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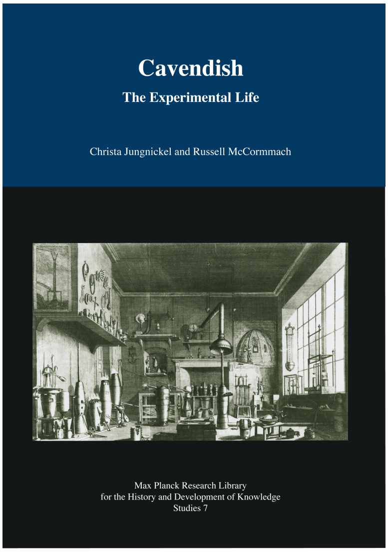
Science



In: Christa Jungnickel and Russell McCormmach: *Cavendish : The Experimental Life (Second revised edition 2016)*
Online version at http://edition-open-access.de/studies/7/

ISBN 978-3-945561-06-5
First published 2016 by Edition Open Access, Max Planck Institute for the History of Science under

Printed and distributed by:
PRO BUSINESS digital printing Deutschland GmbH, Berlin
http://www.book-on-demand.de/shop/14971

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at http://dnb.d-nb.de

Chapter 3
Science

De Moive Circle

Technically speaking, Lord Charles Cavendish was a commoner, but he was nevertheless a member of the highest circle of the British aristocracy, and as such he had been brought up to the values of the aristocracy, including the principal value of "duty of service."[1] To an aristocrat such as Charles, the only acceptable form of occupation (aside from administrating, but definitely not farming, his property) was public service, usually either in government or in the military, or possibly in the church. It came down to a narrow but attractive choice of occupations. The Cavendishes had served in some of the highest offices at court and in the government for almost half a century, and Cavendish, as we have seen, followed their example as soon as he reached maturity. Other interests, in the arts, architecture, belles lettres, various areas of scholarship, or natural science, no matter how expertly pursued, had to keep the outward appearance of an aristocrat's private indulgence, at best to be shared with friends. Cavendish's contemporary Lord Chesterfield made what many would have perceived as a sensible judgment for the time when he censored the architectural expert Lord Burlington for having more technical competence than his rank permitted.[2]

From the perspective of the larger society, Charles Cavendish, who was drawn to experiment and to the instruments of experimental science, would have been seen as overstepping the bounds of his station if he had allowed his experiments to take over his life. The occupational limitations of the aristocracy almost certainly affected the way he worked in science and his scientific reputation, or lack of it. For many years he carried on scientific investigations that were valued and used by other investigators, but he published only the one paper for which he received the Royal Society's Copley Medal. He contributed publicly to science in the same manner in which he had served the government: as a "parliamentarian" of science, a member of the Royal Society who served on its councils and committees, and as a member of boards and committees of other organizations. As a result of this activity, he became one of the most important official representatives of science of his time in Britain, and its untiring servant. His qualifications were his scientific talent, practical ability, long parliamentary experience, and the Cavendish name. He was a good example of a kind of scientific practitioner who was useful in eighteenth-century British science but who did not survive into the later organization of science.

In 1725, the year after he returned from his Continental tour, Cavendish became a Member of Parliament, as we have seen, but since he was so very young, completely inexperienced, and relatively unknown, he entered slowly into the work of the Commons. As he

[1] John Cannon (1984, 34).
[2] Dorothy Marshall (1968, 219).

was also relatively free of family duties, he had time to continue his education. His teacher, or one of his teachers, was almost surely the talented mathematician Abraham de Moivre.

De Moivre's friend Matthew Maty drew up a list of his eminent mathematical friends[3]: Newton, Edmond Halley, James Stirling, Nicholas Saunderson, Martin Folkes, and, on the Continent, Johann I Bernoulli and Pierre Varignon. (To this list we add from other sources William Jones[4] and Brook Taylor,[5] and there were still others.) Maty also listed De Moivre's friends and disciples, all former pupils of his: Lord Macclesfield, Charles Stanhope, George Lewis Scott, Peter Davall, James Dodson, and "Cavendish." (The Lucasian Professor in Cambridge John Colson should be included among his pupils, and no doubt others who come up in this book.)[6]

