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For Carly, Wyatt, and Emerson,
my *tria prima*

And in memory of my grandfather,
Robert Lentz,
a farmer and storyteller

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Manuscripts reading room in the Weston Library, the Royal Society archives, the University of Glasgow Special Collections, the Cambridge University Main Library and the archives of Wren Library, Trinity College, Cambridge, and the University of Chicago Special Collections Research Center. At the University of Chicago, I'd especially like to thank Catherine Uecker for her work.

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ABSTRACT

This dissertation investigates the influence of vitalist matter theories and the practical, operational techniques of alchemy on agricultural improvement projects in seventeenth-century England. It argues that the historical territory of alchemy is much broader than many historians of this subject have conceded over the past generation. In fact, among a subset of utopian social reformers in mid-seventeenth-century England, alchemy was both an expansive worldview that explained physical change in the cosmos as well as a set of practices that could be applied in multiple locations where generation, growth, and change were the ultimate goals. This included the question of botanical growth and, most imperatively, the necessity of improving agricultural production.

This project engages with multiple, overlapping historiographical traditions, including not only the histories of chemistry, alchemy, and agriculture, but also environmental history, and particularly the unresolved tensions over whether early moderns envisioned nature as a practically infinite, exploitable resource under humanity's dominion or as a fragile, finite territory in need of stewardship and conservancy. Many figures I examine were not only social utopians but also believed that human ingenuity—buttressed by empirical science and experimentalism, but constrained within prescribed divine parameters—could create agricultural and economic bounty irrespective of any natural limits. This cornucopian political economy and ecology emboldened mid-seventeenth-century agricultural reformers to devise alternative agricultural regimes that used alchemy as a tool in an attempt to improve crop yields, the potency of seeds, germination speeds, soil fertility, and artificial fertilizers. In terms of science, many of these figures sought an overarching theory of growth that could apply to everything from metals

and minerals underground to plants and animals on earth to more abstract notions like the economy. This natural philosophy was often referred to as a "vegetable philosophy."

With the Hartlib Intelligencer Circle as its primary focus, this dissertation seeks to demonstrate how the post-Baconian scientific worldview of empirical, technocratic, and most importantly, *manipulative* applied sciences induced many to seek solutions to social ills through the application of the basic premises of alchemy to create economic and ecological conditions that would eradicate the need for war, the existence of hunger, the fear of crop failure, and presage a future era of abundance. The Hartlib Circle—named after the Prussian émigré to England and pan-continental intelligencer Samuel Hartlib—was a correspondence network of natural philosophers who shared the results of experiments and carried on theoretical discussions on themes ranging from alchemy, mineralogy, and mathematics to pansophism, educational reform, and the English settlement of Ireland. This loose intellectual community was highly influenced by Paracelsian matter theory and the *sal nitrum* school of alchemy, which viewed salts as the key to unraveling the nature of matter and as the starting point for manipulating nature. For the Harltib Circle's Paracelsians and *sal nitrum* theorists, alchemy was not simply transmuting lead into gold but rather transforming *any* natural substance such as plant matter, soil, water, animal manures, salts, and ash to solve a number of practical problems related to husbandry. These included, among other things, the manufacturing of saltpeter for use as a field fertilizer, the creation of seed steeps and "fructifying waters" to confer fertility on seeds using alchemical recipes, the application of alchemical theories of growth to understand soil fertility, and using alchemical techniques like calcination, fermentation, distillation, and putrefaction to uncover the underlying nature of plant life. The Hartlib Circle—and especially members interested in matter theory, such as Frederick Clodius, Gabriel Plattes, Benjamin Worsley, Johan Moriaen, and John Beale—sought to apply vitalistic theory and its alchemical outcomes with a keen interest in participating in the "improvement" of the natural world for human benefit. This project adds another dimension of this history that views vitalistic alchemy as a study of the intersection of inert and living matter, the practice of which was often done by "amateurs" in the field—on English farms, gardens, orchards, kitchens, and other everyday spaces—as opposed to just in the laboratory.

