11 A preliminary reassessment of Newton's alchemy

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Introduction: problems with the received view of Newton's alchemy

Despite their relative obscurity, Isaac Newton's alchemical manuscripts have long engendered strong claims. In the mid nineteenth century, Newton's biographer David Brewster marveled at the fact that "a mind of such power, and so nobly occupied with the abstractions of geometry" could concern itself with the alchemical charlatanry "of a fool and a knave."[1] More recent historians, on the other hand, have seen Newton's alchemy alternatively as the wellspring of his theory of universal gravitation, as occupying a central place in his attempt to return to an uncorrupted, primitive Christianity, or as an attempt to derive "positive knowledge" of chemistry from the obscurity of alchemical writings. This chapter will take a different approach. After describing the *status quaestionis* of Newton's chymistry found in the existing scholarship and discussing its problems, I will pass to a brief outline of recent discoveries that shed a quite different light on Newton's alchemical project. As we shall see, the decades that Newton spent studying alchemical texts and performing alchemical experiments were neither a quixotic and fruitless dream nor a romantic rebellion against the natural philosophy of his day, nor for that matter an attempt to form an alternative religion. Like Robert Boyle, G. W. Leibniz, and many other natural philosophers of the seventeenth century, Newton tried both to integrate chymical findings

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into his natural philosophy as a whole and to learn the secrets of chrysopoeia. Although his long engagement with alchemy did not lead Newton to his fundamental discovery of universal gravitation, it had highly significant impacts on other aspects of his science, particularly in the realms of optics and in the study of the Earth's internal processes.

Already in 1946, John Maynard Keynes used the alchemical papers to make his famous declaration that "Newton was not the first of the age of reason" but "the last of the magicians."[2] More specific, if less evocative, is the position of B. J. T. Dobbs and Richard Westfall, who at various times both argued that Newton's alchemy 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. The ultimate source for this view may well have been a brief remark made by J. E. McGuire in a 1968 study devoted mainly to Newtonian forces and active principles in the period after the publication of the *Principia*.[3] Far more significant for the subsequent historiography, however, was Westfall's 1971 book *Force in Newton's Physics*, in which he explicitly linked gravitational force to alchemy and what he called "the hermetic tradition," a locution that clearly betrays the influence of Frances Yates's 1964 *Giordano Bruno and the Hermetic Tradition*.[4] Westfall developed this idea further in an article of 1972. There he argued that Newton's concept of force at a distance "derived initially from the world of terrestrial phenomena, especially chemical reactions." In fact, Westfall 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."[5] Dobbs explicitly adopted Westfall's position in her 1975 *Foundations of Newton's Alchemy* and even suggested that Newton's concept of immaterial attraction might first have emerged during the composition of his "Clavis," a treatise that Dobbs thought to have been composed by Newton early in his career.[6] As it turns out, however, the "Clavis" was not by Newton at all – rather it was a fragment of a letter written by the New England alchemist George Starkey in

1651 to his friend Robert Boyle.[7] More importantly, there is no direct evidence for the claim that Newton's alchemical research contributed to his view of gravitation as an immaterial force in any of the documents submitted by Dobbs or Westfall for scrutiny. In fact, on the very few occasions where Newton does describe the causes of gravity in an explicitly alchemical context, he explains the falling of bodies by *mechanical means*, not as a result of force at a distance. This is particularly the case in Newton's important early manuscript "Of Natures obvious laws & processes in vegetation" (Smithsonian Institution, Dibner Ms. 1031B), a work that has only recently received a full edition on the online *Chymistry of Isaac Newton* site.[8] In this acephalous text, which gets its name from the incipit rather than from an actual title, Newton postulates a material ether that forces bodies downward and is also responsible for chymical properties such as cohesion. As he argues, "minerall dissolutions & fermentations" occur continually within the Earth, and like the dissolutions of metals in mineral acids that take place in a laboratory, they often generate "air," or as we would say, gases. This air rises up until "it straggle into y^e ethereall regions," but eventually is forced back down along with the subtler ethereal matter. At this point in "Of Natures obvious laws," Newton makes it clear that the resulting circulation provides an explanation of gravity (fol. 3v):

> This constantly crouding for room y^e Æther will bee comprest thereby & so forced continually to descend into y^e earth from whence the air cam & there tis gradually condensed & interwoven w^th bodys it meets there ^& promotes their actions being a tender ferme<n>t. But in its descent it endeavours to beare along w^t bodys it passeth through, that is makes them heavy & this action is promoted by the tenacious elastick constitu<ti>on whereby it takes y^e greater hold on things in its way; & by its vast swiftness.

The mechanical operation of the ether given here is quite similar to explanations of gravity that Newton provides in his

"Trinity College Notebook" *Certain Philosophical Questions* and in the 1675 *Hypothesis of Light*. The earliest version of the theory as found in Newton's student notebook argues that bodies receive their gravity from a fine, descending matter (Newton does not use the term "aether" here) that passes through their pores and forces them downwards. This subtle, particulate matter then enters the globe of the Earth and evidently combines with other matter so that when it re-ascends, it is "in a grosser consistence" than before.[9] As a result of its increased particle size, the rising stream of matter can no longer penetrate the fine pores of bodies; hence the falling bodies will push it out of the way rather than being significantly impeded by it. As Martin Tamny and J. E. McGuire have noted, the theory probably owes a significant debt to Kenelm Digby's *Two Treatises on Body and the Soul*.[10]

It is true that in later works, such as his unfinished draft preface to the *Principia* written in 1686 or 1687 and in Query 23 of the 1706 Latin *Optice*, Newton does import chymical powers into the realm of immaterial forces. In the draft *Principia* preface, for example, he speaks of "certain forces by which the particles of bodies" are made to attract or repel one another generally.[11] Chymical phenomena form a large part of the ensuing discussion, but then so do surface tension, capillary action, emission of light, transparency and opacity, and magnetism, alongside gravity. Newton's explicit desire here is to suggest a research program whereby interparticular forces in general would be subjected to the mathematical treatment given to "the planets, comets, the moon and the sea" in the *Principia*. There is no hint to support the claim of Dobbs and Westfall that Newton first adopted immaterial forces in the realm of chymistry and then transferred them to gravity. The same may be said of his arguments in Query 23 of the 1706 *Optice:* Newton speaks there of fermentation in the same breath as gravity, since both require the help of "active principles" in order to be maintained or increased.[12] The ultimate origin of this "fermentative force" may well be the Flemish chymist Joan Baptista Van Helmont or his expositor George Starkey, who may also have contributed to Newton's discussion of short-range attractions and repulsions of particles engaging in what we would now call chemical reactions.[13] But the presence of either fermentation or attraction and repulsion at the micro-level does not help the Dobbs–Westfall hypothesis since both are quite distinct from gravitational attraction: these chymical phenomena appear in Newton's text as parallel examples rather than as sources.

Finally, it should be obvious that Newton had more immediate sources to draw upon for the idea of immaterial forces acting on matter than alchemical literature, a point that John Henry made in an important article published over a quarter of a century ago.[14] In particular, Newton was the beneficiary of several centuries of research on the immaterial attraction exercised by magnets, beginning in the thirteenth century and proceeding through the works of many seventeenth-century figures ranging from William Gilbert to Johannes Kepler.[15] In short, when one considers the evidence for and against the idea that Newton derived his theory of universal gravitation from alchemy, the inescapable conclusion is that this claim has acquired the unenviable status of a canard.

