a private scholar and a public servant

During his years in Cambridge, the focus of Newton's activities shifted several times. His initial enthusiasm for geometry, optics, and the making of instruments developed into a passion for alchemical experiment during the 1670s. His growing unease about the doctrines of the Church of England forced him to contemplate giving up his life at Cambridge, until he received royal dispensation to hold his professorship without taking holy orders. It also led him to investigate the beliefs of the early Church, and, in the 1680s, to work intensively on the historical problem of the origin of religion. By then, his ideas about matter and motion were beginning to take shape. Behind these changes of interest lay changes in what Newton was reading. As he built up his library and constructed his own laboratory, the method of his studies also altered. Yet Newton's interests remained those of a solitary intellectual, and it took the political upheaval of the Glorious Revolution in 1688, as well as the publication of the *Principia*, to make him into a public figure. Newton supported the Revolution and was elected as the MP for Cambridge University straight after it. His new patrons soon found ways for him to leave the Fens for good, and Newton effectively gave up the duties of his chair in 1696 when he moved to London permanently to become Warden of the Mint.

9 cambridge university library, ms. add. 4000, ff. 26v–27r
(figure 6)
14.7 × 9 cm
Bound notebook of 164 leaves (originally 166)

Newton appears to have begun using this notebook in the winter of 1663–4 and to have written in it extensively over the next two or three years. It contains notes on his mathematical and geometrical reading, drawn from van Schooten's *Exercitationum mathematicarum* (Leiden,

1657) and from his edition of the works of Viète (Leiden, 1646), as well as from the writings of the Oxford mathematician, John Wallis. Newton was particularly interested in Wallis' *Arithmetica infinitorum* (included in his *Opera mathematica* of 1656–7), in which problems of mathematical methods of reasoning about the quadrature of areas and volumes through consideration of their indivisible elements of line and surface were set out. This notebook also contains evidence of the development of Newton's own mathematical skill in this period, especially his study of infinite series and development of the binomial theorem, the evolution of the differential calculus, and its application to the problem of quadratures and integration. Although Newton had been inspired in his mathematical work on curved lines and surfaces by reading Wallis and by listening to the lectures that Barrow delivered in 1664, his knowledge of Descartes' geometry was also critical in these discoveries.

One of the later entries in this notebook derives from Newton's knowledge of Descartes' *La dioptrique*, which Newton probably read in a Latin edition published at Paris in 1656. By September 1664, Newton had learned about the sine law of refraction through his reading of Descartes' works, and, in the winter of 1665–6, he investigated

6

figure 6
Shaping a wheel for the grinding of lenses, Ms. Add. 4000, f. 26v.

7

figure 7
A copy of Newton's essay 'Of Refractions', from the Macclesfield Collection.

Descartes' findings about refraction at curved surfaces. This is probably the date of the composition of the essay 'Of Refractions', part of which is displayed here. Newton later told Oldenburg that he had first applied himself to grinding lenses that were not spherical in the winter of 1666 and this essay includes the detailed description of a machine for shaping a wheel to a hyperbolical profile, which could later be used for grinding lenses. Such a machine had been discussed in chapter ten of *La dioptrique*, but Newton improved the design and gave a geometrical demonstration of its operation. The final two leaves from Newton's 'Of Refractions', which deal with compound lenses and the aberration of light refracted at a spherical surface, are missing from the notebook. They can now be found in the Macclesfield Collection, box 43.

Alan E. Shapiro (ed.), *The Optical Papers of Isaac Newton*, vol. 1 (Cambridge, 1984), 7–8; D.T. Whiteside (ed.), *The Mathematical Papers of Isaac Newton*, 8 vols (Cambridge, 1967–81), vol. 1, 47–88, 91–119, 219–33, 238–44, 298–321, 348–63, 559–76; A. Rupert Hall, 'Further Optical Experiments of Isaac Newton', *Annals of Science*, 11 (1955), 27–43.

Assessed 'Not fit to be printed' on behalf of Newton's executors by Thomas Pellet (25 September 1727); presented to Cambridge University Library by the fifth Earl of Portsmouth. See *A Catalogue of the Portsmouth Collection of Books and Papers written by or belonging to Sir Isaac Newton* (Cambridge, 1888), p. 48.

10 cambridge university library, macclesfield collection, box 3/6
(figure 7)
19.2 × 12.7 cm

The presence of two stray leaves from one of Newton's notebooks among the papers in the Macclesfield Collection is not wholly surprising. The mathematician, William Jones (1675–1749), who was tutor to the children of Thomas Parker, later Earl of Macclesfield, had obtained many of the papers of John Collins (see catalogue number 38) in 1708, including a number of manuscripts and letters that Newton had sent to Collins. Jones sought to publish these, and, largely because of Newton's dispute with Leibniz over the invention of the calculus, was given permission to edit some of them. It is apparent from notebooks in the Macclesfield Collection that, at some point, Jones had wider access to other manuscripts that remained in Newton's possession. He seems have examined the notebook described above (catalogue number 9) since Newton had himself already decided that it bore witness to some of his earliest work on geometry and infinite series, leading up to the discovery of the calculus. Indeed, Newton had inserted an entry to that effect on 4 July 1699. Jones, however, had mathematical and philosophical interests that went beyond the quarrel over the calculus, and was generally curious about the history of Newton's work. In addition to the copies by Collins that he had now possessed, Jones therefore had several of Newton's own manuscripts copied into fresh notebooks, often bound in blue or grey pasteboard. In some cases, it is clear that manuscripts were damaged and leaves displaced when copies were made for Collins and later for Jones, for example from Newton's essay 'Of Refractions'.

