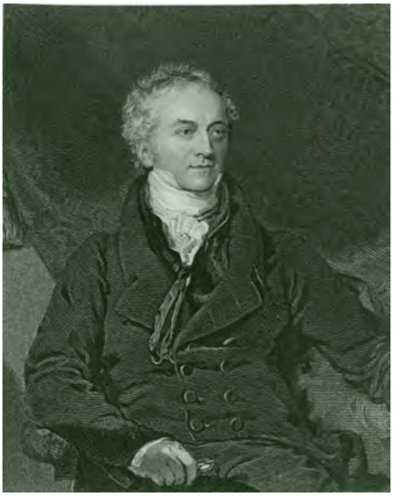

Figure 17.6: Thomas Young. Painted by Sir Thomas Lawrence, engraved by G. Adcock. Natural philosopher, Cavendish's colleague at the Royal Institution. Courtesy of Smith Image Collection, Van Pelt-Dietrich Library, University of Pennsylvania.

Figure 17.7: Sir Humphry Davy. Painted by James Lonsdale, engraved by W.H. Worthington. Chemist, Cavendish's colleague at the Royal Institution. Courtesy of Smith Image Collection, Van Pelt-Dietrich Library, University of Pennsylvania.

Figure 17.8: James Lewis Macie (Smithson). Tempera on paperboard, miniature portrait by Henri-Joseph Johns, 1816. Chemist, said to have worked in Cavendish's laboratory. Cavendish's. Wikimedia Commons.

The loss of weight in the experiments in any case was found to be miniscule, of the order of one grain per coin.The general conclusion was that whatever differences there are between different gold alloys, the loss that coins experience in normal circulation is trifling. The worn look of coins is explained by the prominences being simply pressed into the mass of the coins, not by any appreciable loss of weight. Any significant loss of gold would have other explanations.[145]

The experiments on the composition of coins turned out not to be particularly useful to the government, for they confirmed the practice of the minters, who proceeded with their alloys by experience without the aid of science,[146] but they did bring forward new facts of considerable scientific value. Hatchett said that knowledge of metal alloys had not "kept pace with the rapid progress of modern chemistry," being scarcely superior to what Pliny and the ancients knew.[147] As for knowledge of wear, a recent commentator writes, the grasp shown by Cavendish of its complex nature "was masterly; his work could have been studied with advantage by investigators a century later."[148]

Hatchett wrote the report for the privy council committee on coins. Cavendish prefaced it with a letter explaining that Hatchett had done the experiments and was best able to give an account of them. Hatchett's experiments were carried out with "great judgment & accuracy, & in the manner which to both of us seem best adapted to the object proposed," Cavendish said.[149] He appealed to the government to allow Hatchett to publish his results rather than keeping them a government "secret," as no "bad effect" could come of it.[150] In support, Banks told Liverpool that Cavendish and Hatchett were anxious that their findings on metallurgy might be anticipated, in particular by the French.[151] "At the request of Mr. Cavendish," Hatchett wrote in the abridged paper read to the Royal Society in 1803, "I have written the following account; but I should be highly unjust and ungrateful to that gentleman, did I not here publicly acknowledge how great a portion truly belongs to him." The machines and dies were "entirely contrived" by him.[152] The paper appearing in the *Philosophical Transactions* was very long, 151 pages, Cavendish contributing the section describing the instruments.[153]

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145 Ibid., 111–112.

146 Ibid., 112. In the practice at the time, the best compromise of hardness and color was obtained by an amalgam 1/12th to 1/13th of alloy; pure silver and pure gold were found unsuitable. Joseph Banks to Lord Liverpool, 11 May 1801, BL Add Mss 38424, ff. 158–59. Craig (1953, 269).

147 Charles Hatchett (1803, 193).

148 Chaston (1974, 112).

149 Cavendish to the privy council committee for coins, prefacing Charles Hatchett's report, 28 April 1801; in Jungnickel and McCormmach (1999, 724). Joseph Banks to Charles Jenkinson, Lord Liverpool, 11 May 1801, BL Add Mss 38424, ff. 158–59. The report addressed to Lord Liverpool and the select committee for coins was signed by Hatchett, 28 Apr. 1801, BL Add Mss 38426. The title of the report of the experiments, which begins on f. 25, is "Experiments and Observations on the Various Alloys, on the Specific Gravity, and on the Comparative Wear of Gold."

150 Henry Cavendish to Charles Hatchett, 15 Oct. 1802; in Jungnickel and McCormmach (1999, 726). This letter was enclosed in a letter to Banks by Hatchett, in which Hatchett said that Lord Liverpool was satisfied with Cavendish's opinion on the publishable nature of the material. Charles Hatchett to Joseph Banks, 24 Oct. 1802. Hatchett and Cavendish's desire to see the experiments published was first put to Lord Liverpool by Joseph Banks on 21 Aug. 1801, BL Add Mss 38424, ff. 160–161.

151 Banks to Lord Liverpool, 21 Aug. 1801.

152 Hatchett (1803, 45).

153 Ibid., 140–147.

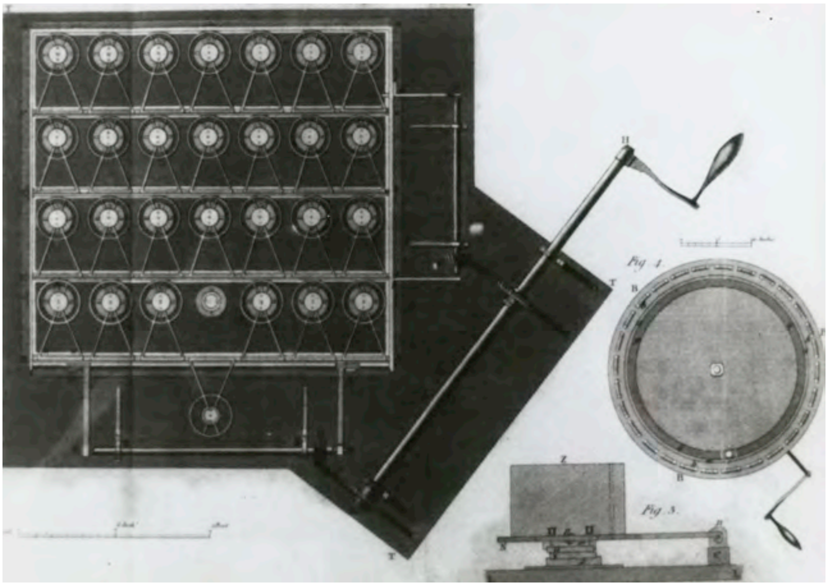

Figure 17.9: Coinage Apparatus. This drawing shows the apparatus invented by Cavendish for measuring the wear of coins, built for him by the instrument maker John Cuthbertson. Twenty-eight pairs of coins are pressed and rubbed together by turning the crank. Each pair of coins is separately weighted, and the frames holding the top and bottom coins vibrate at different rates to reduce grooving. Charles Hatchett, "Experiments and Observations on the Various Alloys, on the Specific Gravity, and on the Comparative Wear of Gold. Being the Substance of a Report Made to the Right Honourable the Lords of the Committee of Privy Council …," *Philosophical Transactions* 93 (1803): at end of volume.

There is a sense in which coinage and nature posed a similar problem. In his researches, as we have seen, Cavendish repeatedly introduced a "standard" by which to measure certain phenomena or substances, and he referred to substances or powers as being in a certain respect "equivalent." The same terms were used to understand the wealth of nations. In a letter to Liverpool on the subject of coinage, Cavendish referred to the "standard" of the fineness of gold.[154] Liverpool told his committee on coins that the "standard coin of every country is the measure of property in it," and unlike other kinds of measures it is also the "equivalent" of the property measured by it. The problem of coinage came about because the standard for measuring the value of things could not be fixed once and for all; money was an equivalent made of gold, silver, or copper, and the prices of those metals fluctuated. From its dual function as standard measure and equivalent, money acquired the "principal difficulties" that attended it in speculation and in practice.[155]

There was a long-standing tradition of scientific service in the government in matters of coinage. Newton had been master of the mint, and after Newton the connection of the mint

[154]Henry Cavendish to Charles Jenkinson, Lord Liverpool, 13 July [1798]; in Jungnickel and McCormmach (1999, 704).
[155]Charles Jenkinson, Lord Liverpool (1805, 8–9). "Heads of So Much of Lord Liverpool's Speech," f. 402.

with the Royal Society remained substantial, most of its masters having been fellows of the Royal Society.[156] So far as we know, Cavendish was never considered for that office, but of the scientific men of his time in England he was closest to Newton in his skills and standing, a possible reason why he was selected as the appropriate scientific authority for examining the condition of the nation's coinage. For Cavendish it would have been performing a duty of service.

Royal Institution

For decades Cavendish served two institutions, the Royal Society and the British Museum, and in the last decade of his life he served a third, the Royal Institution. The last named was the creation of Benjamin Thompson, or as he was then better known, Count Rumford. He had served with the British army in the American Revolution, and later at the court of the elector of Bavaria, he had served as head of the army. He had also made inventions, performed experiments, and conceived of the idea of an institution of mechanics and heat. In 1798 he came to London, where his ideas on kitchens and heating had preceded him, put in place at the Foundling Hospital by the philanthropist Thomas Bernhard. Invited by Bernhard and the recently formed Bettering Society to draw up a plan, Rumford proposed an institution dedicated to teaching the applications of science and spreading knowledge of inventions. To fund it he organized a subscription whereby a person who gave fifty guineas or more became a perpetual proprietor. There was a quick response, and in 1799 the Royal Institution of Great Britain was launched.[157] The first lecture was announced for March 1800 in a house on Albemarle Street (Fig. 17.10).