A second received view lies in the more subtle claim made by Dobbs in her 1991 *Janus Faces of Genius* that Newton's alchemy was primarily the expression of 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. As Dobbs herself put it in one of many similar passages of *Janus Faces*:

> Newton's God acted in time and with time, and since He was transcendent, He required for His interaction with the created world at least one intermediary agent to put His will into effect. Just such an agent was the alchemical spirit, charged with animating and shaping the passive matter of the universe.[16]

In reality, Dobbs was not the first person to argue that Newton's alchemy was part and parcel of his unorthodox religiosity. In a 1967 article published in *Chymia*, Mary Churchill was already making similar declarations. Like Dobbs, Churchill used the idea of the analytical psychologist Carl Jung that the "religious element in alchemy quite outweighs its technical aspect," to bolster a claim that Newton saw the alchemists as upholders of a "pristine religion" closely related to his heterodox anti-Trinitarianism.[17] It is worth quoting Churchill *in extenso* in order to gain an appreciation of the full scope of her vision, later adopted by Dobbs:

> Before Protestantism could speak openly, the alchemists must have seemed to him the early protestants against Romanism. He believed that alchemy in its symbolic search for rebirth and man's perfection held the true soteriological secret, which had been lost in the gross practices of the church. And so he collected and cherished throughout his life alchemical documents not solely for scientific reasons, but because he felt kinship with the often outlawed adepts. Their secret creed supported him in his own unorthodox beliefs in a primitive Christianity.[18]

Now in a certain restricted and highly qualified sense one can agree that Newton's interest in alchemy had a religious origin, since Newton's science as a *whole* was undoubtedly linked to his deep Christian convictions. But when we pass from Newton's transcribing and anthologizing of other alchemists' writings to his own compositions, there is little indeed to support Dobbs's and Churchill's view or even to mark out alchemy as the pinnacle of a theocentric science. To the contrary, Newton's two chymical laboratory notebooks, Cambridge University Library Additional Mss. 3975 and 3973, are resolute in their avoidance of these topics. The word "God" in English or Latin is found only once in these manuscripts, despite the fact that they comprise 452 manuscript pages between them, and despite the fact that those pages are replete with alchemical experiments and *Decknamen*. As for the one case where the word "God" does appear, it occurs in CUL Add. Ms. 3975 (fols. 110r–110v), where Newton has lifted an admonition verbatim from George Starkey's 1658 *Pyrotechny Asserted*:

> O foolish operators! that by yo^{r} devised heats would ~~draw~~ introduce ferments (y^{e} true parents of all forms) & yet know not by any of yo^{r} heats to imitate the Sun in Bermuda in producing Oranges & Lemons. Pray to God to direct you for here (to deal ingeniously) my speech is very obscure.

This mocking passage lifted from Starkey obviously cannot be taken to support a soteriological goal for alchemy, be it his own or that of Newton. The American chymist's point is that his peers lack a proper comprehension of the technical, laboratory processes required for the *arcana maiora* of alchemy, and that their only hope is to pray for a better understanding.

A more central passage for Dobbs's linkage of Newton's alchemy to his religious quest is found on folio 4v of Newton's manuscript "Of Natures obvious laws & processes in vegetation," which contains in passing a brief consideration of the limitless possibilities of the creation:

> Of God. what ever I can conceive wth out a contradiction, either is or may ~~effected~~ bee made by something that is: I can conceive all my owne powers (knowledge, activating matter, &c). without assigning them any limits Therefore such powers either are or may bee made to bee.
>
> Example. All the dimensions imaginable are possible. A body by accelerated motion may ~~becom infinitely long or~~ trancend all ~~space~~ distance in any finite tim assigned also it may becom infinitely long. This if thou denyest tis because thou apprehendest a contradictiō in the notion & if thou apprehendest none thou wilt grant it to the pour of things.

According to Dobbs, Newton inserted this discussion into an alchemical manuscript text in order to explain how God could circumvent the mechanical order of the cosmos by means of "the nonmechanical laws of vegetation."[19] In her theocentric analysis of Newton's alchemy, this was part of an attempt on his part to demonstrate "divine activity in the world."[20] But in fact there is nothing alchemical about this passage, and its linkage to the rest of the text is obscure. It is in fact much closer to the Cartesian-inspired jottings found in Newton's early commonplace book *Certain Philosophical Questions* than it is to his alchemical sources. A related passage can be found there, at the end of Newton's notes on Descartes's *Meditations* and his *Responses*:

> Ax: ~~That thing~~ Tis a contradiction to say, that thing doth not exist, wch ~~may bee conceived~~ whose existence implys no contradiction, & being supposed to exist must necessarily exist. The reason is yt an immediate cause and effect must be in ye same time & there fore ye præexistence of a thing ~~must~~ can bee no cause of its post existence (as also because ye ~~former~~ after time depends not on ye former time). Tis onely from the essence of it that a thing ~~can by it owne~~ perpetuate its existence wthout extrinsicall helpe. Wch essence being sufficient to continue it must bee sufficient to cause it there being ye like reason of boath.[21]

The editors of *Certain Philosophical Questions* assert that this is a Newtonian gloss on the ontological proof for God's existence in Descartes's "Fifth Meditation." Newton was probably thinking of other portions of the *Meditations* as well, and the "Second Set of Objections" in particular, where the following criticism is raised against the ontological proof – "From this it follows not that God really exists, but only that he ought to exist if his nature is something possible or non-contradictory."[22] It is in the light of this criticism that one should approach Newton's emphasis on non-contradiction. The concerns expressed in *Certain Philosophical Questions* are an outgrowth of the criticisms of the ontological proof found in the *Opera philosophica* of Descartes that the young Cantabrigian studied as a student.[23] Similarly, Newton's passage "Of God" in "Of Natures obvious laws" testifies to his encounter with Descartes's ruminations on the existence and nature of God: it is not the affirmation of non-mechanism that Dobbs asserts. What then is this passage doing in the midst of Newton's heavily alchemical text? "Of Natures obvious laws" is itself a sort of commonplace book, organized around topical entries that need not be closely related. The passage "Of God" looks more like a digression than a thought that grew integrally out of Newton's text on alchemical vegetation. Newton himself seems to have acknowledged its outlier status by leaving the rest of the page after the entry blank in his manuscript.

In short, a close inspection of this passage and indeed of most of the evidence used by Dobbs in support of her theocentric reading, does not support her interpretation. Rather than seeing, then, Newton's chymistry as somehow more religious in orientation than his physics, one should view it as arising from the same desire to penetrate behind the appearances and to arrive at the most general possible explanation of reality. In the hands of Newton, both chymistry and physics were tools for arriving at fundamental truths about nature and its operations.