A NOTE ON SOURCES, TRANSLATIONS, AND TERMINOLOGY

Living in the Internet era has furnished historians of the early modern era with the gift of immediate access to abundant sources that, until relatively recently, required lengthy and expensive archival visits. Although travel to physical archives remains an indispensable task for most historians, the breadth and depth of a number of digital archives has made completing fruitful research a much easier process. The manuscripts and published primary sources I have used in this dissertation come from a combination of on-site research at archives in the US and UK as well as digital archival databases. That said, I have examined all unpublished manuscript documents in person in the archives that house them with the following exceptions: the Hartlib Papers, housed at the University of Sheffield Library, which I accessed at https://www.dhi.ac.uk/hartlib/context; the Boyle Papers (with the exception of those documents noted in the bibliography), housed at the Royal Society archives, which I accessed at http://www.bbk.ac.uk/boyle/papers /introduction; the work-diaries of Robert Boyle, housed at the Royal Society archives, which I accessed at http://www.livesandletters.ac.uk/wd/; the Newton Papers, housed at Kings College, Trinity College, the Fitzwilliam Museum, and the Cambridge University Library, which I accessed at http://cudl.lib.cam.ac.uk/collections/newton/1 and http://webapp1.dlib.indiana.edu/newton/; the Winthrop Family Papers, housed at the Massachusetts Historical Society archive, which I accessed at http://www.masshist.org/ publications/winthrop/index.php; and some British state documents (noted in the footnotes), which I accessed at British History Online, http://www. british-history.ac.uk. For published primary sources, I have relied chiefly on the Early English Books Online database at https://eebo.chadwyck.com/home and the Eighteenth Century Collections

Online database at https://www.gale.com/primary-sources/eighteenth-century-collections-online for works in English and the Early European Books database at eeb.chadwyck.co.uk for works in other European languages. In some instances, such as when I have made comparisons between editions or when the provenance, ownership, or marginalia of a book has been important, I have examined physical copies, but unless otherwise noted, I have used these databases.

All translations from French, Latin, and German are mine unless otherwise specified. When I have adapted translations from other scholars, I have cited the original translation for comparison. The sources of translations from all other languages have been referenced in the footnotes. For ancient and classical works as well as some prominent early modern works that have undergone multiple translations over the centuries, I have used well-known, modern translated editions when available. For non-English works that underwent seventeenth-century English translations, I have referred to those translations assuming that my historical subjects also accessed these works.

Finally, a note on terminology. I have endeavored, as far as possible, to retain the language of the historical actors about whom I write. I have preserved the original spelling, punctuation, and shorthand abbreviations to be found in the manuscript documents unless doing so has obscured the modern meaning. In some cases, quotes contain italicized letters within words, which represent editorial choices made by archivists to improve the clarity of heavily abbreviated manuscript writings. This has been the case especially with the Hartlib Papers Online, and I have preserved their edits when I quote from them. I have also attempted to employ terms as my early modern English subjects would have understood them, which sometimes means using early modern terms in ways that differ slightly from their modern versions. Foremost among these are the terms "alchemy," "chemistry," and "chymistry." Following the leads of William Newman and Lawrence Principe, I have used the term "chymistry" to refer to the more expansive body of knowledge and practice that included early chemistry, alchemy, and most studies of nature that involved the interactions of material substances and theories of matter, including more arcane fields like iatrochemistry and spagyrical medicine. The only exceptions to this are when I use the term "chemical philosophy," a modern phrase some historians of science use to refer to the worldview of certain historical actors for whom "chymistry" was the most promising avenue for explaining the natural world, and "chemistry," referring to something approaching its modern meaning, after about 1720. I have used "alchemy" both in a more limited and more capacious way: more limited in that I use it only to refer to practical, operational attempts to directly manipulate matter or transform it from one form to another; more capacious in that I remove it from its usual laboratory confinement and place it into mechanical, artisanal, agricultural, horticultural, botanical, and biological contexts, as well as many others, when the historical sources justify this. I use "chemistry" only to refer to modern chemistry when explaining various historical activities through a modern lens. Since I describe some modern biological processes and chemical reactions, I have included some explanations, formulae, and nomenclature from modern science, but, for the most part, I have confined these asides to the footnotes unless they prove integral to the argument. In general, I have refrained from using modern terminology to describe historical circumstances, though I have taken some liberties when it has provided explanatory clarity (e.g., "life science") to describe certain aspects of seventeenth-century alchemy.

INTRODUCTION

Sometime in the late seventeenth or early eighteenth century, an unknown individual committed a remarkable alchemical reipe for an artificial fertilizer to writing.[1] The proveance of this document is unknown. It may have been a small landholder, the owner of an estate with the time and land to spare for agricultural experiments, or an amateur alchemist who worked with everday chymical materials far from a laboratory setting. Although written in English, the author of what is now Ferguson Manuscript 274 titled it with the pseudo-Latin heading "Vegetani." It was subtitled in English "On Vegetation" and described by its first known owner, the nineteenth-century University of Glasgow chemistry professor John Ferguson, as a "series…of recipes for alchemical methods to agriculture to make barren land fruitful."[2] It may have been intended as the first in a succession of recipes but contains just five folio pages. It provides a step-by-step process for producing a "fructifying alias vegetable Liquor," which could be solidified and spread on cropland or remain a liquid and watered on the roots of plants to aid in their growth. Whatever its origin, it is an excellent late example of the intersection of practical trials and theoretical explanations in effort to use the operational techniques of alchemy in service of agricultural improvement.

