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The Enigma of Newton's Alchemy

THE HISTORICAL RECEPTION

When Isaac Newton died in 1727, he had already become an icon of reason in an age of light. The man who discovered the laws governing gravitational attraction, who unveiled the secrets of the visible spectrum, and who laid the foundations for the branch of mathematics that today we call calculus, was enshrined at Westminster Abbey alongside the monarch who had ruled at his birth. Despite having been born the son of a yeoman farmer from the provinces, Newton was eulogized on his elaborate monument as "an ornament to the human race." Perhaps playing on the illustrious physicist's fame for his optical discoveries, the most celebrated English poet of his age, Alexander Pope, coined the famous epitaph "Nature and Nature's Laws lay hid in Night. God said, *Let Newton be!* and All was *Light*."[1] Thus God's creation of Newton became a second *fiat lux* and the man himself a literal embodiment of the Enlightenment.

Little did Pope know that in the very years when Newton was discovering the hidden structure of the spectrum, he was seeking out another sort of light as well. The "inimaginably small portion" of active material that governed growth and change in the natural world was also a spark of light, or as Newton says, nature's "secret fire," and the "material soule of all matter."[2] Written at the beginning of a generation-long quest to find the philosophers' stone, the summum bonum of alchemy, these words would guide Newton's private chymical research for decades. Even after taking charge of the Royal Mint in 1696, Newton was still actively seeking out the fiery dragon, the green lion, and the liquid that went under the name of "philosophical wine," a libation fit for transmutation rather than consumption.[3] Most compellingly of all, Newton was on the path to acquiring the scepter of Jove and the rod of Mercury, along with the twin snakes "writhen" around the staff that

[1] Alexander Pope, "Epitaph: Intended for Sir Isaac Newton, in Westminster Abbey," in *The Poems of Alexander Pope*, ed. John Butt (New Haven, CT: Yale University Press, 1963), 808. For Newton's eighteenth-century reputation more broadly, see Mordechai Feingold, *The Newtonian Moment* (New York: New York Public Library, 2004).

[2] Smithsonian Institution, Dibner MS 1031B, 6r, 3v.

[3] See chapter nineteen herein for Newton's late use of these terms.

would convert it into the wonder-working caduceus of the messenger god. All these exotic names referred to the material tools of the adepts, the *arcana majora* or higher secrets with whose help they hoped to transform matter from its base and fickle state into the immutable perfection of gold.

The omission of alchemy from Pope's eulogy was of course no accident. Even if the "wasp of Twickenham" had known of Newton's alchemical research, he would certainly not have used it as a means of lionizing the famous natural philosopher. By the 1720s the part of chymistry that dealt with the transmutation of metals, *chrysopoeia* (literally "gold making"), was coming under siege in many parts of Europe. But in the second half of the seventeenth century, when Newton did the bulk of his alchemical research, transmutation had formed a natural part of the chymical discipline, and indeed the term "chymistry" had long been coextensive with "alchemy." Both words had signified a comprehensive field that included the making and refining of pharmaceuticals and the production of painting pigments, fabric dyes, luminescent compounds, artificial precious stones, mineral acids, and alcoholic spirits alongside the perennial attempt to transmute one metal into another.[4] A slow process of separation was already underway by the final quarter of the century, however, and by the second and third decades of the *siècle des lumières* such chymical authorities as Georg Ernst Stahl and Herman Boerhaave, who had long upheld the traditional principles and purview of alchemy, were expressing their doubts about chrysopoeia in a highly public way.[5] Thus when the antiquarian William Stukely compiled a draft biography of Newton after his friend's death, he went so far as to suggest that Newton's work in chymistry had the potential of freeing the subject from an irrational belief in transmutation.[6] Ironically, Newton the alchemist had been transmuted into Newton the Enlightenment chemist.

Yet the celebration of the founder of classical physics as a beacon of pure reason had already begun to show signs of wear when David Brewster composed a biography in 1855 in which he was compelled to come to terms with the fact that Newton had studied alchemy. Brewster expressed his amazement that Newton "could stoop to become even the copyist of the most contemptible alchemical poetry," a fact that the Scottish scientist could only explain as the mental folly of a previous age.[7] The few lines that Brewster devoted to the topic were largely ignored until 1936, when the bulk of Newton's

[4] The archaic spelling "chymistry" has been adopted by scholars to signify this overarching field that combined medical, technical, and chrysopoetic endeavors in the early modern period. See the online *Oxford English Dictionary* under the term "chemistry," where further documentation is given (accessed June 9, 2017).

[5] For Stahl's gradual conversion to a critic of chrysopoeia, see Kevin Chang, "'The Great Philosophical Work': Georg Ernst Stahl's Early Alchemical Teaching," in *Chymia: Science and Nature in Medieval and Early Modern Europe*, ed. Miguel López Pérez, Didier Kahn, and Mar Rey Bueno (Newcastle upon Tyne: Cambridge Scholars, 2010), 386–96. For the similar process of disenchantment in the case of Boerhaave, see John Powers, *Inventing Chemistry: Herman Boerhaave and the Reform of the Chemical Arts* (Chicago: University of Chicago Press, 2012), 170–91.

[6] RS MS/142, folio 56v, from *NP* (http://www.newtonproject.sussex.ac.uk/view/texts/diplomatic/OTHE00001), accessed June 7, 2016.

[7] Sir David Brewster, *Memoirs of the Life, Writings, and Discoveries of Sir Isaac Newton* (Edinburgh: Thomas Constable, 1855), 2: 375.

surviving manuscripts on alchemy and religion were auctioned by Sotheby's in London. Suddenly a very different Newton was thrust into the light, one who had written perhaps a million words on alchemy and even more on religious subjects ranging from biblical prophecy and the dimensions of Solomon's temple to the perfidy of the orthodox doctrine of the Holy Trinity. The cognitive dissonance that these manuscripts inevitably summoned up was captured by the economist John Maynard Keynes, who collected a large number of them for King's College, Cambridge. In his famous posthumous essay "Newton, the Man," published in 1947, Keynes wrote that

> Newton was not the first of the age of reason. He was the last of the magicians, the last of the Babylonians and Sumerians, the last great mind which looked out on the visible and intellectual world with the same eyes as those who began to build our intellectual inheritance rather less than 10,000 years ago. . . . He believed that by the same powers of his introspective imagination he would read the riddle of the Godhead, the riddle of past and future events divinely fore-ordained, the riddle of the elements and their constitution from an original undifferentiated first matter, the riddle of health and of immortality.[8]

In the same article, Keynes would add that Newton's alchemical manuscripts were "wholly magical and wholly devoid of scientific value." Yet despite the pejorative tone of these comments, Keynes was not operating in a naive or unreflective way when he dismissed Newton's alchemy as magic. His 1921 *Treatise on Probability* had argued against "the excessive ridicule" that moderns tended to levy on primitive cultures, and he even went so far as to locate the origins of induction in the magician's attempt to recognize patterns in nature. Keynes would support this claim with observations drawn from the Victorian masterpiece of Sir James Frazer, *The Golden Bough*.[9] Frazer's massively influential study of mythology had used the principle of sympathy (the belief that "like acts on like") to group a wide variety of practices under the rubric of "magic."[10] A similar approach emerges in "Newton, the Man," although it is obscured by the rhetorical brilliance of the essay, with its overriding goal of toppling the traditional image of Newton the rationalist. Like Frazer, Keynes assimilated various "occult" pursuits such as alchemy and the quest for secret correspondences in nature under the same amorphous category, labeling them as magical.[11] It is highly likely that Keynes had Frazer in the back of his mind when he unselfconsciously elided the borders between magic and alchemy, two disciplines that Newton for the most part kept rigorously distinct.