A final claim, namely the position that Newton was only interested in a positivistic quest for chemical knowledge in the modern sense, can be dispensed with in short order. This assertion was presented forcefully by Rupert Hall and Marie Boas Hall in a long article that appeared in 1958.[24] Despite their careful and valuable analysis of Newton's laboratory notebooks in the Cambridge University Library, the Halls were shackled by a tacit definition that equated alchemy with fraud. Thus the Halls asserted that "Alchemy was never disinterested chemical research," and they adopted the goal of showing that "there is no evidence that any of <Newton's> processes are of the kind necessarily preliminary to the Great Work, or that he ever hoped to fabricate a factitious gold." These assertions are clearly belied by the obviously alchemical character of Newton's "Of Natures obvious laws & processes in vegetation," a text that the Halls seem not to have known in 1958. More than this, the Halls' interpretation is challenged even by Newton's experimental notebooks. CUL Add.

Ms. 3975, for example, reveals Newton's quest for such mysterious alchemical desiderata as the Green Lion, the Caduceus of Mercury and the Scepter of Jove. These *Decknamen* come right out of Johannes de Monte Snyders and Eirenaeus Philalethes, authors whom no sane person today would deny to be alchemists. Nor can it be argued that Newton was using the materials represented by these *Decknamen* in a way that was somehow unalchemical. CUL Add. Ms. 3975 contains numerous pages devoted explicitly to chrysopoeia, such as "Of y^e^ work w^th^ common ☉"on 123r–123v (continued on 132r). The entry on the work with common gold follows a course of action that is above all dominated by *The Marrow of Alchemy*, *Secrets Reveal'd*, and *Ripley Reviv'd*, all works written by the famous chrysopoetic author Eirenaeus Philalethes (George Starkey). Newton's process for "common gold" carefully describes procedures for making a sophic mercury that was supposed to lead to the traditional *summum bonum* of alchemy – the philosophers' stone. The recapitulation and attempted decipherment of similar processes in fact make up the bulk of Newton's alchemical *Nachlass*, but the fact that they appear here in his own experimental notebook gives them particular cogency. In a word, the idea that Newton rejected the goals of the alchemists while appropriating their techniques and accidental discoveries can only be described as wishful thinking.

NEWTON'S CHYMISTRY AND ITS RELATION TO HIS SCIENCE AS A WHOLE

Having completed this essential exercise in ground clearing, we are now in a position to raise the questions that must occupy any researcher of Newton's alchemy. What was the real significance of chymistry over the course of Newton's career? Or to phrase it another way, what did he hope to attain from alchemy and how did it fit with his other scientific research? These are very serious questions, and they cannot receive full answers at the moment. But thanks to the online publication of several key Newton manuscripts by the *Chymistry of Isaac Newton* project, we are now in a position to make some preliminary steps towards answering these questions. What we are beginning to see is that Newton himself had very diverse goals for alchemy. In the remainder of this chapter I will briefly describe some recent discoveries pertaining to Newton's alchemical multi-tasking, while focusing on his use of chymical analysis and synthesis. As we shall see, paired chymical analysis and synthesis were immensely fruitful models in Newton's mind that allowed him to reason out processes ranging from the realm of optics to what I have taken to calling Newton's "theory of everything."

The publication of CUL Add. Ms. 3975, Newton's most comprehensive laboratory notebook, has made it possible to place his early optical discoveries in an entirely new context.[25] This substantial manuscript of 348 pages contains a collection of reading notes and experiments extending from at least 1669 to 1693. Most of the reading notes come from Robert Boyle and George Starkey, two authors who were pivotal in directing the young Newton's alchemical interests. The vast majority of the experiments and notes concern chymistry. But imbedded in this overwhelmingly alchemical manuscript one also finds the second version of Newton's most famous optical discovery, his experiments demonstrating that white light is actually a heterogeneous mixture of unaltered spectral colors. Now in this version, "Of Colours," unlike its earlier predecessor in Newton's student notebook, *Certain Philosophical Questions*, is the very first Newtonian document to clearly state that the spectral colors separated out of white light by a prism are completely immutable. Earlier, he had thought that the speed of light-corpuscles hitting the surface of the eye could vary, and that a corpuscle producing the sensation of red could be slowed to produce the sensation of blue. In other words, Newton's earliest experiments with prisms showed him that white light can be divided into spectral rays of differing refrangibility, but did not provide him with evidence that the spectral rays producing different colors were immutable. Hence, the Newton of *Certain Philosophical Questions* was still a believer in the mutability of colors. In other words, he still belonged in the camp of those who believed that colors could be mutually "transmuted," not wholly unlike the alchemical transmutation of metals.[26] All of this changed some time in the second half of the 1660s, and this change is reflected in "Of Colours," the treatise found in CUL Add. Ms. 3975. By the time of this treatise, probably composed between 1666 and 1669, Newton had performed new experiments that completely revolutionized his optical theory, and thereby overturned some 2,000 years of theorizing about the formation of colors.[27]

What did these new and revolutionary experiments consist of? In a word, by the time he composed "Of Colours," Newton had figured out that he could not only *analyze* white light into its spectral components, but that he could subsequently *resynthesize* the white light back out of the previously separated components. At the same time, other experiments described in "Of Colours" revealed that the red and blue produced by a prism could *not* be analyzed into other spectral colors or indeed changed in any way. It followed that the resynthesized white light itself is merely a compound of unaltered spectral colors that produce an illusion of homogeneity when seen by the eye of man. Newton still thought of light as composed of minute material corpuscles, but now the behavior of these corpuscles was fixed among rays of a given type – one spectral color could no longer turn into another, and the whiteness that resulted from their combination was no more innate to the components of sunlight than the redness of cinnabar is innate to *its* ingredients, mercury and sulfur (though Newton himself does not draw this comparison).

Now anyone conversant with the historiography of alchemy over the last ten years will immediately begin to feel a sense of recognition. Recent work has shown that the analysis and synthesis of chemical compounds had a well-developed history in alchemy. Early seventeenth-century chymists such as Daniel Sennert and Joan Baptista Van Helmont were able to draw on a medieval tradition of analysis that helped to bring a decisive end to traditional scholastic theories of mixture, thus setting the stage for the mechanical philosophy.[28] The Thomistic theory of perfect mixture, whereby the ingredients were thought to lose their identity and meld into a perfectly homogeneous substance, was debunked by alchemical experiments that showed exactly how those supposedly lost ingredients actually retained their robust identity all along. An extensive alchemical tradition extending from the High Middle Ages up to Robert Boyle's immediate predecessors had long used the analytic retrievability of the constituents of compounds to argue for the permanence of the ingredients that went into them.

But what about the *resynthesis* of components acquired by chymical analysis? Recent research has shown that Van Helmont was a key figure in converting Paracelsian *spagyria*, which had initially focused mostly on analysis, into a genuine art of analysis and synthesis. Van Helmont famously performed quantitative analyses and syntheses of glass and other materials which served as models for later alchemists.[29] But it was Robert Boyle who first brought these techniques explicitly into the mechanical philosophy and hence into the purview of the young Newton before he began his intensive reading of chrysopoetic texts in the late 1660s. By showing that naturally occurring compounds could be analyzed into their unaltered parts and then reassembled like the components of a watch, Boyle would cast doubt on the need for scholastic substantial forms. Thus Boyle used analysis and synthesis as supports for the corpuscularian basis of the mechanical philosophy, thereby attacking Aristotelian hylomorphism head on. And in his *Certain Physiological Essays* of 1661 and his *Origin of Forms and Qualities* of 1666, Boyle brought chymical analysis and synthesis to the attention of the young Newton.