The recipe followed a reasonably standard format for seventeenth-century alchemical formulae: it contained a list of ingredients, a numbered list of operations for how they were to be combined, and explanations of what alchemical processes were occurring. Though it used idiosyncratic symbols for some of its ingredients, the recipe was

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[1] Glasgow University Library (hereafter GUL), MS Ferguson 274, ff. 1-5.
[2] See http://special.lib.gla.ac.uk/manuscripts/search/detail_c.cfm?ID=44474., last accessed 1 October 2016.

clear and straightforward.[3] It required saltpeter, common salt, urine (preferably human), water, and wood ash, along with a furnace and an alembic or other distilling apparatus. To create the vegetable liquor using these materials, the manuscript instructed the reader to mix bark, branches, and leaves from a number of specific trees in the furnace and heat until they began to turn to ash, at which point one was to add balls of saltpeter, common salt, and urine that had been previously prepared. This mixture was to be heated until white hot, while occasionally stirring, until a uniform "calx," a general term for a calcinated substance, remained. Meanwhile, the vapors given off by the heating process condensed at the top of the furnace and the liquid was directed into the alembic. The author called this condensate an "acid liquor," which was to be reserved in the alembic and distilled. Once cooled, one pounded the calx mixture flat and added the distilled acid liquor little by little until it was all absorbed and dried, a process that was to be repeated at least seven times. The calx sat for a month "to be vivified or animated from the air." The final step was to add this to boiling water and distill it again until the common salt was gone, at which point it could be recombined with water and either used to soak seeds before planting or spread upon fields as a fertilizer.[4] According to the author, about a hogshead (i.e., about 242 liters) was enough for one acre, which was considered the equivalent of twenty cartloads of dung.

The manuscript ended with the promise that "thy land will be so impregnated" by this amalgam and followed this with one of the most succinct descriptions of the

[3] Notably, the alchemical symbol for saltpeter, usually represented as ⦶, appeared as a combination of the symbols for copper (♀) and earth (⊕). Interestingly, many early modern farmers considered copper ore as a signifier of fertile soil, though there is no indication that either copper or soil is meant by this symbol in the recipe.

[4] GUL, MS Ferguson 274, ff. 1-4. In modern chemical terms, this recipe seems to be a method of quickly infusing the soil with nitrates, phosphates, and potassium.

application of alchemy to agriculture in the early modern era. This fructifying vegetable liquor

> will magnetically attract from the air, the fructifying, animating, nitrous particles, to such a degree as to qualify the seed sown therein that every particle thereof may be put into such motion, that the seminating, germinating property will so grow and increase, that the owner thereof will have great cause to praise God, and return Him true and hearty thanks for his goodness and declare the wonders as He hath done for the Children of Men: when he experimentally seeth how that from so little cost, labour, and trouble, so great an increase is had, quite different from common method; so that there need not be any barren land in England, or elsewhere, if this be rightly put into practice.[5]

This passage epitomizes much of what this dissertation explores: the attractive power of fertilizers, which were thought to draw in vital properties from air, water, and soil; the microscopic, particulate nature of transmutation in seeds that ultimately led to germination and growth; the time—and money—saving qualities of these novel creations; the anonymity of most of those who devised them; the socially and epistemologically equalizing nature of experimentalism; the consent granted by God for the manipulation of His creation; the fact that alchemy could be practiced anywhere; and the necessity of improving husbandry for the good of the nation. It also raises the question of how alchemy, and more broadly chemical philosophy, shaped what we would call the "life sciences," as well as, most imperatively, agriculture.

* * *

Was alchemy a "life science" in the seventeenth century? This dissertation is, in part, an attempt to answer this question, memorably posed by historian Ku-Ming Chang in a 2011 article for *Isis*.[6] This perhaps overly broad—and admittedly somewhat

[5] Ibid., f. 5.
[6] Ku-Ming Chang, "Alchemy as a Study of Life and Matter: Reconsidering the Place of Vitalism in Early Modern Chymistry," *Isis*, Vol. 102, No. 2 (2011): 322-329.

anachronistic—question requires yet another foray into the historiographical debate over what alchemy, or more approximately "chymistry," was a study of. Historians of alchemy have waged a long, hard battle describing what alchemy is *not*. Enlightenment historians, eager to distance themselves from anything that smacked of the occult, associated alchemy almost exclusively with fraudulent gold-making attempts and considered it a disreputable pseudoscience overcome by eighteenth-century *philosophes*, when they considered it at all.[7] With the rise of spiritualism, esotericism, panpsychism, and theosophy, especially in late Victorian Britain, many scholars began to explain early modern alchemy in religious terms as a mystical quest or individual, meditative activity in which the physical manipulation of matter was secondary, or even an allegorical cover for the deeper, spiritual goal of unveiling the divine nature of reality.[8] And in the middle of the twentieth century,