[8]John Maynard Keynes, "Newton, the Man," in *Newton Tercentenary Celebrations, 15–19 July 1946* (Cambridge: University Press, 1947), 27–34, see 27.

[9]John Maynard Keynes, *A Treatise on Probability* (London: Macmillan, 1921), 245–46.

[10]Frazer's *Golden Bough* was originally published in two volumes in 1890, but eventually swelled to twelve volumes. For his treatment of the principle of sympathy, see James Frazer, *The Golden Bough* (New York: Macmillan, 1894), 9–12.

[11]For my objections to this type of lumping approach when it comes to the "occult sciences," see William R. Newman, "Brian Vickers on Alchemy and the Occult: A Response," *Perspectives on Science* 17 (2009): 482–506.

The Keynesian picture of Newton as the last of the magicians rather than as the father of the Enlightenment amounted to a radical inversion of the Augustan view: no longer a herald of light, the founder of classical physics now looked back to a dark and fabulous past. This new image of a brooding and troubled Newton buried in the decipherment of riddles "handed down by the brethren in an unbroken chain back to the original cryptic revelation in Babylonia" would go on to exercise its own attraction. One can see the influence of Keynes very clearly in the work of two eminent Newton scholars of the late twentieth century, Betty Jo Teeter Dobbs and Richard Westfall. Both Dobbs and Westfall were pioneers in the scholarly study of Newton's alchemy, and their work has provided an indispensable basis for subsequent research in the field, including my own. One cannot doubt the seriousness of their scholarship, the years that they devoted to understanding Newton, or the significance of their contributions. Yet as we shall see, their embrace of the Keynesian perspective could at times exert its own smothering grip on their critical judgment.

Dobbs, whose 1975 *The Foundations of Newton's Alchemy; or, "The Hunting of the Green Lyon"* provided the first full-length study of Newton's alchemical endeavors, came to the eventual conclusion that alchemy for Newton was above all a religious quest.[12] Although she did not endorse Keynes's blanket assertion that Newton's alchemical writings were a worthless farrago, and even criticized the famous economist for his failure to consider Newton's alchemical experiments, Dobbs built on the idea that alchemy itself incorporated a fundamentally irrational core. Her *Foundations of Newton's Alchemy* contains a largely approving exposition of the analytical psychologist Carl Jung's position that alchemical imagery embodied an "irruption" of the mind's unconscious contents and that alchemy was largely a matter of "psychic processes expressed in pseudo-chemical language," implying that something other than scientific or even material goals were the main driving force behind the aurific art.[13] Dobbs's 1991 *The Janus Faces of Genius: The Role of Alchemy in Newton's Thought* dropped this explicit adherence to Jung's analytical psychology, but nonetheless developed a favorite thesis of Jung's, namely, that the alchemical search for the philosophers' stone was primarily a quest to reunite man with the creator, a form of soteriology. Hence *The Janus Faces of Genius* gives the impression that Newton's alchemy was above all a vehicle for his heterodox religious quest, and that he thought of the philosophical mercury of the alchemists as a spirit that mediated between the physical and transcendent realms in a way analogous to the mediation of Jesus between God and man.[14]

Newton's alchemy also appears through Keynes-tinted glasses in the work of Dobbs's contemporary Westfall, though in a slightly different fashion.

[12] This is not the case in Dobbs's first book, however, where she in fact attacks Mary Churchill for overemphasizing the religious aspect of Newton's alchemy. See Dobbs, *FNA*, 15–16. As her study of Newton's alchemy extended itself over time, Dobbs came more and more to stress its putative religious goals.

[13] Dobbs, *FNA*, 25–43. Despite her affirmation of the Jungian approach to alchemy as "really promising," on page 25, Dobbs does exercise a degree of critical restraint when she correctly describes Jung's views on page 40 as "basically a-historical."

[14] Dobbs, *JFG*, 13, 243–48.

While Westfall seems to have remained impartial to the Dobbsian position that Newton's alchemy was coextensive with his private religion, he did see Newton's interest in the aurific art as a sort of romantic rebellion against the rationalist project of Cartesian physics, harking back to "the hermetic tradition" of late antiquity and the Renaissance.[15] To Westfall, alchemy and magic were characterized by a fascination with immaterial qualities, powers, sympathies, and antipathies, in short, the very antithesis of the Cartesian billiard-ball universe with its attempt to reduce nature to a succession of impact phenomena. Hence Westfall could argue that Newton's alchemy, although it lay outside the domain of rationalist natural philosophy, contributed in a major way to his mature theory of gravitation, and more broadly to his conviction that immaterial forces in general could operate at a distance. Westfall would explicitly argue that Newton's concept of force at a distance "derived initially from the world of terrestrial phenomena, especially chemical reactions." In fact, he even went so far as to claim that Newton's concept of gravitational attraction emerged only after "he applied his chemical idea of attraction to the cosmos."[16]

Westfall's claim that alchemy was behind Newton's theory of universal gravitation was adopted in turn by Dobbs in her *Foundations of Newton's Alchemy*, while her theocentric interpretation of his quest for the philosophers' stone dominated *The Janus Faces of Genius*. Largely as a result of these scholars' authoritative status, the view that Newton's theory of gravity owed a heavy debt to alchemy has become canonical in the popular literature.[17] Current scholarly treatments of the subject endorse the authoritative status of Dobbs and Westfall as well, restating the former's view that Newton aimed "to capture the essence of the Redeemer in a beaker" and asserting with both scholars that alchemy "may have helped him to conceptualize the idea of gravity."[18] It is not too much to say that the picture of Newton's alchemy as a largely theocentric pursuit that contributed to his science by allowing for a rebaptizing of magical sympathy as gravitational attraction has become the received view of the subject.