Boyle's *Certain Physiological Essays*, for example, describes an experiment for what he calls the "redintegration" of saltpeter or niter – the chemical that we now refer to as potassium nitrate. "Redintegration" here refers to resynthesis after analysis – the dissolution of saltpeter into its ingredients and the subsequent recombination of those ingredients to arrive once more at saltpeter.[30] In simplest terms, Boyle's experiment worked by injecting burning charcoal into molten saltpeter, and thus igniting it. This resulted in the release of nitrogen and carbon in combination with oxygen, leaving a non-volatile residue of "fixed niter" that resembled salt of tartar (potassium carbonate – in reality it *was* potassium carbonate). Knowing that spirit of niter (nitric acid) could be produced by the thermal decomposition of niter, Boyle then added spirit of niter to the tartar-like residue, and acquired a product that resembled the original saltpeter in all its significant properties. He was then able to conclude that niter itself is merely a compound of two very different materials, namely spirit of niter and fixed niter, which we would today call an acid and a base.[31] Boyle would expand on this experiment in his 1666 *Origin of Forms and Qualities*, where he described additional experiments for the redintegration of amber, turpentine, and stibnite.

Let us now pause for a moment and consider chronology. In the same year as Newton's famous *annus mirabilis*, 1666, the year in which he later claimed to have begun experimenting with prisms, Boyle had published his *Origin of Forms and Qualities*. The very manuscript in which Newton recorded his first experiments with the resynthesis of white light from the spectral colors – the chymical laboratory notebook CUL Add. Ms. 3975 – also contains extensive notes drawn from Boyle's *Origin of Forms* on the redintegration of stibnite and turpentine.[32] Although the order in which this document was composed remains unclear at present, it is at least likely that Newton had read about Boyle's experiments with chymical redintegration at the time when he composed "Of Colours." Chymical redintegration was a phenomenon that clearly interested the young Newton, and one that he could easily have adapted to his optics from his reading in Boyle's chymistry.

Is it just coincidence that a mere five years or so separated Boyle's devastating attack on the homogeneity of scholastic "perfect mixture" by means of chymical analysis and synthesis from Newton's attack on the scholastic view of white light as a perfectly homogeneous mixture by means of prismatic analysis and synthesis? Boyle had introduced his redintegration experiments in 1661 and

Newton's resynthesis of white light dates from the period between 1666 and 1669. What are we to make of this? In addition to the fact that we know Newton was reading Boyle at the time of writing "Of Colours," there are numerous terminological clues to support a theoretical borrowing by Newton. In Newton's lectures given between 1669 and 1672 as Lucasian professor, called the *Optica*, he explicitly argues that it is the "*redintegration*" of the white light that proves beyond any reasonable doubt that it is actually composed of a mixture of colorfacient rays.[33] Newton speaks of the sunlight reconstituted from spectral colors as being an *albedo redintegrata* – quite literally a redintegrated whiteness.[34] In classical Latin, the term *redintegrata* or "redintegrated" means primarily "renewed" or "restored," as when one's powers are restored by rest after the fatigue of battle.[35] But the English term "redintegration" has a long history in alchemy as well, where the meaning is quite different. George Ripley, for example, uses it to refer to the recombination of the volatile and fixed components of a material after their analysis in the laboratory, in his fifteenth-century *Compound of Alchymy*.[36] This is precisely the sense in which Newton uses the term *redintegrata*, and he was the first in the field of optics to employ it in that fashion. It appears that Newton's use of the term is a direct appropriation from chymistry, most likely stemming from Boyle's chymical redintegration of niter, stibnite, turpentine, and other substances.

NEWTON'S "THEORY OF EVERYTHING"

One could continue with further terminological evidence linking Newton's analyses and syntheses to those of Boyle, for there are a number of cases where Newton transfers Boyle's peculiar corpuscular terminology to light and colors.[37] But for the sake of completeness, it is better here to give a sense of the diverse and wide-ranging character of Newton's chymistry. He did not stop, of course, with the transfer of chymical concepts and practices to optics. Indeed, Newton went so far as to develop a "theory of everything" that would explain organic life, the origin of heat and flame, the mechanical causes of gravitation, cohesion, the generation of metals and minerals, and so forth, by making an appeal to circulatory processes involving the interaction of metallic vapors, the atmosphere, and various forms of ether. This comprehensive theory emerges already in Newton's early interpretation and summary of chymical theory, "Of Natures obvious laws & processes in vegetation," where it is heavily indebted to early modern alchemists such as Michael Sendivogius and Johann Grasseus.[38] Indeed, Newton's already described idea of a circulatory process involving air and ether is largely an attempt to combine mechanical theories of gravitation with the Sendivogian "aerial niter" theory according to which a nitrous component of the air (related to but not identical with ordinary saltpeter) circulates between the core of the Earth and the outer reaches of the atmosphere. In Sendivogius's *Novum lumen chemicum* (1604), the aerial niter is a universal principle of life and also a cause of combustion. Newton similarly says in "Of Natures obvious laws" (fol. 2r) that there is an atmospheric spirit bearing an affinity with niter that is "y^{e} <*illeg.*> ferment of fire & all vegetables." The Earth, being like "a great animall," undergoes continual revitalization from inspiring this nitrous spirit as its "dayly refreshment" and breathing it forth again in altered form (fol. 3v). Similar ideas recur in Newton's "Hypothesis of Light," sent to Henry Oldenburg in 1675, although Newton tried to erase any open debt to the aerial niter theory there.[39] Given this emphasis on niter, it is perhaps unsurprising that Newton would also refer to the redintegration of saltpeter in "Of Natures obvious laws." Nonetheless, the phenomenon of redintegration plays a remarkably central role in that text, just as it did in Newton's optical theory, and this is a fact that has escaped scholars up until the present.

In "Of Natures obvious laws" one finds Newton trying to distinguish between purely mechanical processes and those that he links to a principle of "vegetation." This distinction was a key one for Newton, since even in his undergraduate days he was already searching out the flaws in Cartesian physics, a system that of course left no space for vegetation as a non-mechanical process. As we shall see, the mechanical–vegetable demarcation relied in part on redintegration as a test-case for distinguishing mechanical from vegetative processes. Those materials that could be analyzed and synthesized fit Newton's criterion for mechanical products, whereas substances produced by vegetation were not fit products for redintegration.

"Of Natures obvious laws" begins with a comparison of generative processes across the three kingdoms of nature – animal, vegetable, and mineral. Newton focuses on the idea that metals grow, putrefy, and regenerate themselves within the Earth, much after the fashion of trees on the Earth's surface. But he soon takes the discussion in a different direction. He launches into an apparently quite original treatment of the formation of sea-salt and niter by means of a putative interaction between water and the metallic fumes that rise up from the Earth's depths.