'Of Refractions' was one of the essays of which Jones wanted to keep a copy. The handwriting of the transcription, which includes the contents of the leaves that were removed from the original notebook is not wholly dissimilar to that of Collins, but is more likely to be that of a copyist employed by Jones to transcribe mathematical and philosophical works. The transcription carries the title 'optical Papers of Sr Is. Newton' on its cover and is limited to the essay 'Of Refractions'. It is displayed here open to show Newton's design for a machine to shape a wheel to a hyperbolical profile.

Richard S. Westfall, *Never at Rest. A Biography of Isaac Newton* (Cambridge, 1980), p. 717; Cambridge University Library Ms. Add. 7339, f. 227 (letter from H.W. Turnbull, 17 July 1953).

Purchased from the Earl of Macclesfield by Cambridge University Library, August 2000.

11 cambridge university library, ms. add. 3975, p. 15

(figures 8 and 9)

17.6 × 11.5 cm

Bound notebook of 174 leaves, paginated throughout.

Newton probably began making notes in this book in 1665 and 1666. The entries that he made then followed on both in subject matter and source material from some of the topics in his philosophical commonplace book (catalogue number 2). They fill the first twenty-two pages of this notebook, constituting an essay 'Of Colours' and are further broken down into 64 numbered sections or 'experiments' on pages 1 to 16. Newton's observations in these sections move from the appearance of colour given off by different bodies, through experiments with prisms in which he determines that blue and red light appear to be refracted differently, to investigations of the ability to perceive colour and of the anatomy of the eye. In experiments 58 and 59, Newton writes:

> I tooke a bodkine gh & put it betwixt my eye & [the] bone as neare to [the] backside of my eye as I could: & pressing my eye [with the] end of it (soe as to make [the] curvature a, bcdef in my eye) there appeared severall white darke & coloured circles r, s, t, &c. Which circles were plainest when I continued to rub my eye [with the] point of [the] bodkine, but if I held my eye & [the] bodkin still, though I continued to presse my eye [with] it yet [the] circles would grow faint & often disappeare untill I removed [them] by moving my eye or [the] bodkin.
>
> If [the] experiment were done in a light roome so [that] though my eyes were shut some light would get through their lidds There appeared a greate broade blewish darke circle outmost (as ts), & [within] that another light spot srs whose colour was much like [that] in [the] rest of [the] eye as at k. Within [which] spot appeared still another blew spot r espetially if I pressed my eye hard & [with] a small pointed bodkin. & outmost at vt appeared a verge of light.

figure 8
Newton's experiment with a bodkin, Add. Ms. 3975, p. 15.

figure 9
An experiment to put pressure on the eye, Add. Ms. 3996, f. 123v.


8


9

This account is illustrated with the diagram displayed here. Newton's interest in performing these experiments, however, was not confined to making optical or anatomical discoveries. As the entries in his earlier philosophical commonplace book indicate, Newton was also concerned with the way in which apparent sensations might in fact be the product of imagination and with the question of whether what one saw might be controlled by the nerves, and thus perhaps by the soul itself, rather than by some mechanical process of experience. These were issues that bothered both Descartes and Robert Boyle, on whose work on colour Newton was building, and some of the leading thinkers of contemporary Cambridge, in particular Henry More (1614–1687). More had also grown up in Grantham and had been one of the first English converts to Cartesianism before he became suspicious that Descartes' mechanical philosophy left too little role for the activities of spirits and the soul. Newton's experiments with his own eyes, as well as his investigation of the anatomy both of the human eye (which follows experiment 64 in this manuscript) and of a sheep's eye, need to be interpreted in this context.

One of the entries in Newton's philosophical commonplace book describes another experiment similar to that in the essay 'Of Colours', which is illustrated here as figure 9. Newton had been considering the question of whether the porosity of bodies may have some effect on the colours that they give off, perhaps by hindering the motion of rays of light. To investigate this, Newton experimented with the effects of putting pressure on his own eyeball:

> If I presse my eye on [the] left side (when I looke towards my right hand) as at a, [then] I see a circle of red as at c but [within the] red is blew for [the] capillamenta are more pressed at n & o & round about [the] finger [than] at a towards [the] midst of [the] finger. [That parte] of [the apparition] at q is more languid because [the] capillamenta at o are duller & if [the] finger move towards e two much it vanisheth at q & appeareth semicircular. but if I put my finger at e or s [the] apparition wholly vanisheth. By putting a brasse plate betwixt my eye & [the] bone nigher to [the] midst of [the] tunica retina [than] I could put my finger I [made] a very vivid impression. But of an ellipticall figure because [the] edge of [the] plate [with which] I prest my eye was long & not round like my finger

Newton also described an experiment involving looking at the sun and then at a piece of white paper. He claimed that he could replicate what he saw subsequently by imagining that he had looked at the sun 'whence I gather that my fantasy and the Sun had the same operation upon the spirits in my optic nerve'.

Although these investigations perhaps seem hazardous to us, Newton was far from being the only one of his contemporaries to regard his own body as a suitable object for experiment. His reports of his experiences retain throughout a detachment which appears clinical, yet in fact these were potentially some of the most moving as well as the most painful experiments that the young Newton could have performed. This was because the demonstration of how active spirits or the soul might affect perception could also be a powerful weapon against materialism and its bed-fellow, atheism.

After writing his essay 'Of Colours' and then making notes from various works of Robert Boyle, particularly *New Experiments and Observations touching Cold* (1665) and *The Origine of Formes and Qualities* (1666), Newton may have abandoned this notebook for a year or two. However, the interest in the shaping and ordering of matter that is apparent both in the notes that Newton took from Boyle and in his own experiments on colours, resurfaced shortly afterwards in entries based on fresh reading in the literature of alchemy. Initially, many of these were also drawn from Boyle, including some references to the work of Joan Baptista van Helmont, but they soon contained evidence of Newton's assimilation of the writings of the mid-seventeenth-century alchemist, George Starkey (also known as Eirenaeus Philalethes). Although many of Newton's notes were simply references to his reading, it is often clear that he was also recording his own attempts to reproduce the experiments that he was studying. This is especially apparent in the dated entries from the early and mid-1680s, by which time Newton's library contained copies of all the works by Starkey to which he refers in this manuscript, but it is also suggested by notes that may have been made as early as 1669.