But there are compelling reasons for doubting this interpretation. The once popular notion that alchemy was inherently unscientific—already present in the work of Keynes and advanced by successive Newton scholars—has been largely debunked by historians of science over the last three decades. Indeed, the historiography of alchemy has recently undergone a sort of renaissance that

[15] In his 1971 book *Force in Newton's Physics*, Westfall explicitly linked gravitational force to alchemy and to what he called "the hermetic tradition," a term that clearly betrays the influence of Frances Yates's 1964 *Giordano Bruno and the Hermetic Tradition*. See Richard Westfall, *Force in Newton's Physics* (London: MacDonald, 1971), 369.

[16] Richard Westfall, "Newton and the Hermetic Tradition," in *Science, Medicine, and Society in the Renaissance*, ed. A. G. Debus (New York: Science History Publications, 1972), 2: 183–98, see 193–94.

[17] See for example Michael White, *Isaac Newton the Last Sorceror* (New York: Basic Books, 1997), 106, 207, and throughout. The view that Newton's concept of gravitational attraction owes an important debt to alchemy even receives support in the current Wikipedia entry on Newton. See https://en.wikipedia.org/wiki/Isaac_Newton, accessed January 22, 2016.

[18] Paul Kléber Monod, *Solomon's Secret Arts* (New Haven, CT: Yale University Press, 2013), 104.

has reversed the picture of the aurific art as an atavistic outlier.[19] It is now well known that such luminaries of the scientific revolution as Robert Boyle, G. W. Leibniz, and John Locke were all seriously involved in alchemy; Newton was no anomaly.[20] All of these figures engaged in the broad spectrum of chymical practice, seeing it as a fruitful source of pharmaceutical and technological products and yet hoping as well that it might reveal the secret of metallic transmutation. Chymistry was a natural and normal part of the progressive agenda of seventeenth-century science. Hence the need that Dobbs and others felt to locate Newton's motives for studying alchemy in extrascientific areas such as soteriology and the quest for a more primitive Christianity has lost its force. We are now free to study Newton's alchemy on its own terms and to arrive at a much clearer picture of the field's relationship to his other scientific pursuits. As I show in *Newton the Alchemist*, the claims that Westfall (and subsequently Dobbs) made for an alchemical origin to Newton's theory of gravitational attraction are actually quite weak; in reality, the connection between alchemy and Newton's better known scientific discoveries lies elsewhere, above all in the realm of optics.[21]

Nonetheless, when first confronted by the sheer volume of Newton's million or so words on alchemy, one can only sympathize with the attempts of Westfall and Dobbs to cast about for a means of interpreting this intractable material. Finding the source of Newton's belief in forces acting at a distance in alchemy or linking the subject to his Antitrinitarian Christianity are both ways of rationalizing the immense amount of time and work that he devoted to the aurific art. Nor are these the only motives that historians have claimed to lie buried within the chaotic mass of Newton's alchemical papers. Karin

[19] For a good overview of the current scholarly position of chymistry and some reflections on the earlier historiography, see the four recent essays by Lawrence M. Principe, William R. Newman, Kevin Chang, and Tara Nummedal collected and introduced by Bruce Moran for the "Focus" section of *Isis*: Bruce T. Moran, "Alchemy and the History of Science," *Isis* 102 (2011): 300–337. Additionally, one should consult Moran's *Distilling Knowledge: Alchemy, Chemistry, and the Scientific Revolution* (Cambridge, MA: Harvard University Press, 2005); Newman's *Promethean Ambitions: Alchemy and the Quest to Perfect Nature* (Chicago: University of Chicago Press, 2004); Nummedal's *Alchemy and Authority in the Holy Roman Empire* (Chicago: University of Chicago Press, 2007); and Principe's *Secrets of Alchemy* (Chicago: University of Chicago Press, 2013). Another helpful study is Jennifer M. Rampling, "From Alchemy to Chemistry," in *Brill's Encyclopedia of the Neo-Latin World*, ed. Philip Ford, Jan Bloemendal, and Charles Fantazzi (Leiden: Brill, 2014), 705–17. In the context of the recent historiography of chymistry, one cannot pass over the magisterial study of Paracelsianism in France by Didier Kahn, *Alchimie et Paracelsisme en France à la fin de la Renaissance (1567–1625)* (Geneva: Droz, 2007).

[20] Boyle's career-long involvement in the quest for chrysopoeia forms the subject of Principe, *AA*. A recent article that presents and critiques the earlier historiography of Leibniz's involvement with alchemy may be found in Anne-Lise Rey, "Leibniz on Alchemy and Chemistry," in the online *Oxford Handbook of Leibniz* (http://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780199744725.001.0001/oxfordhb-9780199744725-e-32), accessed June 9, 2017. For Locke and chrysopoeia, see Peter R. Anstey, "John Locke and Helmontian Medicine," in *The Body as Object and Instrument of Knowledge*, ed. Charles T. Wolfe and Ofer Gal (Dordrecht: Springer, 2010), 93–120. See also Guy Meynell, "Locke and Alchemy: His Notes on Basilius Valentinus and Andreas Cellarius," *Locke Studies* 2 (2002): 177–97.

[21] Dobbs herself argued for an influence from alchemy on Newton's optics, but her claims have been debunked by Alan Shapiro. See Dobbs, *FNA*, 221–25, and Shapiro, *FPP*, 116n48. The interaction between Newtonian optics and chymistry that I envision is quite distinct from the one Dobbs maintained. See the present book and also William R. Newman, "Newton's Early Optical Theory and Its Debt to Chymistry," in *Lumière et vision dans les sciences et dans les arts*, ed. Danielle Jacquart and Michel Hochmann (Geneva: Droz, 2010), 283–307.

Figala, who did exemplary work in digging up Newton's chymical collaborations and making sense of the bibliographical entries in his notes, arrived at a grand but poorly substantiated thesis that explained the bulk of Newton's alchemy in terms of specific gravity. Basing herself on Newton's view that ordinary matter consists of corpuscles that are themselves mostly made up of empty space, Figala developed mathematical schemes linking the supposed amount of void and matter in materials to the traditional alchemical principles mercury and sulfur.[22] The problem with her interesting idea is that Newton nowhere makes this linkage himself; in fact, a close reading of his alchemical laboratory notebooks shows that he rarely even mentioned specific gravity in the context of his chymical experimentation. The only way to reconstruct the supposed system Figala found is by assuming that Newton left it entirely implicit, and that the historian must reconstruct it from tacit clues by a process that altogether resembles second-guessing. But this in turn requires that we ignore more obvious approaches taken by Newton, such as his deep concern with the affinities between chemicals that guide their bonding and dissociation.