It is likely that Newton's introductory lines about saline generation are loosely inspired by Bernhard Varenius's discussion of sea-salt in the latter's *Geographia generalis*, a work that Newton edited and published in Cambridge in 1672.[40] Indeed, Newton's words (fol. 1v) betray the direct influence of Varenius's assertion that seawater contains both a fixed and a volatile salt. As Newton says, "Because the sea is perpetually replenished wth fresh vapours it cannot bee freed from ^{a} salin tast by destillation, that salt arising wth y^{e} water w^{ch} is not yet ~~indurated~~ concreted to a grosser body." This passage surely recapitulates a section from Varenius where the latter asserts that tiny saline atoms of light weight are found mingled in with larger, heavier ones in seawater; distillation merely separates the two types of particles by raising the smaller and leaving the bigger behind.[41] Hence it is possible for the smaller atoms of the volatile salt to ascend while the larger, fixed ones remain behind, making it impossible, supposedly, to completely remove the salinity of seawater by distillation. The same ideas linking subtlety to volatility and grossness to fixity pervade Newton's reasoning as well, and it is quite possible that Varenius's influence in "Of Natures obvious laws & processes in vegetation" extends well beyond the discussion of mere sea-salt.

But Newton differs markedly from Varenius in bringing niter into his discussion of salts. Probably stimulated in a general way by Varenius's claim that sea-salt contains components of varying volatility, Newton asserts that niter is a looser, less fixed salt than sea-salt, and that the difference between the two salts arises not from a chemical diversity between their ingredients, but rather from the fact that the niter is made when metallic fumes combine with "subtile invisible" water vapor, whereas sea-salt originates from the combination of the volatilized metals with liquid water or mist. A preponderance of water causes the fumes to be "overwhelmed & drowned," which results in the immediate formation of sea-salt.

What is Newton's first evidence for the claim that physical modes of combination alone, such as solution in liquid water versus solution in water vapor, can produce such different salts as niter and sea-salt? Once again, Newton turns to chymical analysis and synthesis. He points to Boyle's famous redintegration of saltpeter, which we described earlier in this chapter, where niter was first analyzed into its components and then resynthesized. As Newton puts it on fol. 2r of the manuscript: "Nor is it strange y^{t} so slight causes should produce so <*illeg.*> different salts as ⊖ & ⦶ if wee consider y^{t} y^{e} fixt salt <*illeg.*> left in ignition returns to ⦶ by dissolution." "The fixt salt left in ignition" is the potassium carbonate produced by Boyle's injection of burning charcoal into hot niter. The product, Newton says, "returns to <niter> by dissolution." Interestingly, Newton here seems to focus solely on the *physical* features of the experiment – the fact that the fixed salt left by ignition is "dissolved" into saltpeter, without considering the *chemical* fact that the solvent has to be nitric acid. The omission on Newton's part is a calculated move intended to bring the experiment into conformity with his theory, whereby the looser, more subtle niter is formed by mere "dissolution" of the more fixed and impassible potassium carbonate. In other words, he interprets the redintegration of niter as a purely mechanical process resulting in the conversion of one salt into another by a change of gross texture alone. Newton then launches on folios 2r and 2v into a detailed comparison of niter and sea-salt in the world at large in order to confirm his idea that the latter is merely a more fixed version of the former.

As we have seen, Newton wants to locate the essential distinction between sea-salt and niter purely in the mechanical property of texture. Niter is more volatile and subtle, whereas sea-salt is more fixed and gross, and this distinction arises from the respective combination of the same metallic fumes either with water vapor on the one hand or with liquid water or dense mist on the other. Although Newton's reputation lies mainly in his work as a physicist, this is not an empire-building move on the part of a reductionist natural philosopher intent on leading all change back to physical principles such as brute, passive matter and motion. To the contrary, Newton is keenly aware of the fact that not all chemical phenomena can be reduced to what he calls "gross mechanical transposition of parts." Indeed, in the section on niter and sea-salt, Newton is already setting up a discussion of vegetation.

To Newton, as to Robert Boyle and many early modern chymists, vegetation implied a goal-directed process guided by tiny *semina* or "seeds" implanted deep within matter.[42] The processes of salt-production that we have analyzed so far are manifestly *not* instances of vegetation, since they involve only a mechanical change in texture brought on by corpuscular interaction between metallic fumes and water. Newton classifies these changes with such purely mechanical operations as the mixing of differently colored powders to produce new colors (as when jumbled blue and yellow granules give the appearance of green), the dissolution of metals in mineral acids, and the separation of cream into butter, curds, and whey by churning. As for vegetation, Newton defines it in the following terms in "Of Natures obvious laws" (5r):

> Natures actions are either ~~seminall~~ $^{\wedge\text{vegetable}}$ or $^{\wedge\text{purely}}$ mechanicall (grav. flux. meteors. vulgar $_{\text{Chymistry}}$<)>

> The principles of her vegetable actions are noe other then the ~~seeds~~ seeds or seminall vessels of things those are her onely agents, her fire, her soule, her life,
>
> The seede of things that is all that substance in them that is attained to the ~~full~~ fullest degree of maturity that is in that thing <*illeg.*> so that there being nothing more mature to act upon them they acquiesce.
>
> Vegetation is nothing else but y^e acting of w^t is most maturated or specificate upon that w^ch is <*illeg.*> less specificate or mature to make it as mature as it selfe And in that degree of maturity nature ever rests.

In drawing this sharp distinction between mechanical and vegetative processes, Newton had to confront an obvious potential objection. Although the artificial operations employed by a laboratory technician in cases of "vulgar chymistry" might be purely mechanical, there are plenty of instances where a hidden, indwelling nature may actually be driving operations that seem to our senses to be mere mechanism. This seminal "vegetable substance," acting as a latent "invisible inhabitant," may direct grosser particles to take on the structure of bones, flesh, wood, fruit, and other materials subject to growth. As Newton clarifies on folio 5v:

> So far therefore as y^e same changes may bee wrought by the slight mutation of the textures of bodys in common chymistry & such like experi ments ~~may~~ may judg that ~~there is noe other cause that will~~ such changes made by nature are done y^e same way that is by y^e sleighty transpositions of y^e grosser corpuscles, for upon their disposition only sensible qualitys depend. But so far as by ~~generation~~ ^vegetation such changes are wrought as cannot bee done w^th out it wee must have recourse to som further cause And this difference ~~is seen clearest in fossile substances~~ is vast <*illeg.*> & fundamental because nothing could ever yet bee made w^th out vegetation w^ch nature useth to produce by it. [note y^e instance of turning Irō into copper. &c.]

The point of this passage is that even seemingly mechanical operations in nature can be directed by hidden, seed-like entities that occupy an "unimaginably small" portion of matter. How then can we distinguish between the purely mechanical operations of ethereal gravitation, fusion, meteorology, and vulgar chymistry and the vegetative processes employed by nature?

Newton responds by asserting that any laboratory process that allows one to retrieve the initial ingredients from what we would call a "chemical compound" or recreates the compound from its ingredients reveals that the compound in question was a mere mechanical mixture rather than a product of vegetation. A similar ideology underlay Newton's experimental analysis and synthesis of white light, and the use of decompounding followed by recompounding as an index of mere mechanical change in "Of Natures obvious laws" probably also had its sources in Boyle's work.[43] As Newton puts it in "Of Natures obvious laws" (5v):

> all y^e operations in vulgar chemistry (many of w^ch to sense are as strange transmutations as those of nature) are but mechanicall coalitions ^or seperations of particles as may appear in that they returne into their former natures if reconjoned or (when unequally volatile) dissevered, & y^t w^th out any vegetation.