Both Cavendish and the duke of Devonshire paid their fifty guineas about a year after the Institution was founded, by which time it looked respectable, with a substantial aristocratic representation.[158] The governing body consisted of nine managers, elected initially from the proprietors, and Cavendish promptly became a manager.[159] The meetings of the managers were irregular but frequent, attended as a rule by only three or four managers along with the secretary and treasurer, with Cavendish the most faithful attender. He was also a conscientious member of the "scientific committee of council," a standing committee set up to oversee the syllabus and scientific experiments, which included Blagden, Hatchett, and several other fellows of the Royal Society.[160] When the first scientific lecturer Thomas Garnett acted independently, Rumford got the managers to appoint a small committee consisting of Cavendish, Banks, and himself to supervise the drawing up and publication of the syllabus of lectures in the future.[161] In this and other ways Rumford leaned on Cavendish and Banks to establish his authority. The second year saw important changes of staff. On Banks's

[156] John Craig (1964, 161–162).
[157] K.D.C. Vernon (1963). W.J. Sparrow (1964, 109–110). Sanborn C. Brown (1976).
[158] Cavendish became a proprietor on 10 Feb. 1800. The managers at their meeting on 17 Feb. said that the Royal Institution was "now established on a Basis so firm & respectable, that no Doubt can be entertained of its Success." Royal Institution of Great Britain (1971).
[159] He was elected at the annual meeting of proprietors on 1 May 1800. Entry for 5 May 1800, Minutes of the Meetings of Managers, Royal Institution 2:70.
[160] 31 March 1800, Minutes of the Meetings of Managers, Royal Institution Archive 2:39–41. The other members of the committee were James Rennell, Joseph Planta, E. Whitaker Gray, J. Vince, and William Farish. The last two were professors of experimental philosophy and of chemistry at Cambridge. Maskelyne was appointed but declined because he was too busy.
[161] 2 Feb. 1801, Minutes of the Meetings of Managers, Royal Institution 2:126–127. Vernon (1963, 18).

recommendation, Garnett was replaced by Thomas Young, and on Rumford's recommendation, Humphry Davy was hired as an assistant lecturer in chemistry (Figs. 17.6–17.7). By persistently attracting a fashionable audience to his public lectures and by doing outstanding chemical research, Davy ensured the success of the Institution.[162] Rumford's methods were dictatorial and his presence erratic, and as the Royal Institution departed from its original purpose his interest in it flagged; in 1802 this restless man left the Institution for good.[163] The next year the scientific committee was reappointed, with Cavendish, Banks, and Hatchett on it again.[164] That same year the committee recommended as Thomas Young's successor John Dalton, who gave occasional lectures at the Institution.[165]

Figure 17.10: Royal Institution. Distinguished Men of Science. Engraving by William Walker around 1862, from a drawing by Sir John Gilbert. The full title is "Distinguished Men of Science Living in Great Britain in 1807–8." The setting is the library of the Royal Institution, but the men shown in the print never gathered in this room. The artist created the group from individual portraits. Henry Cavendish is placed in the front, sitting apart, his eyes downcast; perhaps this is the artist's interpretation of Cavendish's solitude in company. Cavendish's profile and dress are based on William Alexander's sketch, with obvious differences: Cavendish's hat is removed; he is seated instead of walking; he faces the other direction; and he is made to appear thirty years younger. Cavendish was a manager of the Royal Institution from 1800. Wikimedia Commons.

Cavendish had long been a subscriber to the Society of Arts without taking part, whereas he was fully involved in the affairs of the Royal Institution from the start. The difference is likely explained by the stronger connection to science in the Royal Institution. Cavendish supported formal cooperation between the Royal Institution and the Royal Society, seconding Rumford's motion to direct the secretaries of the two institutions to keep one another regularly informed.[166] We have no way of knowing how much interest

[162] Vernon (1963, 19, 22).
[163] Ibid., 24.
[164] 26 May 1803, Minutes of the Meetings of Managers, Royal Institution 3:137–138.
[165] 5 Sep. 1803, Ibid. 3:151.
[166] The motion seconded by Cavendish requested the Royal Society to inform the Royal Institution of those papers read at its meetings that were suitable for the Royal Institution's journal. It also required that an earlier resolution of 31 March 1800 be communicated to the Royal Society concerning the duty of the scientific committee to commu-

Cavendish took in the lectures at the Institution beyond what was required of him as a member of the standing committee. Among his papers is a letter from Thomas Young asking his opinion on a question about gearwork for his syllabus, and in his lectures Young gave an explanation of halos around the Sun that Cavendish had suggested to him.[167] Cavendish took considerable interest in the scientific research in the laboratory, over which he, Banks, and Hatchett had charge.[168] Through the last year of his life Cavendish followed Davy's experiments.[169]

In addition to his concern with the practical applications of heat, Rumford had an active interest in the science of heat, which he made his specialty. In the arsenal in Munich, he observed the heat generated in boring cannon, which suggested to him an experiment on the heat of friction. He forced a dull steel boring tool against a slowly rotating metal cylinder immersed in about sixty pounds of water, raising its temperature from 60° to the boiling point in about three hours. The heat seemed inexhaustible to Thompson, who concluded that on the basis of his experiment with friction, heat "cannot possibly be a *material substance*," and that it is impossible to imagine it as anything "except it be MOTION." He published his cannon-boring experiment in 1798. The following year he published an experimental investigation into the supposed weight of heat, arriving at the same conclusion: if heat were a substance it would have to be "so infinitely rare [...] as to baffle all our attempts to discover its gravity," whereas if heat were the "intestine vibratory motion of the constituent parts of bodies" it would not affect their gravity.[170] From the point of view of the Royal Institution, Rumford's understanding of heat was fortunate. When a tract on heat and light by Davy[171] came to his notice, he recognized in it ideas on heat similar to his own.[172] Garnett, who had studied under Black at Edinburgh University, gave a full account of Black's theory of "latent heats" in his lectures at the Royal Institution. Throughout his lectures, he used the word "caloric," which he understood to be independent of the cause of heat, but he spoke of it as being "combined" with ordinary matter, suggesting a material theory of heat. Rumford and Garnett had a falling out over another issue, but Rumford may have been dissatisfied with the contents of Garnett lectures as well.[173] Thomas Young, Garnett's replacement,

nicate discoveries to the Royal Society. 5 Apr. 1802, Minutes of the Meetings of the Managers, Royal Institution 2:260.

167 Thomas Young to Henry Cavendish, 3 Sep. 1801, enclosed in a paper, "On the Shape of the Teeth in Rack Work"; in Jungnickel and McCormmach (1999, 725). Young acknowledged Cavendish for the demonstration. Thomas Young (1802, paragraph 179; 1807, 2:308). Joseph Larmor's comment in Cavendish, *Sci. Pap.* 2:410.

168 Vernon (1963, 27).

169 John Davy (1836, 222).

170 Benjamin Thompson, Count Rumford (1798); in Thompson (1870–1875, 1:490); Thompson (1799); ibid. 2:14.

171 Davy was working in Thomas Beddoes's Pneumatic Institution at the time. Beddoes included Davy's "Essay on Heat, Light, and on the Combinations of Light" in his collection *Contributions to Physical and Medical Knowledge, Principally from the West of England* (Bristol, 1799), 3–147. David M. Knight (1971, 599).

172 George E. Ellis (1871, 486).

173 Garnett took up heat in his chemical lectures rather than in his lectures on natural philosophy. He accepted the new chemistry of Lavoisier's together with the new nomenclature: the phlogiston theory, he said, involved its supporters in "continual absurdities, and "the ancient language of chemistry was "very barbarous," "conveying false ideas." Following the new nomenclature, he called heat "caloric," whether it is an imponderable fluid or motion, but as a former student of Black's he talked about caloric in the way Black talked about heat, as if it were a fluid. When a quantity of heat becomes latent, it "becomes absorbed." Bodies become elastic fluids through their "combination" with caloric. Caloric occurs either in a "combined or free state." *Outlines of a Course of Lectures on Chemistry: Delivered at the Royal Institution of Great Britain, 1801* (1801a, 16, 36, 39, 45, 60, 66). He published at the same time *Outlines of a Course of Lectures on Natural and Experimental Philosophy, Delivered at the Royal Institution of Great Britain, 1801* (1801b). On his studies at Edinburgh, "The Life of the Author" (1804, vi–vii).

held a view of heat similar to Rumford's. For a time in the Royal Institution, there was a concentration of advocates of a minority opinion on the nature of heat: Rumford at the head of the Institution, Davy the experimenter and lecturer, Young the lecturer, and the natural philosopher of Rumford's inner circle, Cavendish. It is worth noting that near the end of his life, Cavendish was in the company of scientific investigators who broadly agreed with him on the nature of heat.[174]

When Davy arrived at the Royal Institution in 1801, he was received by Rumford, Cavendish, and Banks, who promised him any apparatus he wanted for his experiments.[175] When Cavendish died, his proprietorship in the Institution was inherited by his heir Lord George Cavendish, from whom Davy obtained some of Cavendish's chemical apparatus. Five months after Cavendish's death, Davy received permission from the managers to bring the apparatus into the Royal Institution for use in experiments and lectures.[176]

At the beginning, Rumford published a prospectus, explaining the need for the Royal Institution. For men of science, he wrote, a discovery was its own reward. Detached from the "ordinary pursuits of life, they lacked the "proper "moral and intellectual habits" to "descend from the sublime general theories of science and enter into the detail of weight, measure, price, quality," the practical side. The Royal Institution existed to close the gap between science and industry. Rumford's biographer says that he was unique in his "insight into the importance for society of the development of technology," and that an opportunity was lost when the Royal Institution did not become a school of mechanics,[177] though as it happened, neither the men of science nor the manufacturers were much interested in Rumford's idea. What Cavendish thought of it is unknown. We know that Rumford valued his active participation in the early years, and from what we know about his interest in industry from his journeys in the 1780s, he may have had some sympathy for Rumford's idea for the Institution, but his natural interest lay with the scientific research carried out there. In any case, the Royal Institution became a productive scientific research laboratory.

The Royal Institution benefited from Cavendish's services, and in return it enriched his life. In his last decade, through his activities at the Royal Institution, he was associated with several of the most talented physical scientists in the country: Rumford, Young, Davy, and Dalton. He did not live quite long enough to see the arrival of the greatest of the scientists to work in the Royal Institution, Michael Faraday.[178]

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[174] G.N. Cantor has noted the agreement on heat between Rumford, Davy, and Young, in "Thomas Young's Lectures at the Royal Institution," (1970, 90). In contrast to Garnett's implied preference for the fluid theory, Young in his lectures at the Royal Institution reasoned by an analogy with the vibrations of sound that heat is the vibrations of the parts of bodies. Young, *Course of Lectures on Natural Philosophy* 1:148–149, 656. Davy wrote in 1799, "It has then been experimentally demonstrated that caloric, or the matter of heat, does not exist" and that heat is a "peculiar motion, probably a vibration, of the corpuscles of bodies." (1839–1840, 2:13–14). Davy and Young included in their lectures the new understanding of radiant heat. With praise for Rumford's experiments, Davy explained that vibrating particles of bodies give rise to vibrations in the ether, which in turn communicate vibrations to particles of bodies. Humphry Davy (1802, 50–54).