Yet another approach to Newton's alchemy may be found in *The Expanding Force in Newton's Cosmos* by David Castillejo, which provides an extreme instance of the Keynesian perspective.[23] To Castillejo, Newton's optics, dynamical physics, prophecy, and the interpretation of the dimensions in Solomon's Temple are all part and parcel of the same project as his alchemy. Here we see the Babylonian magus again regarding the cryptogram of the universe and searching for the hidden clues that God has implanted in the cosmos. Castillejo's research led him to the conclusion that Newton had discovered a "single expansive force" that contrasted with the "contractive force" of gravity and operated at all levels of being. To Castillejo's Newton, the same mathematical relations governing this expansive force are operative in the dimensions of Solomon's Temple and in the corpuscular structure of matter at the microlevel. And for Castillejo, Newton's expansive force is coterminous with the cause of fermentation, which the physicist claimed to be a fundamental force of nature in his *Opticks*. Despite several significant contributions that lie buried in *The Expanding Force in Newton's Cosmos*, much of the numerology that Castillejo claims to find in Newton's work, he has forcibly imposed on the text. It is a peculiar irony that both Castillejo and Figala seem to be unriddling Newton's alchemical papers in much the same way that Keynes claimed Newton to be unriddling the cryptogram of nature itself.

The Tower of Babel presented by the wildly divergent claims of Dobbs, Westfall, Figala, and Castillejo should alert us to the gargantuan difficulties residing in Newton's alchemical *Nachlass*. Although the material is voluminous and disordered, with few obvious indications of the times at which the different papers were composed, these are the least of the problems.

[22] Karin Figala, "Newton as Alchemist," *History of Science* 15 (1977): 102–37, see especially 113–28.

[23] David Castillejo, *The Expanding Force in Newton's Cosmos* (Madrid: Ediciones de arte y bibliofilia, 1981), 17–30, 105–17.

The greatest difficulty stems from the fact that Newton was writing only for himself, and as he progressed more deeply into the literature of alchemy, he assumed the voices and literary techniques of the authors he was reading. As I describe at length in the present book, he took from his sources a veritable language of cover names or *Decknamen* (to employ the German term adopted by historians of alchemy) for the materials with which he was working. Decoding these terms presents difficulties that are grueling at best, since even when we understand a particular author's original meaning, Newton's interpretation often differs strikingly from that of his source. As a result, our hard-won knowledge of other seventeenth-century chymists and their techniques can mislead us as often as it helps us in deciphering Newton's laboratory records and reading notes. A case in point may be found in Newton's pervasive use of the American chymist George Starkey, who wrote elegant Latin treatises on chrysopoeia under the pseudonym of "Eirenaeus Philalethes" (a peaceful lover of truth). Although modern scholarship has probed the depths of Starkey's alchemy and acquired a clear understanding of his processes, the celebrated physicist held an idiosyncratic interpretation of the Philalethan corpus that can only be deciphered by careful analysis of Newton's notes and experiments, and sometimes by disregarding Starkey's original sense.

The Method of the Present Work

How then can we extricate any stable meaning from the shifting and cacophonous world presented by Newton's note taking, derived as it was from the enigmatic utterances of authors whose works were written over a range of cultures and centuries? There is in fact a way, and one that previous scholars have not sufficiently used. I refer to a twofold method that incorporates rigorous textual analysis with laboratory replication of Newton's alchemical experiments. The close analysis of documents needs no justification, having a long and distinguished pedigree extending back to the philological efforts of the nineteenth century and before. "Experimental history," on the other hand, is only now coming into its own among scholars. This is the branch of historical endeavor that involves replication, or if one prefers, "reworking" or "reconstruction" of old techniques and experiments. Just as experimental archaeologists have long been reproducing the techniques that allowed premodern cultures to create the artifacts that populate current-day museums, so historians of science have in recent years come to see the need for a "hands-on" approach to the study of old experiments. The history of chemistry has proven to be a particularly rich area of study for experimental history, and it dovetails closely with the long-standing field of conservation science, a discipline that has traditionally given rigorous attention to the material composition of painters' pigments. Newton's experimental notebooks cry out for this approach, because of the wealth of technical, even artisanal detail that they contain and because of the tacit laboratory-based skill on which they rely. Without some mastery of seventeenth-century chymical techniques, the scholar simply cannot make serious headway against the flood of *termini technici* that make up Newton's notebooks. A recent issue of the journal *Ambix* devoted to experimental history indicates that reproducing experiments can result in "the uncovering of details, difficulties, and solutions left unrecorded or only hinted at by the original experimenter."[24] While endorsing this sentiment, I would go even further in the case of Newton's experimental work in alchemy. Because of his perennial use of *Decknamen* and proprietary names for materials, one cannot even identify the basic subjects of his experimentation without firsthand knowledge of the materials that were available to him. Newton's idiosyncratic terms such as "liquor of antimony" and "sophic sal ammoniac" could in principle mean many different things; only by carefully analyzing his comments and actually putting them to the test in a laboratory can we determine the precise sense of his words.

At the same time, the new digital edition of Newton's extensive alchemical laboratory records on Indiana University's *Chymistry of Isaac Newton* site (www.chymistry.org) has also allowed me to provide the first comparative, in-depth study of these essential documents. Two of them, Cambridge University Additional manuscripts 3973 and 3975, are found in the collection of Portsmouth manuscripts in the Cambridge University Library; the third is a single sheet belonging to the collections of the Boston Medical Library.[25] These remarkable notebooks chronicle Newton's laboratory experimentation for a period of at least three decades. The importance of the first two documents has long been recognized, but Newton's use of his proprietary *Decknamen* and the absence of explicit goals and conclusions in the notebooks render it extraordinarily difficult to make sense of them. Nonetheless, laboratory replications performed on a number of the experiments have led to the unraveling of many of their secrets. Understanding Newton's experiments in turn provides a link to both the Helmontian chymistry of his contemporaries such as Robert Boyle and George Starkey and to the mythological and allegorical output of chrysopoetic authors such as the obscure Johann de Monte-Snyders.

An additional key to Newton's laboratory practice is the remarkable and hitherto unstudied letter written to him by his friend and alchemical collaborator Nicolas Fatio de Duillier in August 1693.[26] In this document, Fatio quotes Newton's Latin directions for making the products that underlie the latter's famous—and famously indecipherable—*Praxis* manuscript, which is

[24] Hjalmar Fors, Lawrence M. Principe, and H. Otto Sibum, "From the Library to the Laboratory and Back Again: Experiment as a Tool for Historians of Science," *Ambix* 63 (2016): 85–97, see 94.

[25] One must not neglect to mention the important article by A. Rupert Hall and Marie Boas Hall, "Newton's Chemical Experiments," *Archives internationales d'histoire des sciences* 11 (1958): 113–53. The Halls analyzed CU Add. 3975 and 3973, but were unaware of the Boston Medical Library manuscript. Moreover, they were hampered by an unnecessarily negative view of alchemy and relied on purely "armchair" chemistry for their interpretations, replicating none of Newton's experiments. Their contemptuous perspective on alchemy led to a misunderstanding of Newton's goals, and their untested guesses about his laboratory work resulted in many misidentifications of his materials and products.