J.E. McGuire and Martin Tamny (eds), *Certain Philosophical Questions: Newton's Trinity Notebook* (Cambridge, 1983), especially pp. 216–325, 394–6, 430–47, 466–89; A. Rupert Hall, 'Further Optical Experiments of Isaac Newton', *Annals of Science*, 11 (1955), 27–43; Rob Iliffe, '"That puzleing Problem": Isaac Newton and the Political Physiology of Self', *Medical History*, 39 (1995), 433–58; Cambridge University Library, Ms. Add. 3970, f. 650; Betty Jo Teeter Dobbs, *The Foundations of Newton's Alchemy* (Cambridge, 1975), pp. 126–93; William R. Newman, *Gehennical*

Fire. The Lives of George Starkey, an American Alchemist in the Scientific Revolution (Cambridge, Mass., 1994), pp. 228–43.

Assessed 'Not fit to be printed' on behalf of Newton's executors by Thomas Pellet (25 September 1727); presented to Cambridge University Library by the fifth Earl of Portsmouth. See *A Catalogue of the Portsmouth Collection of Books and Papers written by or belonging to Sir Isaac Newton* (Cambridge, 1888), pp. 21–4.

12 thomas sprat, *The History of the Royal-Society of London, for the Improving of Natural Knowledge*

(London, 1667)
(figure 10)
4°: a-b^4, a-3i^4
17.3 × 12 cm
Trinity College Library, Cambridge, nq 9/28

According to the accounts given in one of his early notebooks (catalogue number 3), Newton purchased this book for 7s. shortly after it was published in 1667. He had just performed the Act for his Bachelor's degree and may not yet have been elected to the minor fellowship of Trinity that he held from October. As early as 1663, the Royal Society, which was founded in 1660, had begun to consider publishing a *History*, in order to present some sense of its intentions to a broader public. Thomas Sprat (1635–1715), a protégé of one of the most powerful and active fellows of the early Royal Society, John Wilkins, was chosen to write the work. Wilkins was closely involved in its composition, which was however interrupted in 1665 and 1666 as a consequence of the disruption caused by the plague and the Great Fire. Other fellows of the

figure 10
Thomas Sprat, *History of the Royal Society* (1667), folding plate of meteorological instruments, Trinity College, nq 9/28, facing p. 173.

Society, notably its secretary Henry Oldenburg, also contributed to the *History*, which included accounts of their work and of projects that the Society wished, at least in theory, to promote. For example, one of several contributions by Robert Hooke was 'A Method for making a History of the Weather', which included designs for meteorological instruments that were illustrated on an accompanying plate. When it did appear, Sprat's *History* was not an unqualified success. Indeed, in the controversies over the new science that blew up in the late 1660s, it seems to have provided much ammunition for critics of the Royal Society.

John Harrison, *The Library of Isaac Newton* (Cambridge, 1978), p. 242; Thomas Sprat, *The History of the Royal Society of London*, ed. J.I. Cope and H.W. Jones (London, 1959); Paul Wood, 'Methodology and Apologetics: Thomas Sprat's *History of the Royal Society*', *British Journal for the History of Science*, 13 (1980), 1–26; Michael Hunter, *Establishing the New Science* (Woodbridge, 1989), pp. 45–71.

Listed by the booksellers who appraised Newton's library for his executors; bought with the rest of the library by John Huggins in 1727. Bookplate of Charles Huggins. Bookplate of James Musgrave, with shelfmark F5–17. Presented to Trinity College, Cambridge, on 30 October 1943 by the Pilgrim Trust.

13 cambridge university library, ms. add. 3958, f. 5r

(figure 11)

19.6 × 15 cm

In the mid-1660s, Newton seems to have begun taking notes from books on separate sheets of paper as well as in pocket-books. His usual method was to fold a single, full sheet of paper in four, creating a booklet of four leaves or eight pages. He would normally cut the edge between pages two and three but leave that between pages six and seven uncut, even if he had written on those pages. The first notes according to this manner that Newton took appear to have been from Robert Hooke's *Micrographia* (1665). Newton was interested in Hooke's comments on the material structure of various substances as well as in his ideas about the nature of light and colours. Newton's acquaintance with Descartes' optical thought and his own experiences made him confident enough to express a rare note of criticism concerning some of Hooke's explanations of colour, for example in his description of Muscovy glass. It was more usual, however, for Newton's notes to be straightforward records of those parts of books that had interested him, as in the case of Sprat's *History*.

The longest note that Newton made on his reading of Sprat concerned the reports of unusual phenomena in nature and of strange

figure 11
Newton's notes taken from his reading of Sprat's *History of the Royal Society* (1667), Add. Ms. 3958, f. 5r.

devices that the Royal Society had received. He also recorded additional information about Hooke's ideas of matter and noted methods of making telescopic observations. He was certainly interested in summarising the range of activities practised by the early fellows of the Society. The most striking aspect of this sheet of notes, however, is the copy that Newton made of a design for a weather-cock from the folding plate that illustrated Hooke's 'Method for making a History of the Weather'.

Newton was sufficiently impressed by the activities of the early Royal Society, and by the intriguing reports that its members collected, to take notes from the journal produced by the Society's secretary, Henry Oldenburg. He entered these in a further booklet of notes, headed 'Out of Philosophicall Transactions', which covered numbers one to twenty-four (1665–7) of the journal.

A. Rupert Hall and Marie Boas Hall (eds), *Unpublished Scientific Papers of Isaac Newton* (Cambridge, 1962), pp. 397–413; Cambridge University Library, Ms. Add. 3958, ff. 1–4, 9–24.