[175] Humphry Davy to Davies Gilbert, 8 Mar. 1801, in John Ayrton Paris (1831, 78).

[176] Royal Institution of Great Britain, *Minutes of Managers' Meetings 1799–1900* 5:47, 62, 126, 160.

[177] Sparrow (1964, 110, 117).

[178] Three years after Cavendish's death, in 1813, Davy received from Faraday a copy of the notes he took of Davy's lectures at the Royal Institution, the beginning of Faraday's long association with the Institution.

Institute of France

While Rumford was still head of the Royal Institution, in late 1801 he wrote to Banks from Paris to inform him confidentially that he, Banks, headed the list of ten foreigners put up by the class of mathematics and physics of the Institute, the successor to the Royal Academy of Sciences.[179] Each of the several classes of the Institute proposed candidates for foreign membership to be balloted on at a general meeting, the number to be admitted fixed at twenty-four. Interested parties ranked candidates much like racehorses.[180]

Rumford reported that after Banks came Maskelyne, Cavendish, Herschel, Priestley, Pyotr Simon Pallas, Alessandra Volta, and three others, in that order. Rumford was himself proposed but in another class. Blagden, who also was in Paris, kept Banks closely posted on the rapidly evolving, rather undignified scene. Not himself a candidate, Blagden joined in the frenzied lobbying for persons who were. He pressed Cavendish's claim with the scientists he knew in the Institute, fully expecting him to be the first elected after the Institute had fulfilled its duty of electing the former foreign associates from the defunct Royal Academy.[181] His next letter was less certain. Pallas and Cavendish were tied on the first ballot, and on the second Pallas came up one vote ahead, not because the "people here are so ignorant as to think him superior to Cavendish," but because Pallas was a former associate of the Academy. Volta, whose high reputation was "here, perhaps a little exaggerated," Martin Heinrich Klaproth "deservedly," and Watt were very much in the running. Cavendish might be chosen at the next election, and although there was "no certainty" of that, very much in his favor was the opinion of the First Consul Napoleon, who took the opportunity of "expressing how much he esteems Mr. Cavendish."[182] In his next report, Blagden said that at the coming election, the mathematics and physics class intended to present, first, Cavendish, then Watt, "who ran him pretty hard," and third Paolo Mascagni, Volta being out of the running.[183] This time Blagden was proven right; Cavendish was elected.[184] The Institute listed the foreign members according to their merits in science: Banks was first, Maskelyne because of his lunar tables for determining longitude next, and then Cavendish.[185]

Wealth

After Cavendish's death, reports of his wealth appeared in various publications. Georges Cuvier, secretary of the physical sciences department of the reconstituted Academy of Sciences, wrote in his éloge of Cavendish that an uncle of his who had fought in a war in India formed an attachment to Cavendish and left him the entire great fortune he brought home with him. Cuvier said that when Cavendish died, he left behind £1,200,000,[186] which was high but not far off. The following year the French physicist Biot provided more detail. In

[179]The Royal Academy of Sciences, founded in 1699, was abolished together with all academies in 1793. In 1795, the National Institute of Sciences and Arts was established, which brought together the old academies. The Institute of France was established in 1796, containing the Academy of Sciences, no longer "Royal."
[180]Benjamin Thompson to Joseph Banks, 22 Nov. 1801, BL Add Mss 8099.
[181]Charles Blagden to Joseph Banks, 19 June 1802, BM(NH), DTC 3:170–174.
[182]Charles Blagden to Joseph Banks, 15 Oct. 1802, BL Add Mss 33272, pp. 204–205.
[183]Charles Blagden to Joseph Banks, 26 Nov. and 6 Dec. 1802, ibid., pp. 210–213.
[184]Charles Blagden to Joseph Banks, 29 Jan. 1803, Fitzwilliam Museum Library, Perceval H205.
[185]Charles Blagden to Joseph Banks, 1 Feb. 1803, ibid., H206.
[186]Georges Cuvier (1961, 237).

a biographical sketch of Cavendish for an encyclopedia, he wrote that the uncle returned in 1773, when upon seeing that Cavendish was poorly treated by his family left all of his fortune to him, more than £300,000.[187] The uncle from India, the year 1773, and £1,200,000 became facts of Cavendish's life, as it was picked up in biographical works,[188] though an English biographical dictionary added £100,000 to his wealth, £1,300,000.[189] Thomas Thomson, who was the source of the latter figure, said correctly that Cavendish was left a "very considerable fortune" by his father. He also said that "an aunt who died at a later period bequeathed him a very handsome addition to it." He was right about there being an aunt, but she died four years before Lord Charles, to whom she left her considerable fortune. It came to Henry Cavendish by inheritance through the personal estate of his father. Thomson said correctly that because Cavendish did not spend all his yearly income, it steadily accumulated, leaving him very rich at the end.[190]

Wilson regarded the subject of wealth as being important in Cavendish's life, and he gave it appropriate attention. He placed most credence on Cuvier's account supposing that he got some of his information from Blagden.[191] He was right, as we know because Cuvier asked Mme. D. Gautier to thank Blagden for the details about Cavendish he sent him. When Blagden saw Cuvier's éloge, he wrote back that he approved what it said about Cavendish's merits, but that it "contains many inaccuracies taken from a paper published some years before in France under the name of Mr. Biot. Mr. Cavendish's fortune did not come to him in the manner there asserted, but he inherited it regularly from his father."[192] What is indisputable is that both Cuvier and Biot got the source of Cavendish's fortune wrong.

Wilson said that he was unable to discover the overseas general, or learn whether it was an uncle or an aunt who left Cavendish a fortune. He thought that this was not of great significance, but the date when Cavendish acquired the fortune was important because it was then that Cavendish acquired financial independence. According to Biot, Cavendish was forty when he became independent. Wilson put an upper date on it in the belief that Cavendish settled an annuity of £500 on Blagden in 1782 or 1783, when he was fifty-one or fifty-two, implying that he had to be well off by then to afford it.[193] Wilson was right about the time.

The wealth of Charles and then of Henry Cavendish had three sources: the family settlements and legacies, without which there would have been no wealth; financial prudence; and the public debt of the kingdom. In addition to the three revolutions we have discussed, scientific, political, and industrial, Charles and Henry Cavendish were beneficiaries of a fourth "revolution," this one commercial. One of the outcomes of the Revolution of 1688–89 was a change in the relationship between business and government. In the past, most government

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187 J.B. Biot (1813, 233).

188 "Cavendish (Henri)," in Arnault (1827, col. 294). "Cavendish (Henri)," in Hoefer (1855, 294). "Cavendish, Henry," in J.C. Poggendorff (1863, 1:406).

189 John Aikin and William Johnston (1814, 283–285).

190 Thomas Thomson (1830–1831, 1:336–337).

191 Wilson (1851, 159).

192 D. Gautier to Charles Blagden, 30 Apr. 1811; Charles Blagden to D. Gautier, 20 Apr. 1812, Blagden Letters, Royal Society, G11, G11a. There would seem to be a problem with what Blagden says. Cuvier's publication is dated 1812, and Biot's publication above appears in a volume of the encyclopedia for the year 1813. On the face of it, Cuvier could not have copied Biot. However, Blagden's letter pointing out Biot's errors was written in 1812, the year before the volume of the encyclopedia. In it Blagden does not refer to an encyclopedia but to a "paper" published by Biot several years before. This paper I am unfamiliar with.

193 Wilson (1851, 160).

borrowing had been on the king's word, which events had proven untrustworthy. Parliament took over the responsibility for guaranteeing loans in 1693, from which time a "public debt" can properly be spoken of. The public had sufficient confidence in the financial stability of the country to deposit its money in the Bank of England, which was designated to handle the public debt in part, and to buy shares in it, known as the "funds." Because good land was becoming scarce, public loans appealed as an alternative source of income, with several to choose from. An enormous loan was offered by the South Sea Company and a smaller one by the East India Company, and a substantial loan was offered by the Bank of England, which also issued a group of annuities. The latter contained so-called perpetual annuities, or annuities requiring the government to pay a fixed rate of return in perpetuity. Over the course of the century, most of the public debt, and most of our Cavendishes' wealth, came to be held in annuities of this kind.[194] (Fig. 17.11).

Figure 17.11: Great Hall of the Bank of England. By Thomas Rowlandson, 1808. Wikimedia Commons.

The perpetual annuities owned by the Cavendishes were controlled by a new policy introduced in 1751. The outstanding loans paying 3%, some through the Bank of England and some through the exchequer, were consolidated into a single fund, which was named the "3% Consolidated Annuities," or "consols" for short. Other annuities paying more than 3% were united in another fund now paying only 3%, which were named "3% Reduced Annuities." Both of these funds were managed by the Bank of England, which paid out interest, or "dividends." The dividends were paid twice yearly; in other words, 3% annuities paid 6% annually. On stated days the dividends were drawn and signed for; if the owner of

[194] Alice Clare Carter (1968, 2–9). John Carswell (1993, 8, 12, 18–20).

the stock was not present, the dividends were deposited through power of attorney with the Bank or the trading companies.[195]

Most of the owners of Bank of England stock lived in and around London. They were a varied lot, with many migrants, Huguenots and Spanish and Portuguese Jews, a good many gentry, gentleman, and peers, especially dowagers and ladies, corporate bodies such as Cambridge colleges, and increasingly spinsters and widows. Investors usually bought stock and kept it, withdrawing only dividends or else reinvesting them. Most of the stock was held by a very few persons, who included Henry Cavendish.

To the world, Cavendish's great wealth has proven nearly as intriguing as his discoveries, as is evident from Biot's French encyclopedia article: Cavendish was "the richest of the wise and the wisest of the rich."[196] The article on Cavendish in the *Encyclopaedia Britannica* says that he was "indeed not less famed in his country for the great accumulation of his property than for his intellectual and scientific treasure."[197] The interest in the subject and the erroneous statements about it justify a closer look at Cavendish's wealth.