In other words, all the ordinary reactions that Newton groups within the realm of "vulgar chemistry" are mere mechanical interactions, and this is demonstrated by the retrievability of their unaltered ingredients by analysis or their recombination by synthesis. As we have already seen, Newton used the redintegration of niter as a paradigmatic case of such purely mechanical recombination earlier in "Of Natures obvious laws." It is likely that he has the same process in mind here, though the reference to unequal volatility suggests that he has broadened his scope to include compounds that can be separated by mere sublimation or distillation rather than combustion. Like earlier alchemists, Newton viewed such separations and recombinations as a sort of change that took place between "the grosser corpuscles" of bodies. Real transmutation, which Newton has in mind when he speaks of vegetation, had long been thought of in alchemy as something that occurs at a deeper microstructural level of matter.[44]

To the young Newton, who had not yet embraced the principle of action at a distance that marked his mature *Principia*, the phenomena exhibited by falling bodies, melting materials, changes in the atmosphere, and inorganic chemical reactions were all explicable by means of micro-level particles acting mechanically on one another. Vegetation, on the other hand, is a goal-directed process whereby a more mature seed leads a less mature material into a state of maturity equivalent to its own. In other words, vegetation is the procedure whereby generation and growth occur in the natural world. In Newton's mind, it is clearly the operation by which nature retains and replenishes the species of the world around us. Even if the phenomenal world may *appear* to operate by purely mechanical means, nature employs vegetative processes at a deeper level to drive the corpuscular interactions that result in generation and growth. Hence in reiterating the distinction between mere mechanism and vegetation, Newton says (5v) "And this difference ~~is seen clearest in fossile substances~~ is vast <*illeg.*> & fundamental because nothing could ever yet bee made w^th^out vegetation w^ch^ nature useth to produce by it."

CONCLUSION

We have seen, then, that Newton's use of alchemy spanned markedly diverse areas in his scientific work ranging from optics to his theory of everything. Yet chymical analysis and resynthesis were particularly fruitful concepts for him throughout. On the one hand, a transfer of chymical analysis and synthesis to the realm of optics allowed Newton to resynthesize white light out of its analyzed components or to "redintegrate" it in the Boylean language that he uses. This provided conclusive evidence to him for the fact that no transmutation of spectral colors had occurred. Alternatively, analysis and synthesis provided Newton with a marker differentiating the mechanical from the vegetable in the generation of salts. It was the fact that particular substances such as niter could be taken apart and put back together again that demonstrated their immediate origin to be purely mechanical rather than involving the intimate transmutational processes of vegetation. Hence we have seen how Newton used analysis and synthesis both in the realm of optics and the genesis of salts to supplant transmutational processes with mechanical ones. It does not follow, of course, that Newton did not believe in transmutation, but like many alchemists of the time, particularly Van Helmont and George Starkey, he was trying to distinguish genuine transmutation from mere transfer and apposition of gross particles. It is a peculiar irony of history that alchemists, in their undying quest to transmute the products of nature, became the first experimental proponents of the fixity of chemical species in the form of corpuscles that retained their chemical identity throughout their association and dissociation.[45] Like Starkey and Van Helmont, Newton saw the possibility of real transmutation only at the extreme nano-stage of corpuscular hierarchy, well below the level of gross corpuscles that made up the Lego-blocks of vulgar chymistry. Seeing Newton in the light of the longstanding alchemical emphasis on analysis and synthesis provides a new window on the thirty-plus years that he devoted to the aurific art and allows us to discern little explored connections between his chymistry and the scientific work for which he is more famous.

To conclude, then, it is time to abandon the outworn positions adopted by the early pioneers of Newton's alchemy. The roles for alchemy advocated by Westfall and Dobbs and now viewed as matters of fact by large swaths of the public and scholarly communities alike arose in part from the absence of edited texts, which encouraged these scholars to rely on selective core-samples extracted from Newton's large and diverse *Nachlass*. Perhaps even more significantly, these scholars were working during a period when the historical study of alchemy was, to borrow a term from Nathan Sivin, "moribund."[46] It was only natural for Dobbs and her predecessor Mary Churchill to see Newton's alchemy as primarily a religious phenomenon at a time when the dominant interpretation of alchemy as a whole was that of Carl Jung. Similarly, the claim of Westfall and the early Dobbs for the influence of the "hermetic tradition" and alchemy on Newton's concept of gravitational attraction was partly due to the influence of Frances Yates, whose work encouraged the view that the so-called occult sciences made up a homogeneous group characterized by the quest for mysterious and secret sympathies in nature.[47] Over the last two decades a Renaissance in the historiography of alchemy has taken place, however, and the influence of Jung and Yates has accordingly declined. At the same time, the *Chymistry of Isaac Newton* project is well on its way to producing a complete online edition of Newton's alchemical writings. Although many problems remain, particularly the relationship between theory and practice in Newton's records of his alchemical experimentation, we are now in a uniquely favorable position to make sense of his long engagement with the aurific art. The complex picture that is emerging reveals at once a textual scholar intent on disentangling the riddles of alchemical encipherment, an experimental scientist keen on replicating the deepest arcana of the art, and a theorist determined to incorporate chymical explanations into his own theory of nature at large.

NOTES

1 David Brewster, *Memoirs of the Life, Writings, and Discoveries of Sir Isaac Newton* (Edinburgh: Thomas Constable and Co., 1855), vol. 2, pp. 374–5.

2 J. M. Keynes, "Newton the Man," in *Newton Tercentenary Celebrations, 15–19 July 1946* (Cambridge: Cambridge University Press, 1947), p. 27.

3 J. E. McGuire, "Force, Active Principles, and Newton's Invisible Realm," *Ambix* 15 (1968), 154–208; see 166–7. John Henry has already drawn attention to this passage in his "Occult Qualities and the Experimental Philosophy: Active Principles in Pre-Newtonian Matter Theory," *History of Science*, 24 (1986), 335–81; see p. 369, n. 7.

4 Richard Westfall, *Force in Newton's Physics* (London: MacDonald, 1971). See, for example, p. 369: "Neither in the 'Hypothesis' nor in the letter

to Oldenburg did Newton attempt to reduce the 'secret principle' of sociability to mechanical terms, although he employed it in mechanical contexts where it aided the power of mundane factors such as size. Redolent of hermetic tradition, it refused to be made sociable to the mechanical philosophy and stood out starkly against its background. In the case of the principles of motion or of activity mentioned in the 'Hypothesis,' Newton asserted their mechanical nature, although he did not venture to interpret how that might be. With their immediate Helmontian forebears, they too suggested the lingering presence in his thought of a tradition alien to the mechanical. His intensive study of alchemical literature during the latter years of the 1670s may well have intensified these influences."

5 Richard Westfall, "Newton and the Hermetic Tradition," in A. G. Debus, *Science, Medicine and Society in the Renaissance* (New York: Science History Publications, 1972), vol. 2, pp. 183–98; see pp. 193–4. Westfall goes on to argue that Newton only gradually "rejected the specificity of force" thus eventually arriving at the position that gravitational force is universal. Nonetheless, Westfall reasserts at the end of the article that Newton's concept of immaterial attractions originated in "the Hermetic tradition."