Presented to Cambridge University Library by the fifth Earl of Portsmouth. See *A Catalogue of the Portsmouth Collection of Books and Papers written by or belonging to Sir Isaac Newton* (Cambridge, 1888), p. 1.

14 cambridge university library, ms. add. 3973, f. 25a
20.4 × 16 cm

In his alchemical work, Newton often used the same method of taking notes in a booklet constructed from a single folded sheet. This manuscript consists of several of these booklets, the earliest of which is dated December 1678 and the latest February 1696. As the practice of dating them suggests, Newton's notes relate to specific chemical experiments and appear to record laboratory activity, often referring to operations that had been performed at an earlier time or using substances that had already been prepared. Records of some of these experiments were also entered in the alchemical notebook that Newton was keeping (catalogue number 11), sometimes in a more complete form. Newton also kept a note there of his purchases of chemicals in London during 1687, from 'Mr Stonestreet Druggest by Bow Church', and in 1693 from Timothy Langley, who had succeeded Stonestreet in the business. Much of the experimental work that Newton chronicled was carried out in the early 1680s, when Newton was living in E3, Great Court, to the right of the Great Gate into Trinity College (see figure 31). Newton seems to have had a separate laboratory constructed for him by this time. His amanuensis, Humphrey Newton, observed his master's chemical activities, which were particularly extensive in spring and autumn, 'at [which] Times he used to imploy about 6 weeks in his Elaboratory, the Fire scarcely going out either Night or Day, he siting up one Night, as I did another, till he had finished his Chymical Experiments, in [the] Performances of [which] he was [the] most accurate, strict, exact'.

Many of Newton's experiments at this time concern chemical transformations of sal ammoniac (NH_4Cl, or ammonium chloride), processes that were derived largely from his reading of the publications of George Starkey. Like Starkey, Newton was careful to record the weight of chemical substances that he produced. From this, and from Newton's interest in experiments leading to sublimation, it seems possible to conclude that he was searching for the alchahest, a substance that could reduce matter to its essential components, about which van Helmont had written extensively. In addition to these authors, Newton's notes on his experiments at this time also show the influence of works attributed to Basilius Valentinus, which Newton started to read alongside the writings of the German alchemist Michael Maier (see catalogue number 52) in about 1670.

Other experimental notes by Newton in this manuscript, including those on display, date from a later period of intense alchemical investigation in the early 1690s. This activity continued at least until Newton's departure for London in spring 1696. It was encouraged by a new acquaintance of Newton, for a time his closest friend, the Swiss mathematician Nicolas Fatio de Duillier. Fatio helped Newton to acquire and read alchemical texts, in particular those in French, and encouraged him both to revise the *Principia* and to develop ideas about the cause of gravity. Newton and Fatio were both interested in the process of fermentation, through which metals could be made ready for transmutation. They corresponded about the methods involved during 1693 and, between December 1692 and June 1693, Newton took notes on a series of relevant experiments that he was carrying out. These notes were theoretical as well as practical and surely drew on Newton's wide alchemical reading. That reading would also have alerted Newton to the analogy between chemical reactions involving the compounds of metals and the processes of distillation by which beer and spirits are manufactured. Newton's notes opened in December 1692 with an account of the production and virtue of barm (the froth on fermenting malt liquor, which can itself be used in fermentation) in brewing. One of the publications of William Yworth, a chemist from Rotterdam who had recently settled in London, contained a similar description of brewing. Newton owned a copy of this book, *Introitus apertus ad artem distillationis; or the Whole Art of Distillation* (London, 1692), although it seems likely that he came by it a few years later, by which time he was acting as Yworth's patron.

The illnesses that both Fatio and Newton suffered during the early 1690s may have provided an additional reason for intensive chemical activity. After all, one of the aims of alchemical transmutation was to produce a healing elixir. It is more likely, however, that Newton's investigations were linked to attempts to understand the nature of matter and force that built on his earlier experimental work and increasingly preoccupied him after the publication of the *Principia*. Nevertheless, Newton's alchemical activity at this time may have had implications for his health. His notes reveal that he must have exposed himself to high levels of antimony, as well as to lead, iron, copper, mercury, and their compounds, during the experiments that he conducted in 1693. Throughout the year, Newton displayed symptoms of illness, and his correspondence from the autumn suggests that he suffered a serious collapse in his self-confidence and ability to trust others, if not a genuine mental breakdown. Although it is possible that metal poisoning contributed to Newton's suffering, it is just as probable that his long-standing anxiety about publicity and problems created by the closeness of his relationship to Fatio generated the sickness and unease that he experienced.

Marie Boas and Rupert Hall, 'Newton's Chemical Experiments', *Archives internationales d'histoire des sciences*, 11 (1958), 113–52; Richard S. Westfall, *Never at Rest. A Biography of Isaac Newton* (Cambridge, 1980), pp. 290–310, 359–69, 527–39; King's College, Cambridge, Keynes Ms. 135; Lord Adrian, 'Newton's Rooms in Trinity', *Notes and Records of the Royal Society of London*, 17 (1962), 17–24; Betty Jo Teeter Dobbs, *The Janus Faces of Genius* (Cambridge, 1991), pp. 170–4, 288–92 (printing Ms. Add. 3973, ff. 25a–28b, although with frequent mistakes in transcription); Karin Figala, 'Newton, Isaac', in Claus Priesner and Karin Figala (eds), *Alchemie: Lexikon einer hermetischen Wissenschaft* (Munich, 1998), pp. 252–8; William R. Newman, *Gehennical Fire. The Lives of George Starkey, an American Alchemist in the Scientific Revolution* (Cambridge, Mass., 1994), pp. 175–88; H. W. Turnbull, J.F. Scott, A.R. Hall and Laura Tilling (eds), *The Correspondence of Isaac Newton*, 7 vols (Cambridge, 1959–77), vol. 3, 260–3, 265–70; L.W. Johnson and M.L. Wolbarsht, 'Mercury Poisioning: A Probable Cause of Isaac Newton's Physical and Mental Ills', *Notes and Records of the Royal Society of London*, 34 (1979–80), 1–9; P.E. Spargo and C.A. Pounds, 'Newton's "Derangement of the Intellect". New Light on an Old Problem', *Notes and Records of the Royal Society of London*, 34 (1979–80), 11–32; R.W. Ditchburn, 'Newton's Illness of 1692–3', *Notes and Records of the Royal Society of London*, 35 (1980), 1–16.