[26] William Andrews Clark Memorial Library, MS F253L 1693. I thank Scott Mandelbrote for originally bringing this letter to my attention.

sometimes described as his most important alchemical writing. Directions for making such desiderata as volatile Venus, sophic sal ammoniac, the scythe of Saturn, and the sword ("fauchion") of Mars all appear in Fatio's letter, but in a simplified form intended for replication by experimenters lacking Newton's years of experience with these materials. Along with Newton's laboratory notebooks, Fatio's letter makes it possible to reassemble the processes that Newton thought would lead eventually to the summum bonum of alchemy, and indeed the key to nature itself, the philosophers' stone. Using these documents as a guide, I have replicated a number of the stages in Newton's master process, and the results show why one of the most perspicacious experimenters of all time thought that his alchemical laboratory work was leading to success after decades of unremitting labor at the bench.

The physical replication of Newton's experiments is therefore a necessary tool for understanding his alchemical writings. But of course it is only one instrument among many that we must employ in a coordinated effort to extract meaning from these extraordinarily difficult texts. Another essential feature of our analysis relies on Newton's habit of providing the plain sense of a particular passage that he has extracted from his sources in square brackets or parentheses. These bracketed or parenthetical interpolations often act as a sort of Rosetta stone for arriving at Newton's understanding of a particular text. Although the Newton scholars mentioned above were all aware of this annotating practice, they did not make a systematic study of the way in which Newton's bracketed interpretations grew and developed over time. Thanks to the recent emergence of digital, searchable editions of Newton's manuscripts, however, this has become far more feasible. The *Chymistry of Isaac Newton* site has put about three-quarters of Newton's alchemical manuscripts online in edited form, and *The Newton Project* at Oxford University (http://www.newtonproject.ox.ac.uk) has performed a similar service for his religious writings. These digital editions have made it far more feasible to find bracketed expressions and detect parallel passages among widely distributed Newtonian manuscripts, thus allowing us to draw hitherto unsuspected comparisons among his writings. Advanced computational techniques available only for digital corpora such as latent semantic analysis have also facilitated this goal.[27] As a result, *Newton the Alchemist* is the first book to provide a picture of Newton's alchemy as it transformed from its earliest stages in the 1660s up to its full maturity and even after his transfer to London in 1696.

Although many problems remain, we are now well on our way to understanding why the warden and then master of the Royal Mint in his spare time jotted alchemical pseudonyms on his papers related to the Great Recoinage at the end of the seventeenth century.[28] Employing the common

[27] The *CIN* site features a Latent Semantic Analysis functionality, which allows parallel passages (even fuzzy ones) to appear automatically. See www.chymistry.org under "Online Tools." This tool was designed and implemented by Wallace Hooper.

[28] Babson 1006, 1r. It is of course possible in principle that Newton was reusing old paper on which his alchemical pseudonyms had been previously recorded. Even if that should turn out to be the case, however, we know from other sources that Newton was actively collaborating on an alchemical project with the London

early modern practice of hiding one's identity behind an anagram, Newton created two columns of alternative pseudonyms based on the Latin form of his name, "Isaacus Neuutonus." One of these, "Venus ac Jason tuus" conjures up both the classical goddess of love and the Argonaut who circled the globe in search of the golden fleece, a common symbol for the alchemical magnum opus. Although Newton famously eschewed the charms of Venus, his notes reveal that he was still dreaming of the philosophers' stone in the midst of his mission to purify the currency of England and to punish those who debased its coinage. His involvement with alchemy was still active around the time of his elevation to president of the Royal Society in 1703 and even persisted through his acquisition of a knighthood in 1705. Behind the authoritarian visage that controlled the Mint and dominated the Royal Society, the quest that ravished Newton as a young scholar intent on acquiring the caduceus of Mercury was still intact, and for all we know, his interest in the subject never died. Even in his old age, Newton told the husband of his niece, John Conduitt, that "if he was younger he would have another touch at metals."[29]

What Did Newton Want from Alchemy? A Road Map for the Reader

The proper understanding of Newton's alchemy presents an enduring puzzle to contemporary scholarship in much the same way that the decipherment of hieroglyphics or the solution to the Greek script known as Linear B challenged Egyptologists and Hellenists in the nineteenth and twentieth centuries. Although Newton's peculiar alchemical "language" was the creation of one man building on his forebears rather than the dialect of an entire civilization, the linguistic difficulties that it presents share some similarities with these ancient scripts, particularly in Newton's creation of the idiosyncratic graphic symbols introduced in our foreword. Yet Newton's alchemy, even though it offers serious difficulties of language, cannot be deciphered by linguistic means alone; it requires a knowledge of materials, technologies, and tacit practices as well as underlying theories submerged beneath the written word. No book that does full justice to the difficulties presented by Newton's generation-long experimental research project centered on alchemy can be light reading. Newton's purpose and methods were obscure enough to mislead four dedicated scholars, as we have seen, each of them blinkered by a preconceived thesis. In order to avoid adding to the collective misunderstanding of Newton's goals and methods, I have made an effort to assess the evidence in all of its details. This is the only way to arrive at any degree of certainty as to what Newton was doing for over thirty years in his study as he devoured alchemical books and manuscripts, and then tried

distiller William Yworth in the first decade of the eighteenth century, well within his Mint period. See chapter nineteen of the present book as well as Karin Figala and Ulrich Petzold, "Alchemy in the Newtonian Circle," in *Renaissance and Revolution: Humanists, Scholars, Craftsmen, and Natural Philosophers in Early Modern Europe*, ed. Judith Field and Frank James (Cambridge: Cambridge University Press, 1997), 173–91.

[29] Keynes 130.05, 5v. Accessed from *NP* on January 22, 2017.

to test his understanding of them experimentally. The reader who wants to understand Newton's alchemy rather than merely assimilating one of the preexisting views on the subject must therefore be willing to engage with Newton's language, ideas, and practices over a range of genres and in considerable detail. In order to appreciate the whole we must understand its parts, even if it proves to exceed their sum.

The scope and detail of the present book call for a preliminary road map of its contents. Because of the daunting character of traditional alchemical language, which was often expressed in the form of enigmas, the next chapter begins with a consideration of literary deception in alchemy, devoting considerable space to Newton's understanding of the riddling language of the "adepts," the mysterious practitioners of alchemy who had, at least in principle, mastered the secret of chrysopoeia. This exercise requires that we understand the place occupied by the figure of the alchemical adept in the imagination of early modern Europeans and the remarkable powers that the possessors of the grand elixir were thought to possess, powers that not only included the ability to transmute base metals into noble ones but also a parallel skill in verbal deception. According to the prevailing early modern view, the very fact of their dominion over nature forced the adepts to hide behind a veil of secrecy, because of the danger that would accrue to them if the world knew of their abilities and because it was necessary to prevent the accession of the unworthy to their ranks. To the mind of Newton, the adepts were tricksters, not because they lacked the ability to carry out their marvelous transmutations, but because they veiled their knowledge under a sophisticated language of metaphor, allusion, and outright doublespeak. Not that they spoke in gibberish; to the contrary, the intelligent and properly trained student could penetrate behind their fuliginous tropes, but only if God willed it. It was Newton's belief that in his case God did so will.