Since Maty gave only last names, we must decide which "Cavendish" he intended. Writing in the late 1750s, Maty would not have meant Henry Cavendish, who had only recently come down from Cambridge and was not yet a fellow of the Royal Society. Nor was it likely that he had in mind William Cavendish, duke of Devonshire, whom in any case he would have called Devonshire instead of Cavendish. The judgment Maty wanted his readers to make was of De Moivre's standing among accomplished mathematicians, not among unknowns or persons not known to have had significant mathematical interests. There are two likely possibilities, Charles Cavendish and his uncle James Cavendish. Both were active in the Royal Society, and both were proposed for membership in the Society by De Moivre's good friend, the eminent mathematician William Jones.[7] Together with Devonshire, both also subscribed to De Moivre's *Miscellanea analytica de seriebus et quadraticus*; published in 1730, which was the first mathematical or scientific book to which Charles subscribed. James Cavendish was born in 1678, and if he had been a pupil of De Moivre's he would have belonged to a generation earlier than that of the pupils named by Maty, indicating Charles as the more likely pupil of De Moivre's. Authors of a study of De Moivre's "knowledge community" write that both Charles and his uncle James and also his father William "were all taught by De Moivre."[8]

Among Charles's papers, kept and labeled by his son Henry, is a group "Mathematics." Because of the likelihood that by "Cavendish," Maty meant Charles Cavendish, and because of the evidence it provides of the mathematical education of the Cavendish family, we include the following brief discussion of De Moivre. De Moivre fostered a sense of connection between his pupils, evidently bringing them together at social evenings, and later keeping them "together as a kind of clique." Maty kept track of their publications in his *Journal Britannique*,[9] and they appeared together in the list of subscribers to De Moivre's

[3]Matthew Maty (1760, 39).

[4]De Moivre called William Jones his "intimate friend" in the preface to his book *The Doctrine of Chances; or, A Method of Calculating the Probability of Events in Play* (London, 1718), x.

[5]De Moivre called Brook Taylor his "Worthy Friend" in his *Doctrine of Chances*, 101. His correspondence with Taylor is described in Ivo Schneider (1968, 196–197).

[6]In the foreword to his first book, *Animadversiones*, De Moivre referred to John Colson as one of his pupils, noted by Schneider (1968, 189).

[7]James Cavendish was proposed for membership in the Royal Society on 19 Mar. 1718/1719, and was admitted on 16 Apr. 1719, JB, Royal Society 11:311, 326.

[8]The likely intermediary who supplied De Moivre with a letter of introduction was one of two Huguenot friends, Abraham Meure or John Buissière. D.R. Bellhouse, E.M. Renouf, R. Raut, and M.A. Bauer (2009). Published online before print (25 Feb. 2009 http://rsnr.royalsocietypublishing.org/content/early/2009/02/23/rsnr.2008.0017.full).

[9]Uta Jannsens (1975, 17). Augustus De Morgan (1857, 341).

republication of his mathematical papers.[10] Through De Moivre, his pupils formed a living connection with great mathematicians and scientists of the recent past. The intermediary De Moivre was Newton's junior by twenty-five years and Cavendish's senior by about the same number of years.

If we leave aside the foreigners named by Maty, we are directed to a select few mathematicians within the larger group of British mathematicians in the early eighteenth century with whom Cavendish came to be associated. For convenience, we will speak of a "De Moivre circle," whose members give us an idea of the mathematical setting in which Charles Cavendish probably completed his education.

The learned world of London had recently been enriched by an influx of Huguenots, Protestants forced by Louis XIV to leave France with the revocation of the edict of Nantes. Within the Cavendish family, as we have seen, the Ruvignys settled in Greenwich, home to the Royal Observatory, a prophetic location, and they encouraged other refugees to follow.[11] De Moivre and his father, one of a number of Huguenot surgeons and physicians to seek asylum in England, were naturalized in 1687;[12] Abraham was then twenty and an advanced student of mathematics.

In De Moivre's mind, his arrival in England was so closely identified with his discovery of Newton's work that although two years elapsed between the two events, to him they seemed simultaneous. For biographers of Charles and Henry Cavendish, it is gratifying that De Moivre first encountered Newton's work in the house of the earl of Devonshire. It was probably in 1689, when Newton spent a good deal of time in London as a member of the Convention Parliament for Cambridge, and when Devonshire enjoyed the fruits of the Revolution as a prominent politician in Parliament and at the court of William and Mary. De Moivre first saw Newton as he was leaving Devonshire's house after presenting the earl with a copy of his *Principia*. Shown into the antechamber where Newton had just left his book, De Moivre picked it up expecting to read it without difficulty, but he found that he understood nothing at all. He felt that all of his mathematical studies so far, which he had considered entirely up to date, had really taken him only to the threshold of a new direction.[13] He promptly mastered the new mathematics, with the result that Newton is said to have referred persons asking him about his work to De Moivre, who knew it better than he did.[14] Through the astronomer Edmond Halley, De Moivre was properly introduced to Newton and as well to the scientific society of London, leading to his election to the Royal Society. He made himself available to Newton in a variety of capacities: he sent