Presented to Cambridge University Library by the fifth Earl of Portsmouth. See *A Catalogue of the Portsmouth Collection of Books and Papers written by or belonging to Sir Isaac Newton* (Cambridge, 1888), pp. 19–20.

15 gerardus joannes vossius, *De theologia gentili, et physiologia Christiana; sive de origine ac progressu idololatriae*
(Amsterdam, 1641)
(figure 12)
4°: π^2, a-2p^4, $*$-4$*^4$, 5$*^2$, 2q-4x^4, 4y^6, + -5+^{4}
17.3 × 13cm
Trinity College, Cambridge, nq 8/46

During the 1680s, Newton deepened his interest in the thought and belief of the ancient world. He developed the notion that he might be a representative of a remnant of individuals who preserved or were able to recover knowledge of the true religion and the true natural philosophy. This idea manifested itself in a number of ways. It may lie behind some of Newton's alchemical reading and experiment. Many alchemical authors claimed to have had access to ancient and secret wisdom and some also suggested that they belonged to a hidden brotherhood dedicated to passing on such knowledge. By the 1690s, Newton's interest in ancient philosophy had certainly begun to be expressed in his own natural philosophy (see catalogue number 56). Yet, it was most apparent in his theological writing, which took a new turn during the mid-1680s and early 1690s.

In these years, Newton expanded his concern with the corruption of the Christian religion through the growth of idolatry into a reconstruction of the origins of human religion. He argued for the continuity of essential points of doctrine between a primitive religion, which had degenerated into paganism; Judaism, which had been corrupted after the time of the prophets; and Christianity, which had been led into idolatry by proponents of the doctrine of the Trinity.

These developments in Newton's ideas were prompted in part by the widening range of his reading. The volume on display here contains two works, published together, both of which Newton used extensively. One of these is an edition of Maimonides on idolatry by Dionysius Vossius (1641). The other is a book by Dionysius Vossius' father, Gerardus Joannes, which dealt with the history of idolatry through a wide-ranging examination of pagan, Jewish, and Christian sources. The writings of the Vossius family provide good examples of the books that came to make up the bulk of Newton's library. These were works of erudition, normally published in Newton's lifetime and predominantly written in English or Latin. They were often editions or compilations that based themselves on much earlier writings but were usually themselves the product of humanist techniques of scholarship. Although there is evidence that Newton read many of these books from cover to cover, he also used many of them much more selectively. In particular, it was his habit to mark passages that interested him by turning down page corners so that they pointed to the exact phrase that he wished to recall. These phrases were often themselves references or quotations from other works, perhaps accompanied by translations by the author that Newton was himself reading. Newton would later incorporate the information that he had gathered in this way from his reading into his own theological and historical writing, thus furnishing it with a seemingly inexhaustible range of quotations and source material.

figure 12
Vossius' *De theologia gentili, et physiologia Christiana*, from Newton's library and showing his habit of turning down the corners of pages to mark passages of interest or for quotation, Trinity College, Cambridge, nq 8/46, pp. 654–5.

Gerardus Joannes Vossius (1577–1649) was one of the most prominent scholars of the early seventeenth century. He held a chair of Eloquence and Chronology at Leiden University from 1622, later becoming Professor of Greek as well. In 1632, he delivered the oration that opened the Athenaeum Illustre (the predecessor of the University of Amsterdam), where he was one of two founding professors. He was the author of standard works for the study of Greek and of rhetoric (see catalogue number 2). *De theologia gentili* was the crowning achievement of Vossius' historical writing. It examined a huge range of sources to give an account of the development of polytheistic beliefs in classical, teutonic, oriental, and even American history and mythology. Newton used this book extensively as a source for his own essay, 'Theologiae gentilis origines philosophicae' ('The Philosophical Origins of Gentile Theology'), whose title was even derived from Vossius. Written in the mid-1680s, this work described the form of worship practised by the adherents of the true, primitive religion. It suggested that they had prayed and sacrificed at sacred places where perpetual fires burned. This kind of religious practice had survived in the Temple at Jerusalem and, to some extent, in pagan temples, especially those of the cult of Vesta. Much of the information for Newton's argument could be found in *De theologia gentili*. For example, in the pages on display (pp. 654–5) Vossius quoted several classical authors who had written about the Vestal cult and the establishment of its temple at Rome by Numa Pompilius, the mythical successor of Romulus. These are the passages that Newton marked by turning down the corners of pages 654 and 655, and references to them appear both in his theological writings of the late 1680s and early 1690s and in much later works of chronology and natural philosophy.

Richard S. Westfall, 'Isaac Newton's *Theologiae Gentilis Origines Philosophicae*', in W. Warren Wagar (ed.), *The Secular Mind* (New York, 1982), pp. 15–34; Jewish National and University Library, Jerusalem, Mss. Yahuda 16, 17, 41; John Harrison, *The Library of Isaac Newton* (Cambridge, 1978), pp. 1–27, 58–78, 258; Richard H. Popkin, 'Polytheism, Deism, and Newton', in James E. Force and Richard H. Popkin, *Essays on the Context, Nature, and Influence of Isaac Newton's Theology* (Dordrecht, 1990), pp. 27–42; C.S.M. Rademaker, ss.cc., *Life and Work of Gerardus Joannes Vossius (1577–1649)* (Assen, 1981), pp. 306–10; Nicholas Wickenden, *G.J. Vossius and the Humanist Concept of History* (Assen, 1993), pp. 27–30, 142–51.