But however much divine assistance might contribute to one's alchemical success, doing alchemy did not contribute to one's divinity. Newton's private belief in the infallibility and elect status of the adepts did not entail that he viewed alchemy as a path to religious salvation. In fact, references to the aurific art in the vast corpus that Newton devoted to religious topics, consisting of about four million words, are vanishingly small. And like his chymical forerunner Joan Baptista Van Helmont, Newton thought that success at chymistry must be "bought with sweat," the unavoidable, and often mundane labor of the laboratory.[30] Chapter three provides a close analysis of several related themes, considering, for example, the relationship between Newton's exegesis of biblical prophecy and his method of interpreting the textual riddles presented by writers on the philosophers' stone. At the same

[30] Joan Baptista Van Helmont, *Ortus medicinae* (Amsterdam: Ludovicus Elsevier, 1652), 560, #55: "Carbones emant, & vitra, discantque prius, quae nobis dedere, & vigalatae ex ordine noctes, atque nummorum dispendia, dii vendunt sudoribus, non lectoribus solis, artes." See also Newman, "Spirits in the Laboratory: Some Helmontian Collaborators of Robert Boyle," in *For the Sake of Learning: Essays in Honor of Anthony Grafton*, ed. Ann Blair and Anja-Sylvia Goeing (Leiden: Brill, 2016), 2: 621–40. For the most recent sustained look at Van Helmont's life and work, see Georgiana D. Hedesan, *An Alchemical Quest for Universal Knowledge* (London: Routledge, 2016).

time, the chapter also examines Newton's views on ancient wisdom and mythology in their relation to the aurific art, since many alchemists believed that the entertaining tales of the Greek and Roman pantheon contained veiled instructions for preparing the great arcanum. Previous scholarship has tended to assume that Newton too upheld the belief that ancient mythology was largely encoded alchemy, but as chapter three argues, this would have presented a sharp conflict with his views on ancient chronology and religious history. Further evidence shows that Newton may well have considered the mythological themes transmitted and analyzed by early modern alchemists as conventional puzzles reworked from antique sources rather than as true expressions of ancient wisdom. Nonetheless, they were conundrums to be solved if one wished to advance to the mirific tool of the adepts, the philosophers' stone.

With chapter four I also provide necessary background for the reader, but this time it concerns issues of historical context rather than language. As I argue at some length, Newton's belief that metals are not only produced within the earth but also undergo a process of decay, leading to a cycle of subterranean generation and corruption, finds its origin in the close connection between alchemy and mining that developed in central Europe during the early modern period. Alchemy itself acquired a distinct, hylozoic cast that the aurific art, at least in its more scholastic incarnation, had largely lacked in the European Middle Ages. Despite a common scholarly view that holds alchemy to have been uniformly vitalistic, the early modern emphasis on the cyclical life and death of metals was not a monolithic feature of the discipline across the whole of its history, but rather a gift of the miners and metallurgists who worked in shafts and galleries that exhibited to them the marvels of the underground world. Newton, writing for the most part in the last third of the 1600s, was the heir of a unique blend of mining lore and alchemy that had reached its efflorescence almost a century before. The fourth chapter concludes by describing additional sources used by Newton, such as his favorite chymical writer over the *longue durée*, Eirenaeus Philalethes, and also the pseudonymous early modern author masked beneath the visage of the fourteenth-century scrivener Nicolas Flamel.

In chapter five we examine the young Newton from his education at the Free Grammar School in Grantham during the 1650s up to his student years at Trinity College, Cambridge, beginning in 1661, in order to see how his interest in chymistry originated and developed. The standard view is that Newton was stimulated to his early interest in chymistry by the works of Robert Boyle. But my recent discovery of an anonymous and hitherto unexamined manuscript, *Treatise of Chymistry*, provides new evidence to show that Newton was already compiling chymical dictionaries before reading Boyle's works on the subject. Very likely his earliest chymical interests stemmed from his adolescent exposure to writers in the traditions of books of secrets and natural magic such as John Bate and John Wilkins, although he fell under Boyle's spell in due course. Chapter five then passes to what are probably Newton's earliest notes on chrysopoeia, namely, his abstracts and summaries of the works attributed to the supposed fifteenth-century

Benedictine Basilius Valentinus. Finally, the chapter tries to pin down some of the early contacts in Cambridge and London who transmitted the manuscripts and other texts to Newton that provided a major part of his alchemical knowledge. We are able to provide new information here too, although much of course remains dark.

Although Boyle's early influence on Newton already emerged briefly in the previous chapter, the next provides a sustained treatment of the self-styled English "naturalist" and his contribution to Newton's optical research. It is little appreciated that Boyle's analytical approach to chymistry had a profound impact on Newton's optics in the second half of the 1660s, the period that Newton considered "the prime of my age for invention."[31] As chapter six argues at length, Newton transferred Boyle's analysis and resynthesis or "redintegration" of materials such as niter to the realm of light. It was the decomposition of white light into its spectral colors and the subsequent recomposition of whiteness from the spectrum that provided Newton with one of his most cogent demonstrations that white light was actually a heterogeneous mixture. Chapter six establishes the influence of Boyle's chymistry on Newton's experimental methodology, using primarily terminological clues to reveal Newton's borrowings from Boyle's redintegration experiments. At the same time, the chapter also presents Boyle's and Newton's work against the backdrop of scholastic matter theory and optics in order to underscore the epoch-making character of the new color theory, which resulted in the overthrow of two millennia of research on the subject.

The seventh and eighth chapters consist of a detailed analysis of Newton's two early theoretical treatises, *Humores minerales* and *Of Natures obvious laws & processes in vegetation*, both probably written between 1670 and 1674, the very period when Newton was first making a name for himself at the Royal Society with his invention of a reflecting telescope and his controversial publication of his new optical theory. Both *Humores minerales* and *Of Natures obvious laws* employ alchemical theory to describe the process of metallic and mineral generation in the subterranean world. It is here that Newton claims in unforgettable language that the earth resembles "a great animall ^or rather inanimate vegetable" that inhales subtle ether and exhales gross vapors or "airs."[32] I argue that these works provide the theory on which he bases much of his subsequent experimental practice in the domain of chymistry. In particular, the emphasis that these two texts place on reactions in the vapor or gaseous state helps to explain the strikingly heavy emphasis that Newton gave to sublimation of various materials in his experimental practice. *Of Natures obvious laws* is also interesting for its careful attempt to disentangle natural processes that rely on mechanical interactions from those that employ "vegetation," the principle of generation, growth, and putrefaction depending on hidden *semina* or seeds buried within matter.