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[7] Lawrence Principe and William Newman, "Some Problems with the Historiography of Alchemy," in *Secrets of Nature: Astrology and Alchemy in Early Modern Europe,* eds. William R. Newman and Anthony Grafton (Cambridge: MIT Press, 2001), 385-7. For examples of the late eighteenth- and early nineteenth-century disrepute of alchemy and alchemical studies, especially among German scholars who still debated it (they claim it was all but ignored in much of the rest of Europe), Newman and Principe point to J.C. Weigleb, *Historisch-kritische Untersuching der Alchemie* (Weimar, 1777); Sigmund Heinrich Güldenfalk, *Sammlung vonmehr als hundert wahrhaftigen Transmutationsgeschichten* (Liepzig and Frankfurt, 1784); Johann Friedrich Gmelin, *Geschichte der Chemie*, 3 Vols. (Göttingen, 1797-99); and Thomas Thompson, *History of Chemistry*, 2 Vols. (London, 1830). See also Maurice Crosland, "The Chemical Revolution of the Eighteenth Century and the Eclipse of Alchemy in the 'Age of Enlightenment,'" in *Alchemy Revisited*, ed. Z.R.W.M. von Martels (Lieden, Netherlands: Brill, 1990), 67-77; and John C. Powers, "*Ars Sine Arte*: Nicolas Lemery and the End of Alchemy in the Eighteenth-Century France," *Ambix* Vol. 45, No. 3 (1998): 163-189. For an alternative view of the continuance of the occult, natural magic, and related endeavors into the Enlightenment era, especially in North America and the British Atlantic world, see, for example, Herbert Leventhal, *In the Shadow of the Enlightenment: Occultism and Renaissance Science in Eighteenth-Century America* (New York: New York University Press, 1976); Allison P. Coudert, *Religion, Magic, and Science in Early Modern Europe and America* (Santa Barbara: Praeger Press, 2011); and Paul Kléber Monod, *Solomon's Secret Arts: The Occult in the Age of Enlightenment* (New Haven: Yale University Press, 2013).

[8] Principe and Newman, "Some Problems with the Historiography of Alchemy," 388-401. Principe and Newman attribute this interpretation of alchemy, especially in the Anglo-American world, to works such as Ethan Allen Hitchcock, *Remarks upon Alchymists* (Carlisle, Penn., 1855); idem., *Remarks upon Alchemy and Alchemists* (Boston, 1857); Mary Ann Atwood, *A Suggestive Inquiry into the Hermetic Mystery* (Belfast: William Tait, 1918); Eliphas Lévy, *Dogme et rituel de la Haute Magie*, 2 Vols. (Paris, 1854-56), and its English language translation, A.E. Waite, trans. and ed., *Transcendental Magic: Its Doctrine and Ritual* (London, 1897); S.A. [*Sapere Aude*, i.e., "Dare to Know," alias of William Wynn Wescott], *The Science of Alchymy* (London: Theosophical Publishing Society, 1893); Arthur Edward Waite, *The Live of the Alchemystical Masters* (London: 1893); and idem., *The Secret Tradition in Alchemy* (New York: Alfred Knopf, 1926), among others.

Jungian psychology afforded a certain degree of social scientific credibility to these interpretations.[9] Psychologists, historians of mythology and religion, folklorists, anthropologists, and literary critics influenced by Jung envisioned historical alchemy not as experimental, proto-chemistry conducted in laboratory settings but as a material metaphor for what was, in their view, the far more important process of the individuation of the unconscious.[10]

The past two generations of historians of science have done an excellent job of dispelling many of the myths surrounding the actual practices of early modern alchemists. Most of these histories, however, have focused on those alchemists primarily interested in the transmutation of base metals into gold (*chrysopoeia* or *alchemia transmutatoria*), with the creation of *materia medica*, which purportedly improved or prolonged human life, and with the laboratory techniques and operations necessary for these enterprises. Consequently, the historiographical emphasis has shifted to laboratory studies, modern chemical explanations for alchemical activities, and the function that alchemical recipes and procedures played in the origins of modern chemistry.[11] In doing so, I fear the

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[9] For Jung's work on alchemy, see Carl Jung and Richard Wilhelm, *The Secret of the Golden Flower* (1929); Carl Jung, *The Collected Works of Carl Gustav Jung*, 20 Vols. (London: Routledge, 1953-79), Vol. 12: *Psychology and Alchemy*, Vol. 13: *Alchemical Studies*, Vol. 14: *Mysterium Conjunctionis*.