[10] The collection is *Miscellanea analytica de seriebus et quadraturis* (London, 1730), dedicated to Folkes. The list of subscribers could serve as a guide to British mathematics and its patrons in the early eighteenth century.
[11] Mary Berry (1819, 73).
[12] Father and son, "Abraham and Daniel De Moavre," are listed as being in London as of 16 December 1687, in a request to the attorney or solicitor general to prepare a bill for royal signature making them free denizens of the kingdom. Cooper (1862, 50). Samuel Smiles (1868, 235–238).
[13] Maty (1760, 6–7). Although the *Principia* was published in the summer of 1687, there is no evidence that Newton came to London to distribute copies of it at that time, and Edmond Halley handled the presentation copies. Moreover, it would have been of no advantage to him that summer to seek Devonshire's patronage, since he was then out of favor at court, having taken refuge at Chatsworth to avoid being arrested by the king in 1688. By 1689, however, James II had been displaced by William and Mary, at whose court Devonshire had a great deal of influence.
[14] Ian Hacking (1974, 452).

news and results of Newton's work to colleagues abroad;[15] he took charge of Newton's publications;[16] he defended Newton;[17] and he kept philosophical company with Newton at the Rainbow or Slaughters' coffeehouse and elsewhere.[18] De Moivre's own work drew heavily on Newton's, as he acknowledged by dedicating to him his masterwork, a treatise on probability, *Doctrine of Chances*. We can estimate when Cavendish probably studied with De Moivre, the friend of Newton, Halley, and other prominent British scientists, and correspondent of leading mathematicians on the Continent. De Moivre wrote to Leibniz in 1710 that most of his students were adolescents, and if that applied to Cavendish, he would have been with De Moive soon after he left Eton, before he went on his grand tour, sometime in the early 1720s.

In the course of his teaching, De Moivre established extensive and remunerative connections with the Whig aristocracy. It has been suggested that the connections began with De Moivre's call on the earl of Devonshire, as related by Maty above. Newton was probably there on political business, and De Moivre may have been there for the same reason, bearing a letter of introduction from a Huguenot friend. After the meeting with Devonshire, De Moivre presumably was taken on as tutor to Devonshire's sons, William and James. The eldest son William, who became the second duke of Devonshire and Charles Cavendish's father, was closely associated with Robert Walpole, the Whig prime minister and one of the subscribers to De Moivre's book. If this is how it went, De Moivre's entry into the Whig political world came about through the earl of Devonshire and was "tied to events surrounding the 1688 revolution."

Mathematical tutoring served an assortment of ends. It constituted a finishing school for "gentlemen," which probably would not have attracted Cavendish. Nor would have other common ends such as providing a useful skill for persons who sought public office but lacked the advantage of rank,[19] preparing government officials for handling finance, preparing teachers and others who intended to make a living directly from mathematics, and equipping landowners for surveying and military officers for navigation and gunnery. Instead it helped prepare Charles Cavendish for scientific research and administration.

Most of De Moivre's mathematical friends and pupils will enter this biography again as leading members of the Royal Society.[20] Here we briefly discuss two of them, William Jones and George Parker, second earl of Macclesfield. William Jones was a second mathematics teacher Cavendish may have studied with. It was Jones's practice to hand out transcripts of Newton's mathematical writings to his pupils, and Cavendish owned a copy of Jones's transcript of Newton's "Artis Analyticae Specimina vel Geometria Analytica."[21]

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[15]For example, concerning copies of Newton's *Principia* promised by De Moivre: letters from Pierre Varignon to Newton, 24 Nov. 1713, and from Johann Bernoulli to G.W. Leibniz, 25 Nov. 1713; in A.R. Hall and L. Tilling (1976, 42–45).

[16]David Brewster (1855, 248). Schneider (1968, 212–213).

[17]In Newton's dispute with Leibniz over the invention of the calculus. Hacking (1974, 452).

[18]Frederick Charles Green (1931, 31).

[19]A.J. Turner (1973, 51–54).

[20]For example: in addition to Newton, Folkes and Macclesfield were presidents of the Royal Society; Cavendish, Jones, Davall, Scott, and Stanhope were members of the Council; Maty and Taylor were secretaries; Halley was corresponding secretary and editor of the *Philosophical Transactions*.

[21]Cavendish later loaned his copy of the transcript to the mathematician Samuel Horsley, who was preparing a general edition of Newton's papers. D.T. Whiteside in Isaac Newton (1967–1969, 1:xxiii; 8:xxvii).