[31] CU Add. 3968.41 f.85r (= frame 1349 of http://cudl.lib.cam.ac.uk/view/MS-ADD-03968/1349, accessed May 16, 2016).

[32] Dibner 1031B, 3v.

Newton's higher goals for chymistry attempt to harness the power of these latent sources of activity for the purpose of transmutation.

With the ninth chapter we pass from theory to practice. Beginning with Newton's very early interpretations of the Polish alchemist Michael Sendivogius in the manuscripts Babson 925 and Keynes 19, the chapter shows that the brash young Cantabrigian initially thought the secret of chrysopoeia to be attainable by means of two ingredients alone, namely stibnite or crude antimony and lead. Much of his focus on antimony stems from his recent reading of the 1669 text by Philalethes, *Secrets Reveal'd*, which describes the use of that material in fairly clear terminology. The great significance that Newton idiosyncratically attaches to the metal lead in this early phase, however, has gone unnoticed by previous scholars and adds a hitherto unsuspected dimension to his aurific quest. His subsequent exposure to additional alchemical texts, especially in the extended corpus of Philalethes, soon made him understand that he had oversimplified matters. Other metals were also involved in the processes of Philalethes, especially copper. Was lead also part of the Philalethan modus operandi, or had Newton misinterpreted the American adept? In order to resolve this question, Newton turned to the same theories of metallic generation beneath the earth that had inspired *Humores minerales* and *Of Natures obvious laws*. By deepening his understanding of subterranean mineral generation, Newton believed he would be in a better position to replicate nature's processes of growth and transformation in the laboratory.

Newton's abrupt realization that his earliest understanding of the alchemical masters was erroneous also led him to adopt a form of textual interpretation that had hitherto been largely absent from his notes. In a word, he appropriated a venerable genre among medieval and early modern alchemical writers, the *florilegium* or collection and reorganization of snippets and *dicta* of the adepts for the purpose of comparing them to one another and extracting their sense. At this point, roughly corresponding to Newton's withdrawal from public scientific life between 1676 and 1684 after growing disillusioned with the public response to his radical optical theory, he had more than ample time to focus on the decryption of alchemical texts. Working through multiple treatises and winnowing out all but the information that he deemed most crucial, Newton would then group the resulting snippets with those from other texts that he thought threw light on them. This old alchemical practice has made it extremely difficult for modern scholars to determine where Newton's own beliefs begin and where those of his sources end. Patient comparison of Newtonian borrowings to the original texts and to one another, facilitated by digital searching and other computational techniques, has allowed me to obviate this problem, at least for the most part. Chapter ten provides a sustained look at an important florilegium from the period 1678–86 (Keynes 35), which shows the hitherto unsuspected influence on Newton of the German chymist Johann Grasseus.

Another author who acquires newfound significance in Newton's florilegia is Johann de Monte-Snyders, an extraordinarily obscure writer of two published texts. New information that I have unearthed on Snyders shows that he fell squarely into the mold of the self-styled wandering adept, traversing central Europe and performing demonstrations of his aurific prowess, no doubt in the hope of obtaining patronage. His life and influence serve as the subject of chapter eleven. In order to illustrate the way in which Newton tailored the writings of Snyders to fit his own conception of the alchemical magnum opus, the chapter also explores other contemporary accounts of Snyders's processes and shows that Newton's interpretation did not fit the standard view. The German adept exercised more impact on Newton the alchemist than any other author short of Philalethes. By giving a close reading to several important manuscripts, particularly Keynes 58, where Newton describes his plan for experiments that will lead to the scepter of Jove and the caduceus of Mercury, chapter twelve in turn shows how Newton combined his understanding of Snyders with motifs and practices drawn from Philalethes.

The same creative reworking of an earlier author forms the subject of chapter thirteen, which examines Newton's take on the substantial alchemical corpus ascribed to the high medieval Mallorcan philosopher Ramon Lull.[33] One can date his newfound interest in the pseudo-Lullian corpus to the publication of Edmund Dickinson's 1686 *Epistola ad Theodorum Mundanum*, which Newton read soon after its publication. This places Newton's Lullian turn to the very period when he was composing his masterwork, the 1687 *Principia*, after the astronomer Edmund Halley famously encouraged him to put his gravitational theory into written form. Influenced by the work of Dickinson, a prominent physician in Oxford and London, Newton came to believe that Lull's comprehensive description of the quintessence or spirit of wine (our ethyl alcohol) was actually an encoded discussion of the "first matter" or initial ingredient out of which the philosophers' stone, by a long and laborious process, should be made. Newton's ideas on this subject fill a complicated florilegium found in several manuscripts, which links Lull's work to that of Van Helmont, and which in turn presents detailed discussions of the alkahest or universal dissolvent. Also employing Van Helmont's foremost English expositor George Starkey, Newton attempts to determine the precise difference between the Lullian quintessence and "the immortal dissolvent," that is, the alkahest. This florilegium, simply titled *Opera* (Works) by Newton, contains hidden riches, such as a fascinating discussion of the affinities between chemical species that would undergo extensive treatment in *Query 31* of Newton's famous 1717 *Opticks*.

In chapters fourteen, fifteen, and sixteen, we arrive at Newton's experimental notebooks, containing dated chymical laboratory records from 1678 to 1696, which he kept largely distinct from his reading notes. While the two Cambridge collections, CU Add. 3973 and 3975, have been examined by previous scholars, the two sides of the single sheet composing Boston Medical Library B MS c41 c contain very early experiments that

[33] The extensive corpus of alchemical treatises attributed to Ramon Lull forms the subject of Michela Pereira, *The Alchemical Corpus Attributed to Raymond Lull* (London: Warburg Institute, University of London, 1989).

complement the Cambridge records in important ways.[34] All of these texts reveal Newton's extraordinary precision in experimentation and the single-minded discipline that guided his repeated variations on the same basic sets of laboratory protocols. The same exactitude in recording his experiments makes it possible to identify a number of Newton's proprietary *Decknamen* by an approach that combines textual decipherment with laboratory replication. This twofold method has allowed me to identify Newton's all important "standard reagent," the acid "menstruum" that he variously calls liquor, spirit, vinegar, and salt of antimony. With this material in hand, I have been able to produce "vitriols," that is, crystalline salts, of copper and several cupriferous minerals, in the hope of replicating Newton's "volatile Venus," a major desideratum of his alchemical research. The work of replication is ongoing, but already one can see how Newton planned his experiments and reasoned out his conclusions. His notes on the work of a contemporary chymist, David von der Becke, show that Newton was using his knowledge of chymical affinities in combination with a corpuscular theory to predict the course of reactions and to plan individual experiments. But he typically performed these operations with his chrysopoetic sources firmly in mind; in the end, most of the experiments in his laboratory notebooks consist of attempts to reverse-engineer the products allusively described in Newton's readings. Chapter sixteen concludes by examining precisely one such product, the "net of Vulcan" found in the works of Philalethes and elaborated at considerable length by Newton.