6 Betty Jo Teeter Dobbs, *The Foundations of Newton's Alchemy* (Cambridge: Cambridge University Press, 1975), pp. 211–12. Dobbs later acknowledged the demonstration by William R. Newman that the "Clavis" was actually by George Starkey rather than Newton, and even backed away somewhat from her claim that alchemy was responsible for Newton's move to an immaterial gravitational force. See *Janus Faces*, pp. 15 (for the "Clavis") and 207–8, where she admits that "the story no longer seems quite so straightforward." But her partial recantation has escaped the public eye entirely, as may be seen from a passage in *Wikipedia's* entry "Isaac Newton" (accessed April 7, 2013), which is the very first hit encountered when one searches "Isaac Newton" via *Google*. According to *Wikipedia*, Newton "replaced the ether with occult forces based on Hermetic ideas of attraction and repulsion between particles . . . Had he not relied on the occult idea of action at a distance, across a vacuum, he might not have developed his theory of gravity."

7 William R. Newman, "Newton's 'Clavis' as Starkey's 'Key'," *Isis* 78 (1987), 564–74.

8 See the *Chymistry of Isaac Newton* site (www.chymistry.org). "Of Natures obvious laws" can be found at http://webapp1.dlib.indiana.edu/newton/mss/dipl/ALCH00081/ (accessed April 21, 2013).

9 J. E. McGuire and Martin Tamny, *Certain Philosophical Questions: Newton's Trinity Notebook* (Cambridge: Cambridge University Press, 1983), p. 362.

10 *Ibid.*, p. 288. I am less convinced by McGuire and Tamny's suggestion that Newton's main source was Boyle's *Spring of the Air*, for which see *Certain Philosophical Questions*, p. 426 n. 122.

11 A. Rupert Hall and Marie Boas Hall, *Unpublished Scientific Papers of Isaac Newton* (Cambridge: Cambridge University Press, 1962), pp. 302–8.

12 Isaac Newton, *Optice: Sive De Reflexionibus, Refractionibus, Inflexionibus & Coloribus Lucis. Libri Tres* (London: Samuel Smith and Benjamin Walford, 1706), pp. 343–4.

13 I have argued elsewhere that Starkey's speculations about layered corpuscles endowed with forces may have influenced Newton's views on the microstructure of particles and their dynamic interactions in the realm of chymistry. See pp. 228–39 of my *Gehennical Fire: The Lives of George Starkey* (Cambridge, MA: Harvard University Press, 1994).

14 John Henry, "Occult Qualities and the Experimental Philosophy: Active Principles in Pre-Newtonian Matter Theory," *History of Science* 24 (1986), 335–81. Henry has reiterated this point with further evidence in a much more recent article where he also addresses the vexed problem of dating Newton's *De gravitatione et aequipondio fluidorum*. See Henry, "Gravity and *De gravitatione:* the development of Newton's ideas on action at a distance," *Studies in History and Philosophy of Science* 42 (2011), 11–27, esp. 19–23.

15 The important use that Newton made of magnetism in the *Principia* is described by Domenico Bertoloni Meli in his *Thinking with Objects* (Baltimore, MD: Johns Hopkins University Press, 2006), p. 263.

16 B. J. T. Dobbs, *Janus Faces*, p. 13. See also pp. 243–8, where she again stresses the role of "the alchemical vegetable spirit" as a mediator between God and man and associates this with "the Arian Christ."

17 Mary S. Churchill, "The Seven Chapters, with Explanatory Notes," *Chymia* 12 (1967), 27–57; see p. 38: "In alchemical writings, Newton must have believed, lay hidden a religious expression stripped of sacerdotal dogmas, which was very close to his own belief. To him

the Roman Catholic Church had usurped authority. It had abused and degraded Christianity by its drive for power, its use of confession, absolution, and indulgences, and by the corruption of the clergy. To him the alchemists must have represented the true unsullied wisdom of the past. They were the preservers of the teachings of the ancient wise men and of the earliest Christian Church. They kept in its true form the secret of salvation, regeneration and immortality, a matter of individual growth and conscience, not to be legislated by popes or bishops." For the part played by Carl Jung in Churchill's argument, see her p. 36.

18 Churchill, "The Seven Chapters," pp. 38–9. Dobbs originally criticized Churchill, but in *Janus Faces* Dobbs explicitly endorsed her views and went so far as to offer Churchill an apology for her earlier scepticism. See *Janus Faces*, p. 18, n. 42.

19 Dobbs, *Janus Faces*, p. 115.

20 *Ibid.*, p. 116.

21 This passage is found on p. 464 of the McGuire and Tamny edition of *Certain Philosophical Questions*. As Tamny and McGuire point out, this is inspired by Descartes's "Fifth Meditation." I have compared the transcription to the digital scan posted by the Cambridge University Library (cudl.lib.cam.ac.uk/view/MS-ADD-03996/170; accessed April 4, 2013). The term "post existence," altered by McGuire and Tamny to "past existence" in their normalized version of the text, is not a slip of the pen on Newton's part. The point is that if existence is implied by essence, as in the Cartesian ontological proof for God's existence, then cause and effect must be simultaneous. Apparently unaware of the Cartesian background to the related passage in "Of Natures obvious laws," Dobbs links it to voluntarism and tries to give it an alchemical significance. See Dobbs, *Janus Faces*, pp. 113–17.

22 I owe this reference to an extended discussion with Roger Ariew. The translation is from René Descartes, *Meditations, Objections and Replies*, edited and translated by Roger Ariew and Donald Cress (Indianapolis, IN: Hackett, 2006), p. 74. Gideon Manning has also found echoes of the third Meditation in Newton's comments, a fact that he has kindly related to me in a personal exchange.

23 Roger Ariew has kindly pointed out to me that Leibniz made great use of a "contradiction clause" quite similar to Newton's. In his *Monadology*, for example, Leibniz says: "Thus God alone (or the necessary being) has the privilege, that he must exist if he is possible. And since nothing can

prevent the possibility of what is without limits, without negation, and consequently without contradiction, this by itself is sufficient for us to know the existence of God *a priori*" (translation by Roger Ariew and Daniel Garber in G. W. Leibniz, *Philosophical Essays* [Indianapolis, IN: Hackett, 1989], p. 218). Moreover, the main elements of this argument already appear as early as 1676 in Leibniz's *De summa rerum*. Ariew has also provided me with the references for these: see G. W. Leibniz, *De summa rerum* (New Haven, CT: Yale University Press, 1992), pp. 47–9, 63, 91–107.

24 Marie Boas and A. Rupert Hall, "Newton's Chemical Experiments," in *Archives internationales d'histoire des sciences* 11 (1958), 113–52.

25 This new interpretation of Newton's early optical discoveries was first expounded in William R. Newman, "Newton's Early Optical Theory and its Debt to Chymistry," in Michel Hochmann and Danielle Jacquart (eds.), *Lumière et vision dans les sciences et dans les arts* (Geneva: Droz, 2010), pp. 283–307. A preprint version of the article may also be found on the Chymistry of Isaac Newton website, at www.chymistry.org.