Listed by the booksellers who appraised Newton's library for his executors; bought with the rest of the library by John Huggins in 1727. Bookplate of Charles Huggins. Bookplate of James Musgrave, with shelfmark C1–12. Presented to Trinity College, Cambridge, on 30 October 1943 by the Pilgrim Trust.

16 cambridge university library, ms. dd. 9.46, f. 1r

32.6 × 21 cm
110 folio leaves in a modern binding

This manuscript, headed 'De motu Corporum Liber primus', is again in the hand of Humphrey Newton, although the text has been extensively corrected by Newton himself. It was deposited as the lectures given by the Lucasian Professor in 1684 and 1685, and was labelled by Newton to give the appearance that it consisted of nineteen lectures, delivered in two series, beginning in October 1684 and October 1685 respectively. Although Newton had indeed deposited copies of earlier lectures, delivered between 1670 and 1683, it seems most unlikely that he ever delivered this text orally. Rather, it formed a draft for what would become Book I of the *Principia*. The text is broken into two sequences, both incomplete. The first of these contains material relating to the laws of motion and the definitions in Book I; the second, which runs from the corollary to proposition xvi to proposition liv, is much closer to the final manuscript of the *Principia* and includes reworked material from the preceding sequence of pages. Additional material from this draft of the *Principia* may be found in Ms. Add. 3965.3, ff. 7–14; further pages of revisions may also be found elsewhere in the Portsmouth Collection.

Newton probably composed this manuscript between spring and autumn 1685. It was the successor to an earlier treatise ('De motu') that Newton had prepared in the months before November 1684, and greatly expanded its treatment of celestial dynamics. Like its predecessor, 'De motu Corporum Liber primus' was formulated in terms of classical geometry but depended on an understanding of force and motion that derived in part from Newton's own discovery of infinitesimals. It presented Newton's three laws of motion for the first time in the form that they would take in the finished text of the *Principia*.

In addition to its mathematical importance, the manuscript is of interest because of the light that it sheds on Newton's working habits in the mid-1680s. The first page of the text, which is on display, provides a good example. Expanding on his work in 'De motu', Newton composed a series of definitions of matter, motion, and force (Ms. Add. 3965.5, f. 21r) as an introduction to his treatment of the laws of motion. A revised version of this text was then copied by Humphrey Newton, perhaps from dictation by Newton. Newton's amanuensis confined himself to the recto side of each folio, leaving the verso blank for Newton's own alterations and additions. Humphrey Newton's text was generally fluent and carefully written, nevertheless Newton's corrections to it were often brutal. This is especially clear at the start of the manuscript, where Newton has extensively rewritten the 'definitiones', inserting a number of passages that reflect his growing sense of the need for perfect clarity. Some of these alterations (for example, in what became definition 3, 'Materiae vis insita') produced the exact wording that Newton preserved when he had Humphrey Newton write out the manuscript of the printer's copy of the *Principia*. Other changes, for example the cancellation of the original definitions 2 and 3, and the renumbering of the subsequent definitions, represented a partial return by Newton to the form of his earlier draft. Although there is evidence that Newton considered a further expansion of these definitions, in general the corrections that he made in this manuscript established the shape that they would take in the finished text of the *Principia*.

D.T. Whiteside (ed.), *The Preliminary Manuscripts for Isaac Newton's 1687 Principia, 1684–1686* (Cambridge, 1989), pp. xvi–xvii, 37–238 (pp. 37–215 print a facsimile of this manuscript; the folio on display may be found at p. 37); I. Bernard Cohen,

Introduction to Newton's 'Principia' (Cambridge, 1971), pp. 82–98; D.T. Whiteside (ed.), *The Mathematical Papers of Isaac Newton*, 8 vols (Cambridge, 1967–81), vol. 6, especially pp. 92–187; A. Rupert Hall and Marie Boas Hall (eds), *Unpublished Scientific Papers of Isaac Newton* (Cambridge, 1962), pp. 237–92; John Herivel, *The Background to Newton's Principia* (Oxford, 1965), pp. 98–102, 321–6; J. Edleston (ed.), *Correspondence of Sir Isaac Newton and Professor Cotes* (London, 1850), pp. xci-vii; Richard S. Westfall, *Force in Newton's Physics* (London, 1971), pp. 424–525; François de Gandt, *Force and Geometry in Newton's Principia* (Princeton, 1995). Exhibited in 1987: 'The Making of Newton's "Principia" (1664–1687)', case 5, item 1.

17 cambridge university archives, o.iii.8/2

(figure 13)