[10] See, for example, Joseph Campbell, *The Flight of the Wild Gander: Explorations in the Mythological Dimension* (New York: Harper Perennial, 1951); idem., *The Masks of God: Primitive Mythology* (Harmondsworth, UK: Penguin, 1959); Marie-Louise von Franz, *Alchemy: An Introduction to the Symbolism and Psychology* (Toronto: Inner City Books, 1980); Northrup Frye, *Anatomy of Criticism* (Princeton: Princeton University Press, 1957); and Barbara Obrist, *Les débuts de l'imagerie alchemique (XIVe-XVe siècles)* (Paris: Le Sycomore, 1982). This influence, particularly among literary theorists, remains and has proven a resilient topic of study for English and comparative literature. For just some of the most recent examples, see Katherine Eggert, *Disknowledge: Literature, Alchemy and the End of Humanism in Renaissance England* (Philadelphia: University of Pennsylvania Press, 2015); Theodore Ziolkowski, *The Alchemist in Literature: From Dante to the Present* (Oxford: Oxford University Press, 2015); and Alexander N. Zabrovsky, *Chaucer the Alchemist: Physics, Mutability, and the Medieval Imagination* (New York: Palgrave Macmillan, 2015).

[11] Among these, see the excellent work of William Newman and Lawrence Principe, including William Newman, *Atoms and Alchemy: The Experimental Origins of the Scientific Revolution* (Chicago: University of Chicago Press, 2006); William Newman, *Promethean Ambitions: Alchemy and the Quest to Perfect Nature* (Chicago: University of Chicago Press, 2005); William Newman, *Gehennical Fire: The Lives of George Starkey,*

pendulum has swung too far in the opposite direction and the scope of the history of alchemy has refocused too narrowly on its proto-chemical, elite, laboratory-based aspects. Certainly, understanding the actual chemical reactions and material substances couched in the arcane and sometimes deliberately obfuscatory language of medieval and early modern recipe books has been an important development, but the effect has been to pay less attention to the multitude of common laborers who possessed a distinct chemical worldview little different from the elite though they enjoyed little or no formal education or professional training.[12] Historians ignore a large portion of early modern society with an interest in and devotion to participating in alchemical practices at the risk of obscuring the fuller picture of early modern science. This is especially detrimental to understanding the outlook not only of those who practiced it in the laboratory but more importantly of those involved in the most common form of labor in the pre-Industrial era: agriculture. Among agricultural reformers, entrepreneurial projectors, merchants, traders, landholders, and ordinary farmers for whom a vitalistic understanding of physical change in nature was taken for granted, alchemy represented something much more expansive than what elites were doing in the laboratory.

In this dissertation, I seek to expand the focus of the historian of alchemy (and, consequently, historians of agriculture, the environment, botany, and political economy) by discussing the theories, sources, methods, recipes, objects, and locations of alchemical

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an American Alchemist in the Scientific Revolution (Chicago: University of Chicago Press, 2003); William Newman and Lawrence Principe, *Alchemy Tried in the Fire: Starkey, Boyle, and the Fate of Helmontian Chymistry* (Chicago: University of Chicago Press, 2005); Lawrence Principe, *The Secrets of Alchemy* (Chicago: University of Chicago Press, 2013); and Lawrence Principe, *The Aspiring Adept: Robert Boyle and His Alchemical Quest* (Princeton: Princeton University Press, 2000).

[12] For their objections, see Newman and Principe, *Alchemy Tried in the Fire*, 250. For a more sympathetic view on the alchemical work of what they called "armchair alchemists"—meaning alchemists without professional laboratory training—see Thomas Leng, *Benjamin Worsley (1618-1677): Trade, Interest, and the Spirit in Revolutionary England* (Woodbridge, UK: Boydell Press, 2008), 95-117.

practice among what we might call "amateur" alchemists, or perhaps more generously "field" alchemists. They performed hands-on experiments in gardens, pastures, barnyards, personal domiciles, and manufacturing centers in areas ancillary to agriculture, such as salt works, the grain trade, and the mining and metallurgical industries. Though this debate is fraught with conceptual difficulties, for a certain subset of alchemists, and their allies in agriculture in mid-seventeenth-century England, the answer to the question "was alchemy a life science?" was yes.

Many of these historical figures, in addition to everyday farmers, laborers, craftsmen, and artisans, were convinced that the same natural processes were active in the generation and growth of animal and vegetable life as in minerals. For them, the potential for alchemical transmutation went far beyond the possibility of changing base metals into gold, discovering the philosopher's stone, or creating an elixir of life which would confer youth, longevity, and immortality.[13] While these ambitious objectives promised more consequential and more lucrative results, they also remained practically infeasible, fantastical chimeras for many alchemists who otherwise accepted the notion that transmutation was possible. Instead, these historical figures concentrated their efforts on