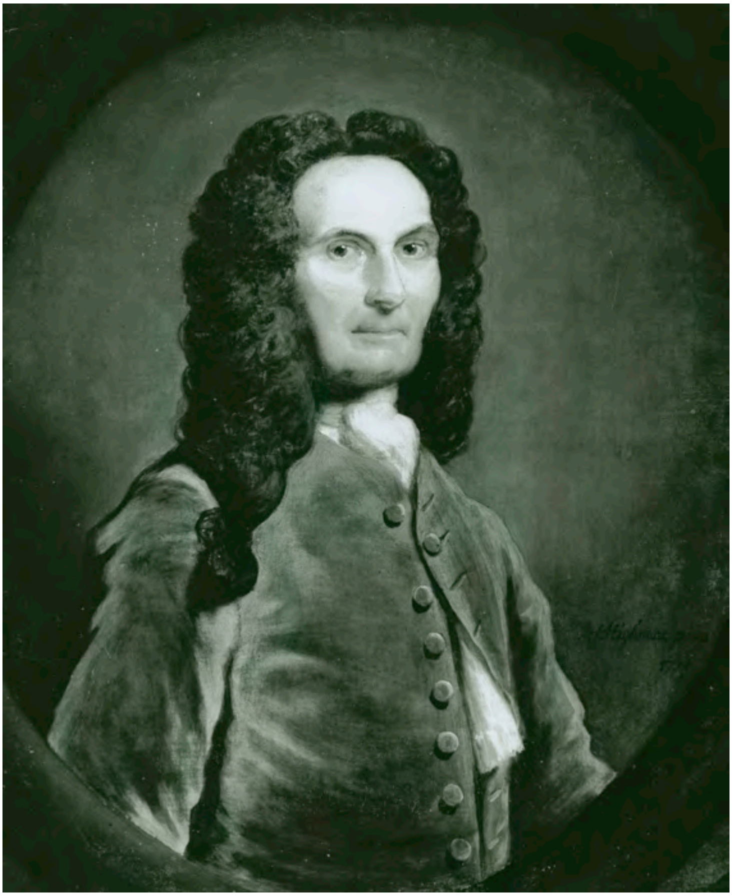

Figure 3.1: Abraham de Moivre. Painting by Joseph Highmore, 1736. Reproduced by permission of the President and Council of the Royal Society.

Jones published a book on navigation and another book, a syllabus of mathematics, which drew the attention of Halley and Newton, both of whom became his friends. Elected to the Royal Society in 1712, he was one of its more active members. As a tutor in mathematics, he became friends with Philip Yorke, later earl of Hardwicke and lord chancellor, and traveled with him on his circuit. He taught Thomas Parker, first earl of Macclesfield as well as his son, and for many years he lived with the Parker family at Shirburn Castle. On Macclesfield's recommendation Jones was appointed deputy-teller to the exchequer. He published a number of original papers in the *Philosophical Transactions*, edited important tracts of Newton's, and served with De Moivre on the committee of the Royal Society on the discovery of the calculus. He intended to write an introduction to Newtonian philosophy but died before he completed it. His library of mathematical books was reputed to be the best in the country.

Like De Moivre, Jones was an important personal and scientific link between Newton and the scientific men coming after him, including Charles Cavendish.[22]

Macclesfield was the other aristocrat besides Cavendish to be listed by Maty as a pupil of De Moivre's. Macclesfield's father the lord chancellor was impeached by the House of Lords under a long list of articles, which taken together include most of the ways money can be misused. He procured for his son an appointment as a teller of the exchequer for life. Like his father, Macclesfield studied law and became a Member of Parliament, but his first interest was always the sciences. He studed under both De Moivre and Jones, and he may have profited from still another Newtonian teacher, Richard Laughton, who was at Clare Hall, Cambridge when he studied there. Elected fellow of the Royal Society in 1722, he served on its Council while Newton was still president. In 1752 he succeeded Folkes as president. That year he was instrumental in bringing about a practical application of astronomy, a change in the calendar, assisted by former pupils of De Moivre's: Davall who drew up the bill and made most of the tables, and Folkes who examined the bill. In the calendar then in use, the new year began on 25 March; in the new style calendar, it began on 1 January, and there was a correction for the accumulated errors in the calendar owing to the precession of the equinoxes, a one-time elimination of eleven days in September. (When running for a seat in Oxfordshire, Macclesfield's son was met by a mob crying, "Give us back the eleven days we have been robbed of.") Macclesfield's private astronomical observatory in Shirburn Castle was said to have had the best equipment of any. He published three papers in the *Philosophical Transactions*, all minor: one on the date of Easter, one about an eclipse of the Sun, and one about the temperature in Siberia. His importance for science was as an administrator and patron.[23]