8.2 × 13.5 cm and 7.7 × 15.1 cm

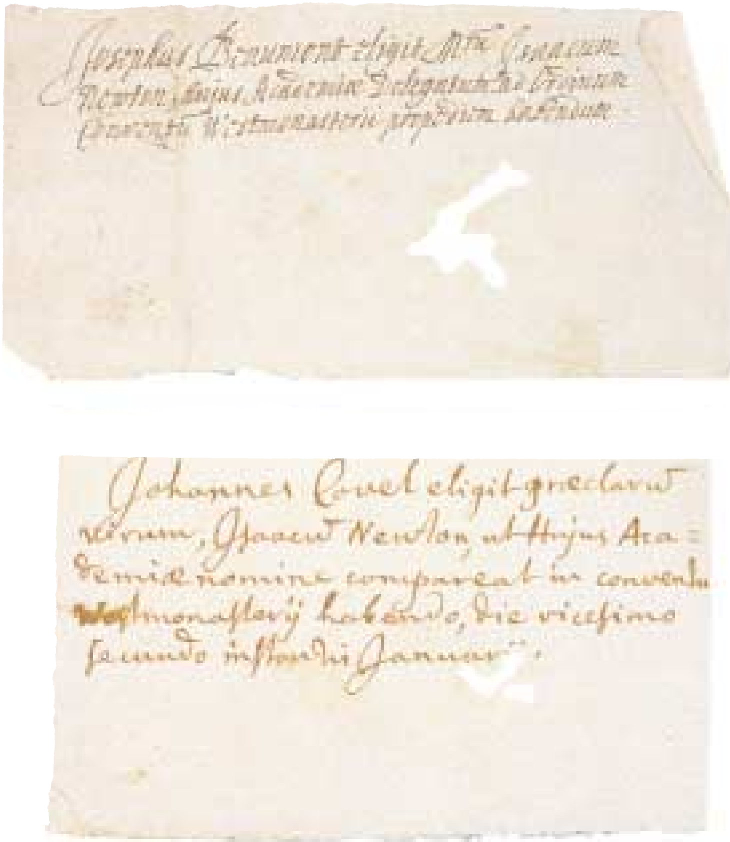

figure 13
Two of the ballots cast for Newton to serve as MP for Cambridge University at the Convention Parliament, 15 January 1689, University Archives, o.iii.8/2.

These two scraps of paper are two of the ballots that were cast for Newton to serve as Member of Parliament for Cambridge University at the Convention Parliament. The election took place on 15 January 1689. The Universities of Oxford and Cambridge had each won the right to send two burgesses to the House of Commons in 1604. Since then, there had been elections for every new Parliament. The Vice-Chancellors of each university usually tried to control these events and the franchise seems to have been limited to senior members who were of the standing of Master of Arts. By the later seventeenth century, it was usual at Cambridge for the vote to be by ballot, although the name of the elector had to be written on the ballot paper as well as the name of the preferred candidate. The Convention was summoned on 29 December 1688, after the landing in England of William of Orange and his successful march on London. It was responsible for the creation of an acceptable constitutional settlement that took into account the flight of James II and the revolutionary events of summer and autumn 1688.

The election in 1689 was a close contest. There were three candidates: Edward Finch of Christ's College, who was brother to one of the candidates in the Oxford University election and to the Earl of Nottingham, one of the peers who had so far supported William of Orange; Sir Robert Sawyer, who may have had the support of the Archbishop of Canterbury, at that stage a prominent critic of James II; and Newton. Despite anxiety about his status as a non-resident member of the University, Sawyer received 125 votes and was elected alongside Newton, for whom 122 votes were cast. 117 electors backed the disappointed Finch.

Newton's success in this contest owed much to the reputation he had forged over the previous two years, when he had helped to lead opposition to James II's attempts to force the University to admit Alban Francis. Francis was a Benedictine monk and it was proposed in February 1687 that he should not have to take the customary oath of allegiance to the Church of England. Newton was one of the ringleaders of resistance to this suggestion and proved a determined (not to say intolerant) defender of the University's privileges from the interference of the king and his allies. Given his own heterodoxy, Newton's concern was perhaps more with the subversion of a Catholic plot than the defence of the Church of England. Nevertheless he was instrumental in constructing the University's case and was one of those chosen to defend it before Judge Jeffreys at the Court of Ecclesiastical Commission. Although the Crown abandoned Father Francis, it was fortunate for Newton that external events altered so quickly in his favour. Once elected as an MP, Newton was a steadfast proponent of the regime created by the Revolution, and, despite his religious scruples, found nothing worthy of objection in oaths of loyalty to the new monarchs, William and Mary. The apparent purity of his ideological credentials also spared him the embarrassing investigations and censure that awaited his fellow burgess, Sawyer.

The two ballots on display were cast by Joseph Beaumont and John Covel. Beaumont (1616–99), Master of Peterhouse and Regius Professor of Divinity, was a powerful defender of the privileges of the Church of England and a stickler for the traditions of the University. He had been one of the most outspoken critics of Henry More and of the Cambridge Platonists. It seems unlikely that he would have given his support to Newton, who had been a friend of More, without the events of 1687–8. Covel (1638–1722), by contrast, was the newly appointed Master of Christ's College and the University's Vice-Chancellor. Between 1681 and 1685 he had been chaplain to the Princess of Orange, who was now about to be proclaimed queen. Covel subsequently relied heavily on Newton's advice from Westminster during 1689, especially on the issue of taking the new oaths.

Newton did not stand for re-election to Parliament in 1690, but was persuaded by his Whig patrons to be a candidate in 1701, when he was again elected for the University. At the election in 1702, he stood down but he was a candidate in 1705, and was knighted by Queen Anne in Trinity College during the run-up to that election. This time, however, Newton received the fewest votes in a field of four candidates. He was humiliated in a bitterly fought party political contest in which knowledge of his friendships and religious leanings, if not of his covert heretical beliefs, may well have contributed to his failure. The mob was said to have cried 'No Fanatic, No Occasional Conformity' against the unsuccessful candidates during the election.

Millicent Barton Rex, *University Representation in England, 1604–1690* (London, 1954), pp. 300–20; Richard S. Westfall, *Never at Rest. A Biography of Isaac Newton* (Cambridge, 1980), pp. 623–6; H. W. Turnbull, J.F. Scott, A.R. Hall and Laura Tilling (eds), *The Correspondence of Isaac Newton*, 7 vols (Cambridge, 1959–77), vol. 2, 467–9; vol. 3, 1–3, 7–8, 10–24.