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[13] For a brief summary of the goals of alchemy across historical time periods, see Principe, *Secrets of the Alchemy*, 1-7. For works addressing the link between the vitalistic matter theory and active alchemical attempts to manipulate matter into bringing forth life or alter living plant matter, see Antonio Clericuzio, *Elements, Principles, and Corpuscles: A Study of Atomism and Chemistry in the Seventeenth Century* (Dordrecht: Kluwer, 2003); Hiro Hirai, *Le concept de semence dans les theories de la matière à la Renaissance: De Marsile Ficin à Pierre Gassendi* (Turnhout: Brepols, 2005); Didier Kahn, *Alchimie et paracelsisme en France à la fin de la Renaissance (1567-1625)* (Geneva: Droz, 2007); Pamela H. Smith, *The Body of the Artisan: Art and Experience in the Scientific Revolution* (Chicago: University of Chicago Press, 2004), esp. 165-181; idem., *The Business of Alchemy: Science and Culture in the Holy Roman Empire* (Princeton: Princeton University Press, 1994), esp. 173-176, 206-214, and 226-227; Allen G. Debus, "Chemistry and the Quest for a Material Spirit of Life in the Seventeenth Century," in *Spiritus: IV Colloquio Internazionale del Lessico Intellecttuale Europeo, Roma, 7-9 gennaio 1983*, ed. M. Fattori and M. Bianchi (Rome: Ateneo, 1984 Kahn), 245-263; and Antonio Clericuzio, "The Internal Laboratory: The Chemical Reinterpretation of Chemical Spirits in England (1650-1680)," in *Alchemy and Chemistry in the Sixteenth and Seventeenth Centuries*, ed. Piyo Rattansi and Antonio Clericuzio (Dordrecht: Kluwer, 1994), 51-83.

more prosaic and utilitarian, though no less important, aims. To them, alchemy entailed the prospect of manipulating plant matter, soil, water, animal manures, salts, ash, fertilizers, industrially produced chymical substances, and other naturally derived materials to solve a number of concrete agricultural and botanical problems. These included creating artificial fertilizers to improve soil fertility, deploying chymical seed-steeps and "fructifying waters" to hasten germination and boost crop yields, and explaining the lifecycle of plants to better understand how to make agriculture as productive as possible.[14] This attitude became possible in the seventeenth century owing to a fusion of multiple, coalescing trends: the rise of vitalism in alchemical theory, the cumulative use of alchemical techniques in experimental agriculture and botany, the notion that agriculture was in need of improvement, the influence of Baconian interpretations of the trades and sciences, and the religiously motivated belief that nature would provide cornucopian quantities of material wealth if properly manipulated.

Vitalism and Alchemy in the Sixteenth and Seventeenth Centuries

The debate over how to define life, how life might arise from non-living matter, and what forces animate life is an ancient one. In the Western world, it dates back to at least the hylozoism of the pre-Socratic Milesian school and arguably to animistic religions of the

[14] For issues concerning the sustainable uses of plant life in an early modern national and imperial context, see, for example, Lisbet Koerner, *Linnaeus: Nature and Nation* (Cambridge: Harvard University Press, 1999); Harold J. Cook, *Matters of Exchange: Commerce, Medicine, and Science in the Dutch Golden Age* (New Haven: Yale University Press, 2007); Emma C. Spary, *Utopia's Garden: French Natural History from the Old Regime to the Revolution* (Chicago: University of Chicago Press, 2000); Richard Grove and Vinita Damodaran, "Imperialism, Intellectual Networks, and Environmental Change: Origins and Evolution of Global Environmental History, 1676-2000 (Part 1)," *Economic and Political Weekly* 41, no. 41 (2006): 4345-54 and idem., Part 2, *Economic and Political Weekly* 41, no. 42 (2006): 4497-505; Londa Schiebinger and Claudia Swan (eds.), *Colonial Botany: Science, Commerce and Politics in the Early Modern World* (Philadelphia: University of Pennsylvania Press, 2005); and Londa Schiebinger, *Plants and Empire: Colonial Bioprospecting in the Atlantic World* (Cambridge: Harvard University Press, 2007).

prehistoric era that endowed inanimate objects in nature with anthropomorphic qualities or animal spirits.[15] Although vitalist interpretations of the cosmos, earth, and inert matter had millennia-old histories, the predominant modes of alchemical practice in the later Middle Ages and the early Renaissance were largely devoid of vitalistic notions.[16] This changed with the rise of various esoteric genres in the fifteenth and sixteenth centuries, including Hermeticism, Neoplatonism, Cabala, and natural magic. Following the revival of ancient Greek thought by Renaissance humanists in general, and Platonic thought by figures like Marsilio Ficino and Giovanni Pico della Mirandola in particular, concepts like a single world-soul (*anima mundi*) connecting all living beings to one another, the universal or vital spirit (*spiritus universalis* or *spiritus vitalis*), the sympathies between microcosm and macrocosm, and the Stoic "breath of life" or "spirit" (*pneuma*) all influenced matter theory, chymistry, alchemy, and other branches of natural philosophy.[17] In each, natural