Royal Society

Early in June 1727, De Moivre's friend William Jones proposed the twenty-three-year-old Charles Cavendish for fellowship in the Royal Society , and two weeks later, on 22 June, he was formally admitted.[24] At a meeting of the executive Council of the Society on that same day, its president, Hans Sloane, raised the question of qualifications for admission of new members. Under English law, sons of peers were commoners until they inherited the family title, but in the Royal Society, by statute as a son of a peer, Cavendish was treated as if he were a peer, having to furnish no proof of scientific achievement, ability, or even interest. To raise the standards of membership of the Society and to reduce the exceptions to the general rules of admission, Sloane proposed to treat all commoners the same way with respect to requirements. The issue came to a head a few months later, in February 1728, when William Jones proposed yet another son of a peer, whereupon the members at large engaged in "Debates arising upon the sense of the Statute with Relation to peers Sons and privy Councellors whether any other Qualifications of such Gentlemen are required

[22]"Jones, William," *DNB,* 1st ed. 10:1061–62. E.G.R. Taylor (1966, 293–294). "Jones (William)," in Charles Hutton (1795–1796, 1:43–644).
[23]"Parker, Thomas, first Earl of Macclesfield," *DNB*, 1st ed. 15:278–282, on 280. "Parker, George, second Earl of Macclesfield," ibid. 15:234–235. Brydges (1812, 4:192–194). Charles Richard Weld (1848, 1:514–516). Maty (1787, 696).
[24]8 June 1727, JB, Royal Society 13:103.

to be mentioned or not." In the event, the Society changed some of its requirements for membership, but let stand those for peers and sons of peers.[25]

Until the end of his life, Newton was active as president of the Royal Society, and when he was absent, Folkes or Sloane took the chair in his place. Newton died three months before Cavendish was admitted to the Royal Society, but his presence was still felt. Several members of the Council were his friends and, as we have noted, De Moivre's friends too. One of them, the astronomer Halley, was especially active in scientific discussions at the meetings. Folkes, Jones, and the astronomer James Bradley were on the Council, as were the two secretaries of the Society, the physician and polymath James Jurin, a pupil of Newton's, and John Machin, an astronomer who Newton thought understood his *Principia* best of anyone, and who with Halley and Jones had been appointed to the committee on the invention of the calculus. Other Council members who had a close association with Newton were Richard Mead, a physician and author of a Newtonian doctrine of animal economy; Thomas Pellet, a physician who with Folkes brought out an edition of Newton's *Chronology of Ancient Kingdoms* in the year after Newton's death; Henry Pemberton, who edited the third edition of Newton's *Principia*; and John Conduitt, the husband of Newton's niece. Sloane was a physician, natural historian, and good friend of Newton's and Halley's. Several members of the Council were physicians with scientific interests: John Arbuthnot, Paul Bussiere, James Douglas, and Alexander Stuart. Roger Gale was a commissioner of excise. The one peer, Thomas Foley, who was repeatedly elected to the Council, had an observatory at his country seat near Worcester, from where observations were sent to the Royal Society from time to time. Two members of the Council represented a distinctive British contribution to science in the eighteenth century, the making of scientific instruments: John Hadley, who was first to develop the reflecting telescope introduced by Newton, and who later introduced a reflecting octet based on a proposal by Newton; and George Graham, to whom Bradley later said that his own success in astronomy had "principally been owing."[26] The governance of the Royal Society was entrusted to the users and makers of scientific instruments and to a good number of able mathematicians. This diverse and, by and large, eminent group of scientific men on the Council enlarged Cavendish's world in 1727. Later he would serve with seven of them on the Council.

Historians are divided over the question of the quality of science in the Royal Society in the eighteenth century,[27] but there would seem to be no doubt that from the standpoint of experimental science, 1727 was an auspicious year for the Society. That year Stephen Hales brought out *Vegetable Staticks*, the most impressive demonstration yet of the promise of Newton's philosophy to clarify a new experimental domain of facts. Educated at Cambridge, where he began experimenting on animal physiology, Hales continued his scientific studies while earning his living as a provincial cleric. With the help of Newton's speculations about forces of attraction and repulsion between particles, contained in the Queries of his *Opticks*, Hales investigated the composition of plants and the air "fixed" in plants. In the chapter of *Vegetable Staticks* concerned with air, Hales went beyond his original inquiry into plants to conclude that air is in "all Natural Bodys" and is "one of the Principal Ingredients or Elements in the Composition of them." His experiments on fixed air helped lay the foundations of pneumatic chemistry, the field in which Charles Cavendish's son Henry would

[25] 8 Feb. 1727/1728, JB, Royal Society 13:175. Weld (1848, 1:461).
[26] Bradley in 1747, quoted in Taylor (1966, 120–121).
[27] Richard Sorrenson (1996, 29–30).