26 Significantly Newton himself later uses the term "transmutation" for the theory that is usually referred to by historians as "modification." For example, his *Lectiones opticae* contains the following sentence – "Quemadmodum si desideretur ut sensui planissimé pateat quòd prisma convertit lucem in colores non transmutando proprietates ejus intrinsecas, sed segregando tantum radios . . ." The same language occurs in the closely related *Optica*. See Alan Shapiro, *The Optical Papers of Isaac Newton, Volume I, The Optical Lectures 1670–1672* (Cambridge: Cambridge University Press, 1984), pp. 165, 472, and 520. The term "transmutation" appears also in Newton's "New Theory about Light and Colours" of 1672.

27 Shapiro, *Optical Papers*, pp. 12–13, says the following: "Sometime between the beginning of 1666 and 1669, but most probably closer to the former than the latter, Newton wrote up the experiments from his 'age of invention' in an essay again entitled "Of Colours" [= CU Add. 3975, fols. 2v–11v.] There is no statement of the theory and little theoretical interpretation, but cautiously reading backward from the later accounts, especially the *Optical Lectures*, it is clear that he already had the main features of his theory, since the essay contains many of the fundamental experiments of the *Optical Lectures*."

28 For a full account of this tradition up to the time of Boyle, see William R. Newman, *Atoms and Alchemy: Chymistry and the Experimental Origins of the Scientific Revolution* (Chicago, IL: University of Chicago Press, 2006).

29 William R. Newman and Lawrence M. Principe, *Alchemy Tried in the Fire* (Chicago, IL: University of Chicago Press, 2002), ch. 2.

30 See Newman and Principe, *Alchemy Tried in the Fire*, ch. 5, for Worsley. See also John T. Young, *Faith, Medical Alchemy and Natural Philosophy: Johann Moriaen, Reformed Intelligencer and the Hartlib Circle* (Brookfield, VT: Ashgate, 1998), pp. 183–216, esp. pp. 198–200.

31 The experiment is clearly described by Boyle, *Certain Physiological Essays*, in *The Works of Robert Boyle*, ed. M. Hunter and E. B. Davis (London: Pickering and Chatto, 1999–2000), vol. 2, pp. 92–6.

32 Newton, CUL Add. Ms. 3975, fol. 32v, from The Chymistry of Isaac Newton, http://webapp1.dlib.indiana.edu/newton/mss/norm/ALCH00110/:

> The purenesse of this ^redintigrated Antimony seemed to proceede from y^e recesse of so much Sulphur w^ch is not at all necessary to y^e constitution of Antimony though perhaps too y^e vitrum a top might proceede from y^e avolation of two much Antimony from y^e superficiall parts. pag 265
>
> But redintegration of Bodys succeded best <*illeg.*> in Turpentine for a very cleare liquor being distilld from it <*illeg.*> was againe put to y^e caput Mortuum (w^ch was very dry brittle Transparent sleeke & red but purely yellow when poudered) it was immediatly dissolved part of it into a deepe red Balsome. And by further disgestion in a large well stopt Glasse became perfect Turpentine againe ~~both~~as all men judgd by y^e smell & Taste. pag 268 of for<ms>

33 Shapiro, *Optical Papers*, vol. 1, p. 504: "Et eadem ratione constat reflexam albedinem similiter compositam esse, siquidem (ut dixi) redintegrata est . . ."

34 Shapiro, *Optical Papers*, vol. 1, p. 162, line 9; and p. 516, line 16.

35 *Oxford Latin Dictionary*, ed. P. G. W. Glare (Oxford: Clarendon Press, 2003): see the entries for "Redintegro" and "Redintegratio" *sub vocibus*. The meanings given for "Redintegro" are "to restore physically" in the

sense of refreshing, "to replenish," and "to revive"; "to revive, renew"; and "to say over again" or "repeat in full." For "Redintegratio," one finds nominal forms of these meanings followed by "Reiteration, repetition."

36 George Ripley, *The Compound of Alchymie*, in Elias Ashmole, *Theatrum Chemicum Britannicum* (London: Nath: Brooke, 1652), p. 176.

37 Some further instances of Newton's terminological borrowing from Boyle may be found in Newman, "Newton's Early Optical Theory," pp. 305–6.

38 For a more complete description of these themes in Newton's "theory of everything," see William R. Newman, "Geochemical Concepts in Isaac Newton's Early Alchemy," in G. D. Rosenberg (ed.), *The Revolution in Geology from the Renaissance to the Enlightenment* (Boulder, CO: Geological Society of America, 2009), pp. 41–9.

39 See A. Rupert Hall, "Newton and the Aerial Nitre," *Notes and Records of the Royal Society of London* 52 (1998), 51–61, esp. 57.

40 On Newton and Varenius, see William Warntz, "Newton, the Newtonians, and the Geographia Generalis Varenii," *Annals of the Association of American Geographers* 79 (1989), 165–91. For the relationship of "Of Natures obvious laws & processes in vegetation" to Varenius, see Newman, "Geochemical Concepts," pp. 41–9.

41 Bernhardus Varenius, *Geographia generalis*, ed. Isaac Newton (Cambridge: Henricus Dickinson, 1672), p. 112 (translation by William R. Newman): "Even if salt is left behind in the bottom of the vessel in both distillation and decoction (which are the same) nonetheless the water separated by distillation or decoction is still found to be salty, so that it is not fit for human drink, which seems a wonder to those ignorant of the cause. But chymistry, that is, true physics, has taught this, by whose help it is known that there is a double salt in bodies; or two genera of salts, which even if they agree in taste yet differ greatly in <their> other qualities: the artificers call one <of them> "fixed" salt, the other "volatile." The fixed salt is not elevated in decoction and distillation on account of its weight, but remains in the bottom of the vessel. But the volatile is a spiritual salt, and is nothing other than a very subtle spirit, which is raised by a very mild fire, and hence it ascends with the sweet water in distillation, and is tightly united <to it> on account of the subtlety of <its> atoms."

42 For Boyle's rather conflicted thoughts about seminal principles, see especially Peter R. Anstey, "Boyle on Seminal Principles," *Studies in History and Philosophy of Biology and Biomedical Sciences* 33 (2002), 597–630.

43 For a discussion of combined analysis and resynthesis as a way of distinguishing mechanical from non-mechanical processes in the work of Robert Boyle, see William R. Newman, "How Not to Integrate the History and Philosophy of Science: A Response to Chalmers," *Studies in History and Philosophy of Science* 41 (2010), 203–13, esp. 206–7.

44 For a discussion of this corpuscular tradition in medieval and early modern alchemy, see Newman, *Gehennical Fire*, pp. 92–114 and 141–69.

45 This argument is made at length in Newman, *Atoms and Alchemy*, particularly pp. 23–44.

46 Nathan Sivin, "Research on the History of Chinese Alchemy," in Z. R. W. M. von Martels, *Alchemy Revisited* (Leiden: Brill, 1990), pp. 3–20; see p. 4.

47 This view of the occult sciences has largely gone out of style in recent decades, but is still upheld by Brian Vickers. See Vickers, "The 'New Historiography' and the Limits of Alchemy," *Annals of Science* 65 (2008), 127–56. See also the response to Vickers in William R. Newman, "Brian Vickers on Alchemy and the Occult: A Response," *Perspectives on Science* 17 (2009), 482–506.