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[15] For animism, see, for example, Paulin Jidenu, *African Philosophy* (Bloomington: Indiana University Press, 1996); Graham Harvey, *Animism: Respecting the Living World* (New York: Columbia University Press, 2005); Nurit Bird-David, "Animism Revisited: Personhood, Environment, and Relational Epistemology," *Current Anthropology* 42 (2000): 67-91. For ancient Greek hylozoism, see, for example, G.E.R. Lloyd, *Early Greek Science: Thales to Aristotle* (New York: W.W. Norton and Company, 1970), 16-23, and R.J. Hankinson, *Cause and Explanation in Ancient Greek Thought* (Oxford: Oxford University Press, 1997), 125. For its development in Aristotelian thought—as *entelecheia*, meaning "complete," "perfect," or "finished," and an actualized form of *dunamis*—see Aristotle *Metaphysics* IX.6, 1048*a*25. This specific notion was reivived by Gottfried Wilhelm von Liebniz in the seventeenth century. See G.W. von Liebniz, *Philosophical Papers and Letters*, ed. and trans. by Leroy E. Loemker (Dordrect: D. Reidel, 1969), 654-55; idem., *Philosophical Essays*, trans. and ed. by Roger Ariew and Dan Garber (Indianapolis: Hackett, 1989), 177, 181, and 222.

[16] William R. Newman, *The* Summa Perfectionis *of Pseudo-Geber: A Critical Edition, Translation, and Study* (Leiden/New York: Brill, 1991); Lawrence M. Principe, "Diversity in Alchemy: The Case of Gaston 'Claveus' DuClo, a Scholastic Mercurialist Chrysopoeian," in *Reading the Book of Nature: The Other Side of the Scientific Revolution*, ed. Allen G. Debus and Michael T. Walton (Kirksville, MO: Sixteenth Century Press, 1998), 181–200; and Newman, *Gehennical Fire: The Lives of George Starkey, an American Alchemist in the Scientific Revolution* (Chicago: University of Chicago Press, 2003), 148–149.

[17] Chang, "Alchemy as a Study of Life and Matter," 324. William Newman and Lawrence Principe has defined "chymistry" as the investigation into the chemical properties of matter that included both alchemical and non-alchemical studies. This term reflects both what was in use in English among seventeenth-century natural philosophers and also provides a fuller disciplinary category into which most chemical philosophy could placed during this time period—including laboratory and non-laboratory, transmutational and non-transmutational, vitalist and non-vitalist varieties. See Lawrence Principe, ed., *Chymists and Chymistry: Studies in the History of Alchemy and Early Modern Chemistry* (Sagamore Beach, MA: Watson Publishing, 2007), and

philosophers sympathetic to these views presumed that an animating force pervaded the cosmos and manifested itself in different ways in mineral, plant, or animal matter, as well as potentially in humans. In vitalist interpretations, all matter was endowed with "seeds," "sperm," or an "agentive force"—such as Johan Baptista Van Helmont's *semina*, Michael Sendivogius's *sperma*, or Paracelsus's *archeus*[18]—which nature animated in various ways.[19]

Paracelsus was highly influential in these interpretations. He envisioned the natural, material world as an immanently malleable place, where "transmutation" meant something much broader than merely changing base metals into gold. According to Paracelsus "transmutation is when a thing loses its shape and is transformed so that it no longer displays…its initial form or substance," and it was something that happened in the physical world naturally all the time.[20] When people set out to change natural substances, they were merely facilitating these natural processes. To Paracelsus, these wide-ranging procedures all fell under the umbrella category of alchemy, which he called the "completing" of natural operations because, as he wrote, "the alchemist is like the baker who bakes bread, or the vintner who makes wine or the weaver who makes cloth."[21] This broad interpretation of

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William Newman and Lawrence Principe, "Alchemy versus Chemistry: The Etymological Origins of a Historiographical Mistake," *Early Science and Medicine*, Vol. 3, No. 1 (1998): 32-65.

[18] "*Archeus*," a word with both Latin and Greek derivation, means roughly "life power" or "guiding spirit." Paracelsus, *Volumen Medicinae Paramirum,* trans. Kurt Leidecker (Baltimore: Johns Hopkins Press, 1949), 25. See also Bruce T. Moran, *Distilling Knowledge: Alchemy, Chemistry, and the Scientific Revolution* (Cambridge: Harvard University Press, 2005), 74. For its probable first appearance in ancient Greek natural philosophy as *arkhē*, see Simplicius, *Commentary on Aristotle's Physics*, 24.13-21, where Simplicius attributes it to the Presocratic philosopher Anaximander. See S. Mark Cohen, Patricia Curd, and C.D.C. Reeve, eds., *Readings in Ancient Greek Philosophy: From Thales to Aristotle*, Fourth Edition (Indianapolis: Hackett Publishing, 2011), 13. Cohen et al. define *arkhē* as "originating point" or "first principle."