Before his father's account was transferred to him, Henry Cavendish had stocks in his own name worth £17,388:[198]

- October 1776. New South Sea Annuities. £1100.
- 14 December 1781. Reduced 3% Annuities. £14,500.
- 23 August 1783. New South Sea Annuities. £872.
- 25 August 1783. South Sea Old Annuities. £916.

Henry Cavendish inherited from his father in 1783 the following funds:

- Bank Stock. £25,815.
- New South Sea Annuities. £48,900.
- Reduced 3% Annuities. £18,285.
- Consolidated 3% Annuities. £62,100.
- Old South Sea Annuities. £6000.

The total comes to £161,100 in funds from his father. On the last day of 1783, through his father, he inherited his aunt Elizabeth Cavendish's funds worth £97,100:[199]

- Reduced 3% Annuities. £22,100.
- Consolidated 3% Annuities. £75,000.

Adding the above amounts gives Cavendish's wealth in funds in 1784 as £275,588. At age fifty-three he was moderately rich. He lived another twenty-five years, over which time his wealth quadrupled, so that at the end he was very rich. We can see how this happened by looking at the growth of several of his funds.

[195] Eugen von Philippovich (1911, 135). John Clapham (1945, 1:77, 97–98). Carter (1968, 10).

[196] In literal translation, Biot's epigram is wordier: Cavendish was "the richest of all the learned and probably also the most learned of all the rich." Biot (1813, 273).

[197] "Cavendish, Henry," *Encyclopaedia Britannica*, 9th ed., vol. 5 (New York, 1878), 271–272, on 271.

[198] He had no money in Consolidated 3% Annuities and Bank Stock. It is possible that he had a small investment in other issues.

[199] The Elizabeth Cavendish inheritance of stocks and mortgages was legally transferred to Henry Cavendish after his father's death. Lord Camden who was named with Lord Charles executor of Elizabeth Cavendish's will agreed to transfer to Henry Cavendish the £75,000 in 3% annuities and the £22,100 in reduced annuities together with mortgages worth just under £50,000. "Lord Camden and the Honourable Henry Cavendish. Assignment and Deed of Indemnity, 31 Dec. 1783, Devon. Coll., 88/66.

Bank Stock. Lord Charles had £25,815 in Bank Stock.[200] Cavendish did not touch this fund, which at his death was worth £71,120. At that time, it represented about $8\frac{1}{3}$% of the value of his funds.

Reduced 3% Annuities. In October 1783, Cavendish received £18,285 from his father's estate, which he added to his own holdings, £14,500. In January, he received £22,100 from Elizabeth Cavendish's estate. Between 16 January 1782 and 5 [?] 1783, he sold £8500 of this, leaving £58,385 in his account.[201] The value of the fund on several dates gives a picture of its growth:

- 5 April 1785. £58,385.
- 13 June 1788. £86,000.[202]
- 2 November 1791. £115,000.[203]
- 5 April 1801. £216,504.[204]
- 5 July 1805. £281,528.[205]
- 5 April 1807. £347,809.[206]
- 1810, at his death. £433,852.[207]

Consolidated 3% Annuities. In 1782, Lord Charles held £47,100 of this stock. On 3 September of that year, he added £7000, and on 3 December, £8000, giving a total at the beginning of 1783 of £62,100.[208] The value of Henry Cavendish's account in this stock was:

- 22 October 1783. £62,100. From Lord Charles.
- 7 January 1784. £137,100. The increase came from Elizabeth Cavendish, £50,000, and her husband Richard Chandler Cavendish, £25,000.[209]
- 15 August 1786. £145,000.[210]
- 2 November 1791. £172,600.[211]
- 17 November 1796. £240,739.[212]
- 12 April 1802. £322,857.[213]
- 9 September 1808. £505,000.[214]

The last figure was the value of this fund when Cavendish died. He never sold any of this stock.

New South Sea Annuities. At his death, Lord Charles had £48,900 in this fund.[215] From October 1776, Cavendish had £1100 in it. On 23 August 1783, £872 was deposited by the

200 Bank Stock 1783–1798, Bank of England Archive, No. 59, p. 389.
201 Reduced 3% Annuities, Bank of England Archive, Supplement Ledger 1781–1785, p. 10614.
202 Ibid., Ledger 1785–1793, p. 1505.
203 Ibid., p. 2242.
204 Ibid., Ledger 1793–1801, p. 1727.
205 Ibid., Ledger 1801–1807, p. 1801.
206 Ibid., p. 1937.
207 Ibid., Ledger 1807–1818, pp. 4449–4450.
208 Consolidated £ 3%, Bank of England Archive, 1782–1788, p. 3854.
209 Ibid., p. 3927.
210 Ibid.
211 Ibid., 1788–1792, p. 8000.
212 Ibid., 1792–1798, p. 8730.
213 Ibid., 1799–1804 (part 1), p. 8001.
214 Ibid., 1804–1812, p. 8001.
215 New South Sea Annuities, Bank of England Archive, 1776–1793, vol. 154, p. 65.

earl of Hardwicke, a relative on his mother's side. By 5 July 1793, the value of his account had increased to £59,255, where it remained to the end of his life.

As in other ways, in matters of finance Cavendish followed his father's course, investing in gilt-edged securities and almost never touching them. Shortly before his father's death, when he was establishing an independent life and considering buying properties, he sold a small part of his securities, receiving £8500 for them, but that was the exception. During the Napoleonic Wars, the government offered a higher return on loans and very substantial bonuses as a percentage on capital on top of the half yearly dividends,[216] but we see that throughout the time after his father's death Cavendish's account rose fairly steadily.

On the day Cavendish died, 24 February 1810, his personal property was worth the following:

1. Stocks. He owned shares in ten funds. On face value, they were worth £1,080,681. Their market value at that date was £821,050. Three quarters of the value were in two stocks, Reduced 3% Annuities and Consolidated 3% Annuities.
2. Funds held in trust. All of these stocks and annuities stand in the names of Cavendish's first cousins the earl of Hardwicke, Lord George Augustus Cavendish, and Lord Frederick Cavendish. There were five funds, with face value £21,755 and actual value £17,832. Most of the value was in one fund, Old South Sea Annuities.
3. Mortgages. He had three mortgages, worth £48,000.
4. Balance in banker's hands. £11,373.[217]

Apart from his funds, Cavendish's wealth at the end of his life consisted of his land and his houses at Clapham Common and Bedford Square together with their contents, and probably other property.[218]

Cavendish's worth was in line with great fortunes in the eighteenth century. Lady Bute was said to have inherited around £800,000 in 1761 from her father, E. Wortley Montague. Lord Bath was said to have left £1,200,000 at his death in 1764. Sir Samuel Fludyer was said to be worth £900,000 in 1767.[219]

In his biography of Cavendish, Wilson gives an account of an exchange between Cavendish and his banker. The banker called on Cavendish unannounced, and Cavendish's displeasure at the interruption is the point of the story. However, the beginning of the story is relevant here: "The bankers where he kept his accounts, in looking over their affairs, found he had a considerable sum in their hands, some say nearly eighty thousand pounds, and one of them said, that he did not think it right that it should lay so without investment."[220] The

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216 Clapham (1945, 2:39–40, 46).

217 "The Personal Property of the Hon. Henry Cavendish 24 February 1810," Devon. Coll., 114/74. The evaluation was from Mess^{rs} Snow & Co. The family obituary gave different figures for Cavendish's wealth: Cavendish "died worth 1,175,000*l* in different public funds, the value of which is estimated at 700,000*l*." This information was given to Wilson by a member of the family. Wilson quotes the above sentence, except that two digits are reversed: 1,157,000*l*. Wilson (1851, 176). The family obituary says that "50,000*l*, also were in the hands of his bankers," and Wilson repeats this. The discrepancy between the family's account of Cavendish's worth and what the bank documents say may have to do with the lapse between Cavendish's death and the time his funds were distributed to his heirs. The discrepancy in any case is not large, and the point is made that Cavendish had a great deal of money invested in funds at the time of his death.

218 The family obituary says that at his death Cavendish had "freehold property about 8,000*l*. a year and canal and other personal property." Wilson quotes from the obituary (1851, 176).

219 L.B. Namier (1929, 164).

220 Wilson (1851, 175).

banker who called recommended investing £40,000, and Cavendish agreed. The amounts, £40,000 and £80,000, are plausible, as we see from receipts for purchases of funds. Cavendish was accustomed to buying additional stock in the same funds every year, but sometimes a large balance accumulated. The year 1788 is an example. On 13 June, he bought £18,000 of Reduced 3% Annuities, and on 7 July he bought £17,000 of Consolidated 3% Annuities, a total of £35,000. (He paid £13,500 and £12,580.) In 1791, he bought £35,000 of these same two funds. In 1805, he bought £51,000 of the same. In 1808, he bought £45,000 of Consolidated 3% Annuities.[221]

The story about the banker could give the wrong idea about Cavendish's management of his wealth. Take 1793, for example. At Chatsworth, there is a bundle of receipts for purchases in March and April. The first of these reads:

- Messrs Denne & Co. 25 March 1793. Please to layout the sum of twenty-six thousand pounds in the purchase of four different stocks as under & charge to my account. H. Cavendish
- Old South Sea £26,000
- New South
- Cons.: & Red.

Cavendish's order produced the following transactions. On 26 March, he bought £8400 of Consolidated 3% Annuities and £4000 of New South Sea Annuities. On 30 March, he bought £4383 of New South Sea Annuities. On 20 April, he bought £8333 of Reduced 3% Annuities and £5000 of Old South Sea Annuities. On 24 April, he bought £2000 of the same. On 26 April, he bought £1370 of Reduced 3% Annuities. The total came to £33,486. Cavendish paid the actual value, which was below par, plus commission, £25,965, which is just under the £26,000 Cavendish specified.[222] After receiving a purchase order like this from Cavendish, Robert Snow, his main contact with his banker Messrs. Denne & Co., would write to him, "Agreeable to your order of the [date], we yesterday purchased [the amounts and the funds]…," closing with, "This sum is as near the order as possible to keep the stock in even sums." Cavendish's directions were straightforward and consistent; his dividends were reinvested alternately in four securities: new and old South Sea annuities and consols and reduced 3% annuities, primarily in the latter two.[223] His farm and other rents went directly to his bankers, and his business was transacted through them. He had enough wealth that he did not have to spend much time with it, an ideal life which he did not want disturbed by house calls from his bankers.