make his major contribution. The full significance of *Vegetable Staticks* could not have been foreseen—it was to encourage a generation of experimentalists—but it was valued from the beginning. Hales was included in the Council of the Royal Society at the next election, at the end of 1727. Newton, who had presided during the final reading of Hales's chapter on air, died five weeks later, shortly before his hand-picked experimenter, J.T. Desaguliers, demonstrated experiments from that chapter,[28] one of which falling on the day Cavendish was elected to the Society. At that meeting, the president of the Royal Society Hans Sloane said that he and Abraham Hill had decided that the £5 interest on the £100 legacy of Godfrey Copley's hereafter would be paid to a person to perform an "Annual Experiment" before the Society.[29] Four years later, in 1731, Copley's legacy was used to award the first Copley Medal to the author of the "most important scientific discovery or contribution to science, by experiment or otherwise."[30] Both Charles and Henry Cavendish would receive the medal.

To follow Charles Cavendish's education in science, we look at the kinds of subjects that came up in the meetings around the time of his election, beginning with practical schemes. In 1627, exactly 100 years before Cavendish entered the Royal Society, Francis Bacon published his scientific utopia, *New Atlantis.* Salomon's House, Bacon's projected cooperative scientific college, whose goal was the "effecting of all things possible," was the original inspiration for the Royal Society. The expectation was that the Royal Society, like Salomon's House, would advance human welfare through science. That a century later the claims for the utility of the Royal Society could still be seen as utopian is shown by Jonathan Swift's satire of it in *Gulliver's Travels*, published one year before Cavendish entered the Royal Society. The Royal Society, renamed by Swift the Academy of Lagado, labors to extract sunbeams from cucumbers to warm the air on cold days.[31] The source of this ridicule was probably Hales's experiments on the effect of sunlight on the respiration of plants, which had been read to the Royal Society before being collected in his *Vegetable Staticks*.[32] Swift, to whom the disparity between the utopian faith of improvement and the hard reality of life was self-evident, was repelled by the Baconian optimism of the Royal Society. Whatever its logic, Swift's satire was overtaken by events. At a meeting of the Royal Society three months before Cavendish became a member, a letter was read from the secretary of the newly founded scientific academy at Petersburg, giving the plan of the academy, which largely followed the plan of the academies in Paris and Berlin, which in turn had benefited from the original academy, the Royal Society of London. Like its predecessors, the Petersburg academy would seek to promote human betterment by improving medicine and encouraging inventions.[33] Scientific academies with their Haleses—Stephen Hales was an avid applier of science as well as a plant and animal physiologist—would have a permanent presence in the Cavendishes' world and in the world to come.

[28]Stephen Hales (1727). Henry Guerlac (1972, 35–36, 41–43). References to the reading of Hales's discussion of air and to Desaguliers's repetition of experiments from it: 2, 9, 16 Feb., 13, 20 Apr., 4 May, 8 June, 16 Nov. 1726/1727, JB, Royal Society 13:44–45, 48–50, 70 , 74, 83, 103, 144. Newton's death caused a cancellation of the Society's meeting on 23 Mar. 1726/1727, JB, Royal Society 13:62.
[29]8 June 1727, JB, Royal Society 13:99–100.
[30]The criteria of the award have been stated variously at different times. It remains the oldest and most prestigious award of the Society.
[31]Jonathan Swift (1726/1962, 177).
[32]It is widely thought that Hales was Swift's source, though evidently it is not proven. Clive T. Probyn (1978, 148).
[33]2 Mar. 1726/27, JB, Royal Society, 13:52.

Long practiced in the East, inoculation against smallpox had just been introduced in Britain when Cavendish entered the Royal Society. The eminent physician and secretary of the Royal Society James Jurin warmly supported inoculation in the face of opposition from doubting physicians and clerics. The operation posed a risk to the community as well as to the patient, but so did the disfiguring and killing epidemic disease, and Jurin argued with figures that the danger from inoculation was less than that from exposure. After the operation had been tried, at royal request, on several condemned criminals, without loss of any, the royal children were inoculated.[34] It is unknown if Cavendish was inoculated, but he certainly was exposed; at the time he and James went abroad, their sister Elizabeth wrote that "the small pox continued here very fatal."[35]

Inoculation was based on an empirical observation—a mild form of smallpox often prevented a serious infection—insuring that it would become a topic of interest in the Royal Society. From far and near, Jurin received reports of inoculations written down methodically in columns, like weather reports, with which they had a connection. Despite Jurin's best efforts, inoculation fell into disfavor in Britain owing to deaths in prominent families. It revived in the 1740s as a remunerative surgical practice, but the Baconian promise began to be realized only at the end of the century, when the English physician Edward Jenner introduced cowpox vaccination, a safe method of controlling smallpox, which he came upon in the course of his practice of giving original smallpox inoculations. George III, who was roughly Henry Cavendish's age, was given Jenner's cowpox vaccination. Medicine was a large concern of Charles Cavendish's Royal Society, and though it did not happen to be one of his own, he was an active and longtime governor of the Foundling Hospital where his good friend William Watson regularly gave smallpox inoculations to children over three (Fig. 4.7).[36]