18 cambridge university library, ms. add. 3966, f. 117r
30 × 18.6 cm

As a result of his political activity and exposure to the world of Westminster, Newton was able to explore the possibility of holding public office. He approached a number of friends during the early 1690s with this in mind. He also allowed himself to be consulted on issues of public policy, especially those in which a knowledge of mathematics played a role (see catalogue number 8). Newton's opportunities increased following the appointment of Charles Montague, who had been a fellow of Trinity, as Chancellor of the Exchequer. Newton's opinion had already been sought in connection with plans for recoinage. On 19 March 1696, Montague invited him to become Warden of the Mint. He perhaps intended this as a sinecure, from which Newton might draw an income of £500 a year. But Newton proved a dedicated public servant. He moved to London and oversaw much of the business associated with calling in old money and issuing new coin. He was zealous in the fight against counterfeiters and helped to plan the establishment of new Mints in regional centres. Following the death of Thomas Neale, Newton was appointed Master of the Mint on 26 December 1699, and was thus relieved of his resentment at having to serve in a subordinate post. Despite the need to provide securities, Newton's new office enabled him to become a rich man through the commission that he received on every pound of gold or silver minted, in addition to his salary of £500. It also made it possible for him to reward relatives, friends, and sympathisers with lucrative jobs. Newton was an active and successful Master, who reintroduced strict measures in coining and presided over several new ventures, generally attempting to raise the standard not only of gold and silver money but also of copper coin.

The letter on display is typical of many documents from Newton's time at the Mint. Although he was now wealthy, Newton's habit of saving scraps of paper for his own use did not die just because more and more business passed over his desk. Almost immediately after his nomination as Master of the Mint, Newton received this letter from Robert Blackborne at East India House, dated 30 December 1699. Its business related to an issue with which Newton had been familiar as Warden, the control of the machinery for minting coin. Blackborne was responding to a query from Newton about the right of the East India Company to request mills and presses from the Mint. Newton, however, preserved the paper generated by this routine matter and drew on it a few months later when he was engaged in calculations for his theory of the moon's motion. He covered Blackborne's original letter with calculations of the relative positions of the sun and the moon. These included estimates of the position of the sun and the moon at Greenwich on 1 January 1701 and may have related to a memorandum about the reform of the calendar that Newton prepared for the Royal Society in April 1700. Yet Newton's interest in calculating positions of the moon also played a larger role in his work at this time.

By February 1700, Newton had shared his ideas about the motion of the moon with his friend and client, the Scottish mathematician and Professor of Astronomy at Oxford, David Gregory. Gregory published Newton's lunar theory in Latin in 1702, and an English translation appeared in the same year. It represented an unsuccessful attempt to expand on the findings of the first edition of the *Principia*, in particular through the consideration of how three gravitating bodies (the sun, the earth, and the moon) act upon one another in a single system. It also promised to yield useful information for navigation at sea. Newton, however, found it impossible to derive the inequalities of the moon's motion from his theory of gravity, although he did set out the range of observations necessary to make accurate calculations. He incorporated a number of corrections to the account of the moon in the *Principia* (see catalogue number 43) as a new scholium to proposition xxxv of Book III of the second edition (1713) and continued to revise this part of the work in the third edition (1726).

Like so much of Newton's work on celestial dynamics, his theory of the moon's motion depended on access to accurate astronomical observations taken over a long period of time. In addition to historical series, especially those of the late sixteenth-century Danish astronomer Tycho Brahe, Newton based himself on information provided by his own observations and those of his contemporaries. The Astronomer Royal, John Flamsteed, was by far the most reliable source of this material, derived from his observations at Greenwich. Under strict conditions of secrecy, Flamsteed agreed to feed Newton with observations of the moon from 1694, but the two men had begun to quarrel by the beginning of 1699. Newton was subsequently able to use the political influence at his disposal to try to force Flamsteed to provide him with information. In particular, he was instrumental in the establishment of a

Committee of Referees to oversee the publication of Flamsteed's long-delayed star catalogue. But political change and delays at the press, allied to Falmsteed's intransigence, obstructed Newton's plans. By 1714, Flamsteed was at last able to break free of the controls that Newton had imposed.

Sir John Craig, *Newton at the Mint* (Cambridge, 1946); Richard S. Westfall, *Never at Rest. A Biography of Isaac Newton* (Cambridge, 1980), pp. 551–626; H. W. Turnbull, J.F. Scott, A.R. Hall and Laura Tilling (eds), *The Correspondence of Isaac Newton*, 7 vols (Cambridge, 1959–77), vol. 4, 195, 317–8 (printing this letter), 322–48; I. Bernard Cohen (ed.), *Isaac Newton's Theory of the Moon's Motion (1702)* (London, 1975); Francis Baily (ed.), *An Account of the Revd. John Flamsteed* (London, 1835).

Presented to Cambridge University Library by the fifth Earl of Portsmouth. See *A Catalogue of the Portsmouth Collection of Books and Papers written by or belonging to Sir Isaac Newton* (Cambridge, 1888), pp. 5–6.

19 cambridge university library, ms. add. 3966, f. 232r
30.6 cm × 20 cm

This page comes from one of a number of tables of eclipses of the sun and the moon that Newton prepared, using data derived largely from the observations of Tycho Brahe and John Flamsteed. It helps to demonstrate the dependence of Newton's work on the history of astronomical observation as well as on the work of his contemporaries. Although it is hard to be certain of its date, it may well have been compiled in the mid-1690s, when Newton and Falmsteed corresponded extensively about lunar eclipses. At that time, Newton was also collecting the data for his theory of the moon's motion.

H. W. Turnbull, J.F. Scott, A.R. Hall and Laura Tilling (eds), *The Correspondence of Isaac Newton*, 7 vols (Cambridge, 1959–77), vol. 4, 73–114.

Presented to Cambridge University Library by the fifth Earl of Portsmouth. See *A Catalogue of the Portsmouth Collection of Books and Papers written by or belonging to Sir Isaac Newton* (Cambridge, 1888), pp. 5–6.

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