As Biot said, Cavendish was the richest of the wise, and insofar as his investments were concerned, he was at least one of the wiser of the rich; over the long run, during the years in which he amassed his fortune, he could hardly have managed his inheritance better than to reinvest its earnings in consols and reduced 3% annuities, especially since he was a man who had other things to do with his days than to spend them in his counting house.

[221] Bundle of receipts for purchases of annuities, Devon. Coll., 86/comp. 3.
[222] "1790–1816. Accs. & Receipts. Case & Opinions," ibid.
[223] Correspondence from Cavendish's bankers, ibid.

Religion

From what Wilson was able to learn from persons who had known him, Cavendish "separated himself… apparently from God." The qualification "apparently" would seem to have referred to Everard Home's account of Cavendish on his deathbed: "Cavendish sent his servant out of the house, 'ordering him not to come near him till night, as he had something particular to engage his thoughts, and did not wish to be disturbed by any one!'" Wilson said that he "would willingly believe that the 'something particular,' which he told his servant was to engage the undisturbed attention of his last, and solemn, silent hours, was his preparation for the unseen world into which he knew he was about to pass."[224] Being a deeply religious man himself, Wilson wanted to believe that Cavendish saw the spiritual truth too. Let us consider the evidence for his belief.

In the one published comment on Cavendish's religious persuasion, Biot wrote that Cavendish was "religious in the manner of Locke and Newton." Wilson assumed that Biot had some authority on this point, but he considered his statement to be ambiguous. Because Cavendish showed none of the earnestness of Newton and Locke on the subject of religion, Biot would have had in mind religious doctrine not religious fervor, and as such his statement was ambiguous, since at the time Newton's position on the doctrine of the Trinity was uncertain. Wilson supposed that Biot intended to say that Cavendish's religious views resembled Newton's only in the sense that they were unorthodox, probably Arian or Unitarian. He was told that at Cavendish's college in Cambridge there was a kind of hereditary belief that he was a Unitarian, but he could find no foundation for it.[225]

In the last two decades of his life, as we have seen, Cavendish shared Clapham Common with evangelical members of the Church of England known as the Clapham Sect, who were distinguished for their spiritual intensity. They were troubled by what people did on Sundays, which they insisted should be dedicated to quiet devotion.[226] At a meeting in 1798, the inhabitants of Clapham parish agreed unanimously that in the interest of both the individual Christian and civil society, it was "highly improper, on that Day [Sunday], to exercise our worldly occupations, to travel, except in cases of urgency, or for purposes of benevolence, or to employ our domestics in any thing interfering with their public or private religious duties."[227] In this way, the evangelicals imposed on Clapham Common the quiet contemplation of the life to come, known later as the Victorian Sunday. There was a call for the prosecution of violators. Wilson noted that Cavendish's decisive experiment on the composition of water was done on a Sunday. We add that Cavendish performed the fifth part of his experiment on the density of the Earth on a Sunday in 1797. He treated Sunday like any other day of the week; he worked, doing what he always did. He had no known run-ins with his evangelical neighbors. After his death, his house had a brush with the movement; John Thornton, son of Samuel, a member of the Clapham Sect, lived in the house for a few years.

Wilson received a few comments on religion from his inquiries. A member of the Cavendish family heard his grandmother say that Cavendish once came to a christening, but he may only have stayed for dinner. A fellow of the Royal Society said that "as to

[224]Wilson (1851, 184–185).
[225]Biot (1813, 273). Wilson (1851, 180–181). Privately, Newton held a Unitarian view.
[226]R. de M. Rudolph (1927, 89).
[227]*Resolution Agreed to by the Inhabitants of Clapham for the Better Observance of the Lord's Day, 1798.*

Cavendish's religion, he was nothing at all." A neighbor of Cavendish's at Clapham believed that he "never attended a place of worship."[228] Other than to list a church as a landmark in taking bearings, his one known reference to a church occurred during a dinner of the Royal Society Club, when he said that some wood at Clapham Church was eaten "thro' by the insects… working their way out."[229] In the absence of any outward display of interest in religion on Cavendish's part, Wilson concluded "that the World to come did not engross his thoughts."

Newton wrote in the *Principia* that the discussion of God "does certainly belong to Natural Philosophy." In the previous edition of this biography, which I prepared with Christa Jungnickel, we said correctly that Cavendish did not record any thoughts on religion in his writings on natural philosophy. We did not mention in this connection Cavendish's contribution to the University of Cambridge's volume of lamentations in Latin in honor of the crown prince Frederick, to which I now give more weight. It was Cavendish's first publication, and because it is his only publication on a subject other than science, it holds an interest for us. The poem follows form for memorials of this kind, but it is also revealing of its author. Cavendish writes that by understanding nature we can understand the occasion of the lament, the prince's death. Nature has nothing to do with human comforts and desires. Libitina, goddess of death, "spares no beauty, no youth, no faith," but to the "intimate" of nature, by which I take him to mean the student of nature, "natural truth" is disclosed, and what is disclosed is the destination of the royal prince, "a dweller in heaven."[230] Cavendish may have had in mind natural religion or a version of religion close to it, certainly a religion without the notion of a personal God, though one that seemed to promise an afterlife. Cavendish was only eighteen when his poem was published, and as he matured his thoughts on religion may have changed, or never returned. He may have rejected religion altogether, an impression he gave the world, or he may have rejected only its social forms. Because after his youthful poem, he wrote nothing again on the subject, we cannot know his subsequent religious leanings, if he had any.

The End

The later years of Cavendish's life were ones of peril for the nation. He met with men of science as always, at the Royal Society, at his clubs, and at Banks's house, but the talk was now often more about politics, impending war, and battles than about science. In the year Cavendish weighed the world, the Council of the Society put to the ballot a motion to pay £500 to the Bank of England "as a voluntary contribution towards the defense of the country at this critical period.[231] Blagden's diary, a main source of information about Cavendish's comings and goings during these years, is mainly concerned with the general agitation, when it is not about his private agitation over Madam Lavoisier or his difficulty in getting a passport to return to France. There is little about science. Even Cavendish was caught up in the events of the world at large. At the Royal Society, he said "that if Pitt came in against K[ing]'s inclinations, the K. if quite well, wod soon find the means of getting him

[228] From Lord Burlington, in Wilson (1851, 181).
[229] 19 Feb. 1807, Charles Blagden Diary, Royal Society 5:39.
[230] Henry Cavendish (1751).
[231] 22 Feb. 1798, Minutes of Council, Royal Society 7:353.

out again"; to Blagden's observation that North Germany was then quiet, Cavendish "still thought Holstein wod be attacked at some moment."[232]

Toward the end of his life, as at any time during it, what was most conspicuous about Cavendish was his steadfast desire to learn more about and to practice science. When Blagden was given a paper by Herschel to look over, he knew Cavendish was the "best person" to read it,[233] and this was one year before Cavendish died. Two months before he died, Cavendish told Blagden that he had "doubts about some part of Malus's paper, & did not know if [he] understood it."[234] The French physicist Étienne Louis Malus had just begun publishing his important work on optics, and Cavendish was following it. In the last year of his life, Cavendish saw much of Davy. At one point Davy thought he had converted azote (nitrogen) into oxygen, an extraordinary finding if true. Blagden reported that "Mr.Cavendish has gone thro' the experiment with him [Davy], & detects no source of fallacy"; he was "quite satisfied that the gases convertible," seeing "no way of explaining Davy's expt but by conversion of nitrogen."[235] Cavendish was actively following and in this case aiding in Davy's researches in chemistry. As late as 1806, he was still doing experiments of his own in chemistry, undertaking a long series on platina that year.[236]

In their few surviving letters, Henry and his brother Frederick addressed one another as "Dear Brother," and Frederick closed his letters with "your affectionate brother." Henry was "alarmed" upon hearing on good authority that Frederick was ill, but Frederick reassured him that he had never felt better other than for the gout that cramped his handwriting, keeping occupied "as usual visiting my friends or riding out most days."[237] Frederick lived in Market Street, as he had from about age forty, first in the home of a clergyman, then in a small house and later in a larger house of his own, attended by two "confidential domestics." This was a quiet village in Hertfordshire, just across the border from Bedfordshire, near the Benedictine Monastery of St. Albans, and there is a brief letter from Henry to Frederick setting a time to meet with him at "St Albans."[238] Frederick spent much of his time visiting in the neighborhood, where he was regarded as a harmless eccentric. He was a skillful drawer of leaves and other natural objects and fond of displaying his portfolios, which he intended to leave to the British Museum (he did not). He had a large library of classics in literature, which he read and remembered, reciting poetry with such accuracy that he was called a "living edition." His preferences among the modern poets, such as Thomson, Akenside, and Mason, were thought to be influenced by their politics. Extremely proud of his family, he often quoted the epitaph of the first duke of Devonshire, friend of good princes and enemy of tyrants. With his bag wig, cocked hat, and deep ruffles, Frederick in his later years was a quaint relic. Whig, bookish, unfashionable, unmarried, without a profession, proud of his family name, in several respects Frederick resembled his brother Henry. In other respects he differed; he was drawn to literature and art instead of to science, and to society rather than to solitude, having a "very social disposition."[239]

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[232] 26 Mar. 1804, Charles Blagden Diary, Royal Society 5:214.
[233] 16 Feb. 1809, ibid. 5:286.
[234] 3 Dec. 1809, ibid. 5:396(back).
[235] Charles Blagden to Richard Chenevix, 1 May 1809, draft, Blagden Letters, Royal Society, C.35.
[236] In January 1806, for example: "White Book No. 1," 68.
[237] Henry Cavendish to Frederick Cavendish, n.d., draft; Frederick Cavendish to Henry Cavendish, 10 Sep. 1809; in Russell McCormmach (2014, 260).
[238] Henry Cavendish to Frederick Cavendish, n.d. [1784], draft, Cavendish Mss, Misc.
[239] "Memoirs of the Late Frederick Cavendish, Esquire," *Gentleman's Magazine* 82 (1812): 289–291.