Inventions came up repeatedly at meetings of the Royal Society. For industry and for domestic heating, coal was increasingly in demand. British forests, the source of firewood and charcoal, were becoming depleted, encouraging the use of coal as the alternative for domestic heating and industry. Mining coal was hazardous because of the accumulation of unhealthy and inflammable air in the pits. Two weeks before Cavendish's election to the Royal Society, as the annual Sir Godfrey Copley's Experiment, the curator of experiments Desaguliers reported on his invention to remove bad air from mines and demonstrated it with a working model.[37] Through a sister, Charles would become involved in the coal mines of Sir James Lowther, who brought samples of air from his mines to the attention of the Royal Society.

Navigation was a natural subject for the Royal Society, joining science, invention, and national welfare. Ships were lost or delayed because navigators did not know their position

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[34]King George I allowed two of his grandchildren, the children of the future George II, to be inoculated in 1722, and they survived. However, two of King George III's children did not; about three percent of those inoculated did not. Susan Flantzer, "August 20, 1783—Death of Prince Alfred, Son of King George III of the United Kingdom" (http://www.unofficialroyalty.com/featured-royal-date-august-20-1783-death-of-prince-alfred).

[35]Elizabeth Cavendish to James Cavendish, 24 Apr. [1721], Devon. Coll., No. 166.1.

[36]7 Dec., 7, 21 Mar., 11 Apr. 1727/28, JB, Royal Society 13:148, 191, 198, 210. "Jurin, James," *DNB,* 1st ed. 10:1117–18, on 1118. Leonard G. Wilson (1973, 96). William H. McNeill (1993, 249–250). After 1800, smallpox mortality in London fell to one half of what it had been in the eighteenth century. Charles Creighton (1965, 479–481, 504, 568).

[37]Desaguliers published the experiments on his model pump for removing bad air from mines in the *Philosophical Transactions of the Royal Society of London* 34 (1727). Hereafter *PT.*

relative to the neighboring land, a scientific and practical problem. A ship's latitude could be found by taking the altitude of the Sun or a star, but its longitude was not that simple. The astronomer royal Halley, an advocate of the lunar method of determining longitude at sea, criticized a book on longitude referred to him by the Society: the author, Halley said, made two mistakes, one in thinking his method was original, the other in assuming what did not yet exist, "a true Theory of the Moons Motion." Later Charles Cavendish advised on an alternative to the lunar method, a marine clock, discussed in the section on his scientific work below. Other practical problems of the sea such as measuring its depth and mapping its coast came up at meetings of the Society.[38] One of Charles Cavendish's self-registering thermometers was suited for measuring the temperature of the sea at considerable depths, and under Henry Cavendish's supervision, it was used for that purpose.

The atmosphere of the Earth was another kind of fluid of practical importance and scientific interest. In 1723 James Jurin, secretary of the Royal Society, invited uniformly recorded weather observations—date, time, thermometer, barometer, wind, and general observation of weather[39]—and around the time of Cavendish's election, the Society received observations of everyday weather in considerable numbers. In addition it received occasional observations of remarkable atmospheric events such as great cold spells and auroras.[40] The weather was one of Charles Cavendish's persisting scientific interests, as it would be Henry's later.

Like Hales's fixed air, electricity was a relatively new field of experimental study in the early eighteenth century. It had no immediate utility yet, but it posed scientifically curious questions. Desaguliers alternated his demonstration of Hales's experiments on air with experiments on the communication of electrical virtue to a glass, demonstrated by the attraction and repulsion of fibers of a feather and of gold leaves. Within a year of Cavendish's election, Desaguliers announced that Stephen Gray intended to bring before the Society experiments showing that rubbed glass communicates its electrical quality to any body connected to it by a string.[41] Cavendish would make valuable experiments on the conduction of electricity, as again would Henry.