Despite the fact that Newton kept his cards close to his chest when discussing matters related to chrysopoeia, he did nonetheless engage in a variety of collaborative chymical projects. Chapter seventeen discusses one of these in considerable detail. The first of the collaborations took place in 1693, when Newton's Genevois friend Nicolas Fatio de Duillier encountered a French-speaking alchemist in London, apparently a Huguenot serving in King William's forces in the Low Countries. By examining Fatio's hitherto unstudied letter to Newton from the summer of 1693 in conjunction with Newton's manuscript "Three Mysterious Fires" (now found at Columbia University), I show that the latter text represents the fruit of an elaborate set of procedures devised by Newton in conjunction with Fatio and his Francophone friend. These processes were related to another set of operations from Newton that Fatio recapitulates in the aforementioned 1693 letter. As I argue in chapter seventeen, the procedures that Fatio quotes from Newton provide an important key for understanding both Keynes 58 and the laboratory notebooks. In a word, they are simplified procedures for making such important desiderata as the caduceus of Mercury and the scythe of Saturn, *Decknamen* that arise in the records of Newton's experimentation and reading notes.

The cover names employed in Keynes 58 and the materials alluded to by Fatio also make a sustained appearance in Newton's famous *Praxis* manuscript (Huntington Library, Babson 420), which chapter eighteen analyzes

[34]Boston Medical Library B MS c41 consists of three separate manuscripts, all by Newton, kept in separate envelopes. "B MS c41 c" refers to the single, folded sheet that begins "Sal per se distillari potest."

in the light of Newton's work with his young friend. Scholars have traditionally viewed *Praxis* as the culminating record of Newton's alchemical career; at the same time, some have seen its seemingly incomprehensible processes and profusion of *Decknamen* as proof that Newton was undergoing a mental crisis around the time it was written. After all, *Praxis* refers to Fatio and might even have been composed in Newton's "black year," 1693, when he angrily (if briefly) isolated himself from his friends and complained of symptoms that were subsequently interpreted as a "derangement of the intellect." Hence I devote considerable space to the analysis of this challenging text and argue that it is in reality quite comprehensible in the light of Newton's epistolary exchanges with Fatio and other collections such as Keynes 58.

Fatio was not the only chymist with whom Newton collaborated in his maturity. After his move to London in 1696, Newton was evidently approached by the obscure "Captain Hylliard," who wrote a brief alchemical manifesto that the now famous intellectual and Mint official copied. Chapter nineteen provides an extensive analysis of the episode with Hylliard and also describes Newton's extended collaboration with the Dutch distiller William Yworth, which also took place after Newton's move to London. Beyond casting new light on the processes behind Yworth's *Processus mysterii magni* and linking them to Newton's late florilegia, the chapter also uses a recently discovered manuscript in the Royal Society archives to show that the document actually contains the record of a live interview between Newton and Yworth.

The final three chapters of *Newton the Alchemist* continue the story, already begun in chapter six, of the relationship between Newton's private chrysopoetic ventures and public science in the seventeenth and early eighteenth centuries. The interaction between chymistry and optics did not end with Newton's transfer of Boyle's redintegration experiments into the realm of light and color. Chapter twenty shows that Newton developed a theory of refraction based on the chymical principle sulfur, which he described in the first edition of his famous *Opticks* (1704). The chapter also finds that the seeds of this theory extend back to Newton's 1675 *Hypothesis of Light*, where he explicitly abandons the Sendivogian theory of an aerial niter that he had affirmed in *Of Natures obvious laws*. Newton replaced the aerial niter, which had accounted for phenomena ranging from combustion and respiration to the fertilization of the earth, with a growing reliance on sulfur. Although he had reasons of his own for making this shift, Newton was also influenced by parallel developments in European chymistry, a field that was rapidly moving toward what would eventually be known as phlogiston theory. Another trend that would soon acquire great significance in Europe and England was the increasing emphasis chymists placed on affinity among different materials. Affinity also enters into Newton's sulfurous theory of combustion and into the *Opticks*' explanation of refractive power in a major way. Chapter twenty-one presents this topic by building on Newton's increasing interest in sulfur, placing his theories in the context of developments within the chymical community of the late seventeenth and early eighteenth centuries. The chapter provides a new look at Newton's developing ideas about affinity and his role in the eighteenth-century development of affinity tables, the graphic representations of selective attractions by materials that cause those with less affinity to precipitate. Finally, chapter twenty-two considers Newton's relationship with Boyle in the light of both men's attempts to arrive at a "sophic mercury" that would in principle dissolve gold into its primordial constituents and make it possible for the noble metal to "ferment," as Newton says in his short text of 1692, *De natura acidorum*. The two major English representatives of public science in the seventeenth century had very different ideas about the path to chrysopoeia, though both, in the end, were alchemists in the fullest sense of the term.

Returning then to the variations on a Keynesian theme with which I began this chapter, one can see how *Newton the Alchemist* changes our understanding of the celebrated natural philosopher. Already as a very young man, even before he had absorbed the chymical knowledge of Boyle, Newton enlisted himself in the school of the adepts. Yet alchemy was not an alternative religion for Newton, nor was it the origin of his theory of gravitation. The short-range forces operating in the chymical realm were objects of study in themselves, just as gravitational attraction was. In the later editions of the *Opticks* Newton even erects the active principle behind the phenomenon of "fermentation," by which he here means chemical reactions in general, to the status of a fundamental force like magnetism and gravitation. But these theoretical speculations, important as they were, represent very little of the immense work that Newton devoted to alchemy. To see these published ruminations as the end goal of Newton's decades of alchemical research would be a disingenuous and misleading perspective. Although he employed theories of alchemical origin as a means of understanding and enlarging natural philosophy, the countless hours he spent deciphering alchemical texts and putting his conclusions to the test in his laboratory had a more practical goal. In a word, the founder of classical physics aimed his bolt at the marvelous menstrua and volatile spirits of the sages, the instruments required for making the philosophers' stone. Difficult as it may be for moderns to accept that the most influential physicist before Einstein dreamed of becoming an alchemical adept, the gargantuan labor that Newton devoted to experimental chrysopoeia speaks for itself. The chymical tools envisaged by Newton, had he been able to acquire them, would have handed him the power to alter nature to its very heart. These were the secrets that the "true Hermetick Philosopher" must keep hidden lest they cause "immense dammage to ye world," as he said to the Secretary of the Royal Society in 1676.[35] The core of Newton's labors at deciphering the documents of the adepts lay in his own undying quest to join their number.

[35] Newton to Henry Oldenburg, April 26, 1676, in Newton, *Corr.*, 2: 2.