Frederick was known to be a soft touch. One of his last letters to Henry is about a young married man who was just getting started and needed £150 to pay off his upholsterer's bill. Frederick asked Henry for this amount, since he did not have it, "confident [it] will do a great deal of good."[240] Henry obliged him. When Frederick exceeded his modest income, he asked Henry for money.[241] He needed help with his taxes, which were then, as ever, baffling. Henry was sympathetic: "the printed forms sent both by the commissioners of Income & assessed taxes are intricate & not clearly expressed."[242] On his side, Frederick was mindful of his brother's interests: "As I believe you attend a good deal to the observation of the barometer," he sent Henry a careful account of his reading of the barometer that morning. Frederick was two years younger than Henry, and he outlived him by two years. The life span in this branch of the Cavendishes was long and remarkably constant: the three of them, Charles, Henry, and Frederick, lived to the age of seventy-eight and seventy-nine.

Up to the end Henry Cavendish was vigorous, physically and mentally. His physician was John Hunter, whom we hear of in that capacity for the first time in 1792, when Cavendish was sixty. Blagden went to Clapham Common only to be told that Cavendish was ill. He responded with sympathy (and perhaps hurt): "If you had chosen that I should wait upon you, I cannot doubt but you would have sent to me."[243] That same day upon learning that Cavendish was being seen by Dr. Hunter, he wrote again to Cavendish to say that he "could not do better" and to ask only if he could visit him "as a friend."[244] Blagden told Banks the next day that he was "engaged to be with Mr. Cavendish (who is much indisposed) at Clapham."[245] We know what was wrong with Cavendish from another friend, Alexander Dalrymple, who sent a sympathy note to him together with a folk remedy: he was "very sorry yesterday to hear that You were prevented from coming amongst us by an attack of the Gravel."[246] Gravel, a common complaint then, meant painful or difficult urination possibly caused by a deposit of urinary crystals.

Because there was a famous contemporary surgeon and anatomist named John Hunter, we need to point out that Cavendish's doctor was not that John Hunter. He is not well known today, but at the time he was (Fig. 12.4). When he was proposed for membership in the Royal Society in 1785, his certificate was signed by twenty-five fellows,[247] which was the same number James Cook received ten years before in an extraordinary expression of support. Cavendish was one of the signers, along with Cavendish's colleagues, Dalrymple, Aubert, Heberden, Blagden, Nairne, Smeaton, Maskelyne, and others including the other John Hunter. Hunter, then a physician to the army, was according to his certificate "well versed in various branches of natural knowledge." A graduate of the University of Edinburgh, his writings on medicine show that he followed the teachings of William Cullen. His dissertation in 1775 was unusual because of its subject, anthropology, but just as he has been eclipsed by his namesake, his dissertation has been eclipsed by a better-known work on the

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240 Frederick Cavendish to Henry Cavendish, 5 and 12 Feb. 1810; in McCormmach (2014, 61).
241 Frederick Cavendish to Henry Cavendish, 9 Feb. 1810, ibid.
242 Frederick Cavendish to Henry Cavendish, 28 Oct. 1806; Henry Cavendish to Frederick Cavendish, n.d., draft, ibid., 259–260.
243 Charles Blagden to Henry Cavendish, 12 Mar. 1792, draft; in Jungnickel and McCormmach (1999, 689).
244 Charles Blagden to Henry Cavendish, 12 Mar. 1792, draft, ibid., 690.
245 Charles Blagden to Joseph Banks, 13 Mar. 1792, draft, Blagden Letters, Royal Society 7:626.
246 Alexander Dalrymple to Henry Cavendish, 16 Mar. 1792; in Jungnickel and McCormmach (1999, 691).
247 12 Jan. 1786, Certificates, Royal Society 5.

subject appearing in the same year by J.F. Blumenbach.[248] Hunter regarded humans as a species, circumscribed within limits by Divine Wisdom, and the differences among them as varieties; in this respect, humans were like plants, butterflies, and shell creatures, in which natural history took greater interest. He had no need for the Scriptural explanation of Cain as the father of the blacks, nor need for a Deity to explain differences in mental faculties. He looked instead to "natural causes" to explain differences in human color, stature, parts, and minds. One of the principal natural causes of such differences was "heat," which is where his path crossed Cavendish's.[249] Before Hunter set sail for Jamaica in 1780 to superintend military hospitals, Cavendish suggested that he observe the heat of springs and wells while he was there. His paper on the subject, appearing in the *Philosophical Transactions* for 1788, gave a full account of Cavendish's hypothesis: assuming that the heat of the Earth comes solely from the Sun, not from the Earth's interior, precise measurements of the temperature underground, where the temperature remains constant through the seasons, ought to provide the mean temperature of any climate; in this way a few observations of the heat of springs and wells could be as informative as "meteorological observations of several years."[250] Hunter included this discussion in his main publication, *Observations on the Diseases of the Army in Jamaica*.[251] Other publications of his appeared in medical journals, but the judgment on his work is that it did not live up to its early promise. When he died at the age of fifty-four, in 1809, the year before his famous patient Cavendish died, he had not published any new work in over ten years.[252]

From Blagden we learn of Cavendish's next illness. Cavendish came faithfully to Banks's open houses, so when he was absent one Sunday in 1804 Blagden made note of it.[253] A few days later Blagden was informed that Cavendish was ill.[254] This time he was attended by the physician Everard Home, who told Blagden that Cavendish had a rupture, nothing more serious; he would need a truss, that was all. Home was about the same age as Cavendish's previous physician Hunter, and had served at the same time as Hunter with the army in Jamaica; the two were well acquainted, both active members of a medical club founded in 1783 which met at Slaughter's Coffee House.[255] By the time Cavendish called on his services, Home was eminent both professionally and scientifically. He had succeeded the anatomist John Hunter as surgeon to St. George's, and he was known as a prolific writer on surgical and anatomical subjects. Cavendish would have met him at the Royal Society, where he repeatedly was chosen to give the Croonian lectures.[256] With Home, as with Hunter, Cavendish formed a scientific as well as a medical connection, performing an op-

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[248] Blumenbach's *De generis humani varietate nativa* was translated by T. Bendyshe and published together with a translation of Hunter's inaugural dissertation, *Disputatio inauguralis quaedam de Hominum varietatibus, et harum causis exponens* ...(Edinburgh, 1775) in *The Anthropological Treatises of Johann Friedrich Blumenbach* [...] *and the Inaugural Dissertation of John Hunter, MD On the Varieties of Man* (London, 1865).

[249] Hunter, On the Varieties of Man, 365–368, 378.

[250] John Hunter (1788, 53, 58, 65). Charles Blagden to William Farr, 21 Jan. 1788, draft, Blagden Letters, Royal Society 7:107.

[251] Hunter included the paper from the *Philosophical Transactions* as an appendix to the second edition of his *Observations on the Diseases of the Army in Jamaica* (1796). The first edition was in the same year as the paper, 1788.

[252] Lise Wilkinson (1982, 235–236).

[253] 12 Feb. 1804, Charles Blagden Diary, Royal Society 4:201.

[254] 16 Feb. 1804, ibid. 4:202(back).

[255] The Society for the Improvement of Medical and Chirurgical Knowledge, whose leading member was the "other" John Hunter. Wilkinson (1982, 234)

[256] William LeFanu (1972).

tical experiment on the cornea in response to a paper by Home.[257] Home would remain Cavendish's physician to the end.

When Cavendish had his rupture, Home told Blagden that the disorder began with a swelling of the legs: "as if old the first time," Blagden wrote in his diary that day.[258] Cavendish was ill on 16 and 17 February 1804, and Blagden went to see him on the 18th, on which day Cavendish made out his final will, though it seems he did not show it to Blagden.[259] Either Home or Blagden, or both, evidently had an insight. Cavendish was seventy-two, and he had an intimation of death. On a day when the Royal Society Club met in 1807, Blagden recorded in his diary, "Spoke to Cav. about parallax of fixed stars; it seemed as if he began to forget."[260] Cavendish was perhaps a bit forgetful, but after a meeting of the Council of the Royal Society in 1809, eight months before he died, Blagden wrote that he "looked in excellent health."[261]

Within natural philosophy, Cavendish's breadth of competence was impressive, but as a sensible and observant man, he recognized that he knew only some things well and that other persons knew other things well. He declined to advise Bristol on its sewage problem partly on the grounds that "physicians" knew more about health and "engineers" knew more about rivers than he did. Physicians, engineers, and the men of science came together in clubs and societies based upon what they knew better than other people. With one exception, Cavendish did not take part in them. The Society of Civil Engineers, centering on Cavendish's colleague John Smeaton, was founded in 1771 and reorganized in 1792; honorary or regular members included colleagues of Cavendish's such as Banks, Rumford, Hatchett, James Cockshutt, and Charles Greville, but not Cavendish himself. He was not a member of the patriotic Society for the Improvements of Naval Architecture, founded in 1791, which brought together practical men and certain men of science who were colleagues of Cavendish's such as Banks, Hatchett, Aubert, Maskelyne, and Hutton.[262] He did not belong to the Linnean Society, founded in 1788, nor would we have expected him to; but he did not belong to the Mineralogical Society, founded in 1799, or the Geological Society, founded in 1807, though mineralogy and geology were favorite subjects of his. Near the end of his life, a number of small, private chemical societies were founded in and around London: the London Chemical Society, announced in 1807 by Friedrich Accum, a chemistry teacher and briefly Davy's assistant at the Royal Institution; the Lambeth Chemical Society, launched around 1809; and the Society for the Improvement of Animal Chemistry begun in the same year.[263]

The Society for the Improvement of Animal Chemistry had a close connection with the Royal Society, as is clear from the founding resolution at a meeting of the Council of the Royal Society in April 1809. The new society was designated an "assistant society," in no

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[257] In 1795 Blagden sent Cavendish a paper by Home. Evidently the paper contained Home's account of what would have appeared in John Hunter's Croonian Lecture if he had not died before he could give it. Everard Home (1794). Hunter believed that the cornea can adjust itself by its own internal actions to focus the eye at different distances. Cavendish, assisted by Blagden, performed an experiment to detect changes in the convexity of the cornea accompanying changes in the focus, using a divided object-glass micrometer. Entries for 8, 11, and 16 Nov. 1795, Charles Blagden Diary, Royal Society 3:75(back), 76, and 77(back).