The breadth of topics discussed at the Royal Society around 1727 was greater than these examples suggest. For instance, from the side of medicine, there were reports on stones, cataracts, and aneurysms. From the side of natural history (and the far-flung British colonies), there were reports on coconuts, cinnamon, and poison snakes, and fossils, curious specimens such as two headed calves, and various natural collectibles were regularly displayed at the meetings. Investigative reports of earthquakes and other singular natural disasters were heard as often as opportunity allowed. Apart from certain formalities—correspondence read, books received, and guests introduced—the meetings were kept reasonably lively by the variety of their proceedings. A fairly typical meeting from around the time Cavendish was elected to the Society was recorded in a private journal kept by John Byrom, a fellow of the Royal Society and frequent attender: "Vernon there from Cambridge; Dr. Rutty read about ignis fatuus; humming bird's nest and egg, mighty small; Molucca bean, which somebody had sent to Dr. Jurin for a stone taken out of a toad's head; Desag-

[38] 11 May, 29 June 1727, JB, Royal Society 13:84–85, 113; 25 Jan. 1727/28, 2 May 1728, 23 Jan. 1728/29, ibid., 168–169, 214, 287. Humphrey Quill (1966, 1–6).
[39] William E. Knowles Middleton (1969, 138).
[40] 12 Jan. 1726/27, JB, Royal Society 13:34–36, and many other places.
[41] 27 Feb., 13 Mar., 1 May 1728/29, ibid., 307, 316, 330.

uliers made some experiments about electricity."[42] That evening there was something for just about everybody.

The contents of the *Philosophical Transactions of the Royal Society of London* are not identical with the papers read at meetings of the Society, but they give an idea of what went on. In the decade of the 1720s, when Cavendish entered the Society, the numbers of papers on natural history and on mixed mathematics (scientific fields with mathematical content but not pure mathematics) were about equal, together accounting for about half of the total number of papers. Medicine came next, accounting for about a fifth of the papers, then experimental natural philosophy and anatomy, each with above a tenth, and there were a few other categories such as speculative natural philosophy, pure mathematics, and antiquities. The two categories to which Cavendish's work belonged, mixed mathematics and experimental natural philosophy, accounted for one third of the papers, a proportion which did not change much over the next fifty years, into the time when Cavendish's son Henry was active in the same areas.[43]

The Royal Society wore two crowns, one scientific and one royal. Newton lived on in the causes that continued to be championed in his name. Thomas Derham wrote to the Society from Rome about a book by an Italian who "pretends" to refute propositions in Newton's *Opticks*; Desaguliers responded to the perceived danger. The dispute over whether the measure of force is as the velocity, as Newton said, or as the square of the velocity, as foreign mathematicians said, was settled by Desaguliers (he thought) by experiment and clarified by Jurin, who regarded it as a dispute arising from an ambiguity in the meaning of the word "force." Andrew Motte presented to the Society his English translation of Newton's *Principia*, and William Jones was asked to give the Society an account of it.[44] In the year Newton died, King George I died, and his successor to the throne, George II, agreed to succeed him as patron of the Royal Society. The change in monarch entailed protocol, such as carrying the charter book to St. James's for the royal signature, making an address, and paying compliments to the queen. There was also a change of heir to the crown, Prince of Wales Frederick, to whom the volume of the *Philosophical Transactions* for 1728 was dedicated. That year Cavendish became gentleman of the bedchamber to Frederick.[45]

Directly below the rank of royalty, within the dukedom of the Devonshires, there was about to be another succession, but for the time being Cavendish's father, the second duke of Devonshire, was still alive. The duke was the owner of a great magnet, which turned up in discussion at the Royal Society a few months after Cavendish was elected. Supported in a fine mahogany case and raised by screws, the "famous Great Lodestone of his Grace the Duke of Devonshire" had prodigious force, as Folkes bore witness, having seen it lift "more than its own weight."[46] In 1730 the magnet was produced again, this time by Desaguliers, who lifted 175 pounds with it.[47]

[42] Entry for 27 Feb. 1728/1729: R. Parkinson, (1854–1857, vol. 1, pt. 1, 334). 27 Feb. 1728/1729, JB, Royal Society 13:303–307.

[43] Sorrenson (1996, 37). From another source, there is a similar estimate: physics, including mechanics, meteorology, and various border subjects, accounted for about a third of the papers appearing in the *Philosophical Transactions*. John L. Heilbron (1983, 43).

[44] 8 Feb., 4 July, 24, 31 Oct., 7, 14 Nov. 1727/28, JB, Royal Society 13:175–176, 242, 252, 257, 262; 22 May, 5 June 1729, ibid., 339–340, 341.

[45] 11 May, 6 July 1727, ibid., 86, 114.

[46] 13 Mar. 1728/1729, ibid., 314.

[47] 9 Apr. 1730, ibid., 454.

Encouraged to learn that the king of France had just instituted a medical society, Heberden wrote to a colleague that "the knowledge of other parts of nature has increased more, by means of such societies, within the last hundred years, than it had done from the age of Aristotle to the time of their foundation."[48] To judge by their work in the Royal Society, Charles and Henry Cavendish would have agreed with their friend on the importance of scientific societies for the improvement of scientific understanding.

[48]William Heberden to Charles Blagden, 9 Dec. 1778, Blagden Letters, Royal Society, H.22.