[258] 17 Feb. 1804, Charles Blagden Diary, Royal Society 4:202(back), 203.

[259] "Copy of the Will of Henry Cavendish Esq.," In "Account of the Executor of Henry Cavendish Esq. as to Money in the Funds," Devon. Coll., L/31/65.

[260] 4 June 1807, Charles Blagden Diary, Royal Society 5:76.

[261] 8 June 1809, ibid. 5:328(back).

[262] Gwendoline Averly (1989, 26–29).

[263] Gwendoline Averley (1986, 102, 108–109, 113).

sense in competition with the original. To underscore the continuity with the host society, and to add prestige to the new, at the same meeting the Council resolved "that Mr.Cavendish be requested to allow his name to be added to those of the members of this new society."[264] The meetings, which took the form of dinners and conversation every three months, were held alternately at the house of Cavendish's doctor, Home, and at the house of his collaborator, Hatchett. Other members included Davy, William Thomas Brande (who would succeed Davy as professor of chemistry at the Royal Institution), the physician William Babington (one of the founders of the Geological Society), and the physician Benjamin Collins Brodie (the outstanding pupil of Home's).[265] Later the Society turned into a dinner club, but at the beginning it was given to serious scientific discussion. In 1809, the year of its founding, the Society sponsored two papers printed in the *Philosophical Transactions*, one by Home and one by Brande, both electrochemical. Homes's paper continued the study of the electric eel or torpedo, Cavendish's subject; it is revealing of the change in science that Cavendish heard Home describe the torpedo as a "Voltaic battery" instead of Cavendish's battery of Leiden jars, the torpedo having become a problem addressed by a chemical society.[266]

If Cavendish came to the few meetings of the Society for the Improvement of Animal Chemistry before his death, he would have been an interested party to the discussions. He had given considerable thought to plant and animal substances in his study of putrefaction and fermentation in his first paper on pneumatic chemistry in 1766. In his study of the phlogistication of air in 1784, he based his preference for phlogiston theory over the new chemistry on the greater complexity of a living plant over a burnt one. His active interest in living things was directed to what they had in common with non-living things, such as the electricity of the torpedo. His young colleague James Lewis Macie offered him an appropriate problem: to determine the density of tabasheer, a rock-like substance found in the joints of tropical bamboo, which for the product of a plant had improbable properties (Fig. 17.8). Macie found it to be indestructible by fire, totally resistant to acids, and glass-like when fused with an alkali, concluding correctly that it was "siliceous earth." Tiny specimens of tabasheer were given to Cavendish, who took "great care" in weighing them in water.[267]

The Society for the Improvement of Animal Chemistry was the only specialized society Cavendish belonged to, and as an extension of the Royal Society, it was a special case, Cavendish being included as an honorary member on the initiative of the active members. His distance from specialized societies might be explained by his age, but he was vigorous; in 1805 Banks proposed to augment the Board of Longitude and to include Cavendish.[268] The most likely explanation is that specialized societies largely belonged to a different stage of science, emerging together with the professional identity of the scientific expert. Cavendish was content with the national scientific body, the Royal Society, which acknowledged specialized skills in the membership of its committees.

To the end Cavendish was fully active in the work of the Society, as shown by his agreement to superintend the construction of an apparatus for measuring the temperature at different depths of the sea. He did not have time to oversee the experiment.[269] He attended

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[264] 27 Apr. 1809, Minutes of Council, Royal Society 7:527–31.
[265] Benjamin Collins Brodie (1865, 88–92).
[266] Everard Home (1809, 386).
[267] James Lewis Macie (1791, 370, 384–385, 388).
[268] 23 Feb. 1805, Charles Blagden Diary, Royal Society 4:313.
[269] Joseph Banks to William Scoresby, Jr., 8 Sep. 1810, copy, Whitby Literary and Philosophical Society.

Council the last time on 21 December 1809, missing only one meeting, on 15 February 1810. Henry Cavendish died on 24 February 1810.

The several accounts of Cavendish's last days vary but agree in this particular: he was fully conscious and resigned to the imminent end. The account most at variance with the others was given by Home to John Barrow, who published it long after the event. It is also the most likely. When one of Cavendish's servants came to Home to say that Cavendish was dying, Home went directly to Clapham, finding Cavendish "rather surprised" to see him. His servant should not have bothered him, Cavendish said, since he was dying, and there was no point in prolonging the misery. Home stayed all night at Cavendish's bedside. Through it all Cavendish was calm, and shortly after dawn he died.[270]

Home was certainly there, as we know from an entry in Blagden's diary from the time. Heberden would seem to have been there too, as we know from Lord George Cavendish, who as Cavendish's executor paid his fee as well as Home's.[271] This Heberden was William Heberden, son of Charles and Henry Cavendish's old friend, who had died in 1801. The younger Heberden, who was as distinguished as his father, being physician in ordinary to the king and queen, prescribed neutral salts, which Cavendish could not keep down. At Banks's house, where Blagden learned of Cavendish's death, Home gave him an "affecting account" of Cavendish the previous day. There was a "shortness of questionings," Home said; Cavendish "seemed to have nothing to say, nor to think of any one with request." He told Home "it is all over, with unusual cheerfulness, & at parting wished Home good by with uncommon mildness." Cavendish ordered that his heir Lord George Cavendish "be sent for as soon as the breath was out of his body, but not before."[272] Home, who had treated Cavendish six years before for a rupture, told Blagden that the rupture had nothing to do with Cavendish's death, even though he evidently had refused to wear a truss. Cavendish had an "inflammation of the colon," which for the past year had caused diarrhea and which in the end obstructed the passage of food.[273] Banks lamented the loss to science, but that was all; he "felt nothing." Blagden, by contrast, was moved, noting in his diary that he "continued all day to feel the effect of this event on my spirits." He also noted that it was a cloudy, threatening day, as if a mirror to his spirits.[274] Two weeks later Blagden watched from his window the "funeral procession of my late friend; with much emotion."[275]

We now pass to another, all-too-human emotion. Cavendish's fortune was on everyone's mind, including his physician Home's; on the morning Cavendish died, Home had Cavendish's servant give him the keys, with which he prowled through the house opening drawers, trunks, and cupboards looking for treasures, which he found and noted.[276] In a few days word was out that no will had been located. Blagden had seen it but not "since the time I was intimate with him," and he thought that Cavendish had probably changed it since then.[277] Blagden told the company at Banks's that Cavendish's income was above £40,000 a year. Because Cavendish was not a "person who gave the £40,000 to hospitals,"

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[270] John Barrow (1849, 153–154).

[271] Heberden gave a prescription. 25 Feb. 1810, Charles Blagden Diary, Royal Society 5:426(back), 427. Home's fee was £105, Heberden's £21. Lord George Cavendish, "Mr.Cavendish's Executorship Agenda," Devon. Coll.

[272] 25 Feb. 1810, Charles Blagden Diary, Royal Society 5:426(back), 427.

[273] 4 Mar. 1810, ibid. 5:429(back), 430.

[274] 24 Feb. 1810, ibid. 5:426, 426(back).

[275] 8 March 1810, ibid. 5:431(back), 432.

[276] Barrow (1849, 154–155).

[277] 1 Mar. 1810, Charles Blagden Diary, Royal Society 5:428(back).

and because he did not spend more than £5000 a year he had to have left a fortune.[278] In good time the will was found. Of the funds, valued at over £800,000 on the market, as we have seen, one sixth went to Frederick Ponsonby, third earl of Bessborough, and five sixths to his executor Lord George (Augustus Henry) Cavendish and his family; the latter was apportioned into two sixths for Lord George and one sixth each for Lord George's three sons, William and, still minors, the namesakes of our branch of the family, Henry and Charles. At the Sunday soirée at Banks's house, a gossip told Blagden that "Lord George Cavendish courted Henry Cavendish abundantly."[279] If he did, it was unnecessary. Both Charles and Henry Cavendish had a history of dealing with Lord George over property, and Henry having early on decided on him as his principal heir met with him once a year for a half-hour or so.[280] Lord George had married sensibly and was rich even by Cavendish standards; Henry Cavendish's legacy had nothing to do with need but only with principle and, within rather narrow limits, preference. The dukedom would eventually revert to Lord George's descendents, an eventuality Henry Cavendish might well have considered.

Apart from his brother, Henry had outlived his own generation of Cavendishes. In the next generation, there were seven prospective male heirs, two of whom Henry named in his will, Lord George Cavendish, who as his main heir probably surprised no one, and Frederick, third earl of Bessborough, son of Caroline Cavendish, daughter of the third duke of Devonshire. Cavendish is said to have enriched Bessborough because he was pleased by his conversation, and that may well have been. Bessborough and Cavendish met often at the British Museum, where Bessborough was an active trustee, serving on the standing committee and attending meetings regularly. In the last years they also met at the Royal Institution, where they were both managers. Because of their family connections, they both visited Devonshire House, where Cavendish heard talk about Bessborough's quick and capable drawings of Italy. Unambitious politically, Bessborough declined office under the Grenville ministry. His biography in the *History of Parliament* describes him as "a man of little political consequence." Henry Cavendish did not consider this a disqualification of an heir of his.[281]

The last five living male Cavendishes of the next-generation were Horatio, George, and Robert Walpole, sons of Rachael Cavendish and Horatio Walpole; George Ponsonby, son of Elizabeth Cavendish and John Ponsonby; and William Cavendish, fifth duke of Devonshire, the older brother of Cavendish's main heir, George Cavendish. We have no indication that Henry Cavendish associated with the Walpole brothers, and nothing suggests that their paths would have crossed, but we note that the great political connection between the Walpoles and the Cavendishes at the time of the second duke had been replaced by a connection with the Walpoles through marriage. Horatio Walpole was a Whig Member of Parliament for about thirty years, during which time he gave only one speech, and he seems to have left little imprint.[282] George Walpole was a major general and a Whig Member of Parliament for twenty-three years, and though not a cabinet member he held a number of offices, evidence of a respectable political career. George Ponsonby, lawyer and Whig Member of Parliament

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[278] 1 and 2 Mar. 1810, ibid. 5:428 (back), 429.
[279] 17 Sep. 1809, ibid. 5:330.
[280] Wilson (1851, 173).
[281] Wilson said of Lord Bessborough that Cavendish "was not, I believe, a connexion of his." He missed the family connection, though it was close. Wilson (1851, 190). 1 Sep. 1794, Charles Blagden Diary, Royal Society 3:14. J.M. Collinge (2016)
[282] R.G. Thorne (2016b).

for about fifteen years near the end of his life, was the son of the speaker of the Irish House of Commons and served over twenty years in the Irish Parliament. He was said to be a man of unimpeachable integrity, however "a slow, and, in politics, a timid and narrow-minded man."[283] Again his and Henry Cavendish's paths were unlikely to have crossed. One obvious *Cavendish* who was not in Henry's will was, formally speaking, the first and most expectant Cavendish, the tenant for life of the vast family estate, the fifth duke of Devonshire. Lady Sarah Spencer speculated on why Henry Cavendish forgot the duke's existence in his will: perhaps Cavendish "thought that said existence was something of a *disgrace* to the noble name of Cavendish," and we have grounds for thinking he did. She did not regret that the duke gained nothing from Cavendish's death, since he and his heir, Hartington, were "*pretty well* off."[284] For his part, the duke was "quite convinced" that Cavendish would leave him nothing.[285] Resigned to nothing, he was said to be delighted to learn that Cavendish had left his money to the family, specifically to the earl of Bessborough. He was, however, "disgusted to see the disposal of so vast a property in a few lines, as if to save trouble."[286] We have seen many wills from the time and with the exception of his father's, none briefer or clearer than Henry Cavendish's. This would agree with Home's observation that on his deathbed Cavendish seemed to think of no one.

Grandson of Henry de Grey, duke of Kent, Henry Cavendish had three living male relatives of his own generation on the Grey side: John, second earl of Ashburnham, who was eighty-six and very infirm, and the brothers John William Edgerton, seventh earl of Bridgewater, and Francis Henry Edgerton, future eighth earl of Bridgewater. He had only one male relative of the next generation on the Grey side: George, future third earl of Ashburnham. The two earls of Bridgewater were fellows of the Royal Society, and Francis Henry, the eighth earl, is well known to historians of science as the founder of the *Bridgewater Treatises*, the authors of which were selected by the president of the Royal Society and the Bishop of London to demonstrate the "Power, Wisdom, and Goodness of God, as manifested in the Creation."[287] This clergyman was strongly interested in science but probably not in a way that would have brought him and Henry Cavendish together. Charles Cavendish kept a correspondence with his sister-in-law Lady Ashburnham, Jemima de Grey,[288] but we have come upon no record of contact between Henry Cavendish and the Ashburnham or Bridgewater families. Henry Cavendish would not have included his Grey relatives in his will in any case, since the source of his wealth was the Cavendish side of the family. His wealth would remain within the Cavendish family; his will made perfect sense, its surprises being minor variations on the standard theme.

Henry Cavendish's landed property was left to his brother, Frederick. This consisted of his fifteen-acre freehold estate on Clapham Common, which returned £200 a year in rent, and his farmland in Derbyshire and Nottinghamshire, which at the time of his death returned over £3000 a year. In 1784 Frederick made a will, which he did not revise, leaving his personal estate and his real estate in Market Street to his brother, Henry, but since he outlived Henry it went instead to his maternal first cousins, the earl of Ashburnham, the

[283] R.G. Thorne (2016a).
[284] Lady Sarah Spencer quoted in Hugh Stokes (1917, 315, 350).
[285] Letter from the fifth duke's second wife, Elizabeth Foster, to Augustus Foster, 1 Mar. 1810, in Foster (1898, 345).
[286] Quotation from the "Journal" kept by the duchess of Devonshire, in Dorothy Margaret Stuart (1955, 174).
[287] Charles C. Gillispie (1959, 209).
[288] Henry Cavendish, "Papers in Walnut Cabinet," Cavendish Mss Misc.

earl of Bridgewater, and Francis Henry Edgerton, the earl of Bridgewater serving as his executor.[289] After Frederick, the estate in Derbyshire and Nottinghamshire reverted to the duke of Devonshire.

The funeral procession that Blagden watched from his window set out with the body from Clapham Common at seven in the morning on 8 March 1810. Five private carriages belonging to the duke of Devonshire and to Henry Cavendish's heirs, Lord George Cavendish, Lord Bessborough, and Lord George's oldest son, William, traveled northward through London on their way to Derby.[290] There they were met at the gates of the city by twenty-four burghers, twenty-four constables, and a retinue of city officials (all of whom were paid to do this) dressed in black. They then proceeded to the Church of All Saints, where Cavendish was buried in the family vault. The pomp and ceremony were invariable for the Cavendish dead, and it was elaborate and expensive. Everything had to be rented, the hearse and coach ornamented with black ostrich feathers and drawn by six horses, eight men on horses, and on and on. The bill for nine days came to about £750.[291]

In his will, Henry Cavendish left £15,000 to Blagden, and £5000 each to Dalrymple and Hunter, though both of them had already died. Some of Cavendish's "warmest admirers have expressed regret that no portion of that vast wealth was appropriated to scientific objects."[292] Blagden thought that Davy had expectations: "Davy said, Mr. C[avendish] has at least remembered one man of science [Blagden], in a tone of voice which expressed much."[293] It was rumored that Blagden was disappointed, having expected more,[294] but there is no indication of this in anything we have seen, including his frank diary. In the days following Cavendish's death, Blagden stood up for his old friend.

The scientific colleagues who gathered at Banks's house in the weeks following Cavendish's death had other concerns too. There was Cavendish's large library, which passed along with his other personal possessions to Lord George Cavendish. Blagden said that at some point Cavendish wanted his library not to be dispersed but to be kept accessible, as it had been in his lifetime.[295] No doubt there was talk about Cavendish's instruments and apparatus, for Davy was soon to be given his pick of them, while other pieces went to the instrument maker John Newman of Regent Street, son of the maker of Cavendish's wind-measurer. The remainder was sold at auction by Lord George.[296]

From the beginning, there was discussion of an edition of Cavendish's published works, but what to do about his unpublished papers was an open question.[297] Blagden thought that these papers would be found in a state unfit for publication, but Lord George Cavendish wanted Blagden to look over the papers anyway, and so on 6 April Blagden, Banks, and evidently other interested colleagues met with Lord George at Cavendish's house on Clapham

[289] W. Ware to John Heaton, 27 Feb. 1810, Devon. Coll. "Memoirs of the Late Frederick Cavendish," 291.
[290] Lord Bessborough to Charles Blagden, 7 Mar. 1810, Blagden Letters, Royal Society, B.149.
[291] "Mr. Swift's Bill for Expenses at the Funeral of Hen: Cavendish Esq.," 29 Aug. 1810, Devon. Coll., L/114/74.
[292] "Cavendish, Henry," *Encyclopaedia Britannica*, 9th ed., 5:271.
[293] 8 Mar. 1810, Charles Blagden Diary, Royal Society 5:431(back), 432.
[294] Brougham (1845, 1:258).
[295] 3 and 4 Mar. 1810, Charles Blagden Diary, Royal Society 5:429, 429(back), 430.
[296] Wilson (1851, 475). *A Catalogue of Sundry Very Curious and Valuable Mathematical, Philosophical, and Optical Instruments*.
[297] This discussion of Cavendish's papers is taken from Russell McCormmach (1988, 37–38). The first mention of a proposed edition of Cavendish's works appears in the entry for 8 Mar. 1810 of Blagden's diary; other entries on this subject are on 10, 26, and 27 Mar. 5, 8–9, 11–12, and 26 Apr. and 24 May 1810, Charles Blagden Diary, Royal Society 5.

Common to inspect the manuscripts. After spending about four hours on them they decided that the papers were, for the most part, "only mathematics." Blagden returned to Cavendish's house, and for the next two weeks he was kept busy with the papers, after which he reported to Lord George:

> We have now finished the search which your Lordship desired us to make, in the hope of finding, among the papers of the late Mr. Henry Cavendish, something which he had prepared & thought fit for printing. Our search has in this respect been fruitless; a result for which we are sorry, though we must confess that it was not unexpected to us; because we knew that Mr.Cavendish was always ready to publish whatever he had made out to his full satisfaction. There are some few small scraps, which are transcribed nearly fair, as if he had thought of communicating them to the R.S.: but as it is apparent that they have been laid by, in that state, for a considerable time, it is to be supposed that he afterwards discovered some weakness or imperfection in them, or that they had been anticipated in a manner of which he was not aware when he composed them; in short, that he had some good reason for not giving them to the public. In truth, Mr. Cavendish's fame stands so high already in the scientific world, that no papers but of the most perfect kind could be expected to increase it, whilst it might be lowered by anything of an inferior nature.[298]

Blagden and his colleagues firmly recommended against including any of the unpublished papers in the proposed edition of Cavendish's papers, but they expected that dates and circumstances of his discoveries might be found among them that would be useful for the introduction. Since the papers were in "great disorder," some qualified person with time to spare would have to be found to go through them. They could think of only one person, the clerk of the Royal Society, George Gilpin, but they decided that he was probably too ill. They supposed that Lord George might ask around. Three months after Cavendish's death, Blagden and Banks between themselves agreed to postpone plans for an edition of Cavendish's works.

Blagden, Banks, and others recognized the peril of trying to improve a reputation posthumously, but they were mistaken about the worth of Cavendish's manuscripts. That could hardly have been otherwise, since the papers contained much that was original, and much more than the work of a few hours or a few days was required to appreciate this. Blagden was right in thinking that Cavendish's reputation was then so high that no unfinished papers could increase it, but he was wrong about the future interest in them. Today Cavendish is nearly as well known for what he did not publish as for what he did. One eminent scientist after another has studied his manuscripts and has come away impressed at what he achieved with the instruments and concepts available to him. To them it has seemed as if Cavendish were not of his own century but of the next.

[298] Charles Blagden to "My Lord" [George Augustus Henry Cavendish], n.d., draft, Blagden Collection, Royal Society, Misc. Matter – Unclassified.