[19]Chang, "Alchemy as a Study of Life and Matter," 324. Chang has differentiated between "cosmic vitalism," which presumed that the vital nature of matter came externally from the macrocosm, and "immanent vitalism," which presumed that it came from within matter. In this dissertation, I focus primarily on "immanent vitalism," though these were hardly exclusive categories and overlap was very common. See also page 144 below.

[20] Paracelsus, *Sämtliche Werke*, eds. Karl Sudhoff and Mattießen (Hildesheim: Georg Olms Verlag, 1996), Vol. 11, 349, quoted in Moran, *Distilling Knowledge*, 70.

[21] Ibid., Vol. 8, 181.

transmutation as any change in nature that fundamentally altered the chymical constituents of a physical material had a profound effect on natural philosophers, alchemists, and many agricultural reformers. In these contexts, there were more than simply conceptual commonalities and rhetorical resonances between "improvement" in agriculture and the idea of "completing" natural processes through alchemy. This is what Paracelsus called "*natürliche alchimei*" and what historian of alchemy Massimo Luigi Bianchi has described as an art that "brings to completion, for man's benefit, what nature has left in an immature state."[22] Those who adhered to vitalistic alchemy and cornucopian notions of nature viewed these as intertwined processes. Though seventeenth-century agricultural reformers did not adopt his ideas wholesale—many of them were diluted through successive iterations of his work and generations of his disciples—they liberally quoted Paracelsus, who remained a formidable authority, in husbandry manuals, recipe books, and letters to one another.

Vitalism, in its many forms, worked its way into alchemy, botany, and agriculture, among others fields, in the sixteenth and seventeenth centuries. According to Allen G. Debus and Antonio Clericuzio, varieties of vitalistic thought can be found in a number of prominent sixteenth- and seventeenth-century alchemists, including not only Paracelsus but also Johan Baptisa Van Helmont, Peter Severinus, Joseph Duschesne, Michael Sendivogius, Oswald Croll, Robert Fludd, and Johann Rudolf Glauber.[23] The ambiguity of the concept of vitalism meant that these theories could often be easily incorporated into,

[22] Paracelsus, *Paragranum*, in *Sämtliche Werke*, Vol. 8, 59; Massimo Luigi Bianchi, "The Visible and the Invisible: From Alchemy to Paracelsus," in *Alchemy and Chemistry in the Sixteenth and Seventeenth Centuries*, ed. Piyo Rattansi and Antonio Clericuzio (Dordrecht: Springer, 1994), 20.
[23] For breakdown of their positions, see Allen G. Debus, "Chemistry and the Quest for a Material Spirit of Life in the Seventeenth Century," 245-63; Clericuzio, "The Internal Laboratory: The Chemical Reinterpretation of Medical Spirits in England, 1650-80," in *Alchemy and Chemistry in the Sixteenth and Seventeenth Century*, 51-83; and Hiro Hirai, *Le concept de semence dans les theories de la matière à la Renaissance, passim*.

subsumed under, or absorbed by other natural philosophies. Early modern chemical philosophers such as Van Helmont, Daniel Sennert and Andreas Libavius, for example, hoped to combine corpuscularianism with *semina* theory. In the case of Libavius, a vehement anti-Paracelsian and staunch critic of transmutational alchemy, the hope was to reconcile Democritean atomism with Aristotelian hylozoism.[24]

Even mechanical philosophy—once identified by historians as the death knell for vitalism in the physical sciences—possessed a great deal of intersecting intellectual territory with these interpretations of life and matter.[25] According to Jole Shackleford's work on Peter Severinus, for example, several alchemists who adhered to mechanical philosophy elsewhere regarded the Paracelsian *archeus*—which presided over the generation and growth of all living things—as a mechanical agent at the atomic or corpuscular level.[26] It was the very mechanical nature of the *semina* or *archeus* that allowed its vital properties to be studied with regularity in the first place. This "mechanical process"

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[24] William R. Newman, *Atoms and Alchemy*, 76-8; Christoph Lüthy, "Seeds Sprouting Everywhere," *Annals of Science* 64 (2007): 418; Chang, "Alchemy as a Study of Life and Matter," 325.

[25] Much has been made of the influence of mechanism and the mechanical philosophy in the Scientific Revolution, and while it is not my intention to dismiss much of the excellent work done on this topic, it should be noted that the mechanical philosophy had a much smaller impact on the chemical philosophy of vitalists and vitalism than has previously been noted. It should also be noted that many early moderns were perfectly comfortable combining aspects of mechanism and vitalism together to describe their material worldview. Beyond the philosophical works of Descartes and Hobbes, there was much diversity in chymical thought that did not relegate all matter and motion to such inert sterility. For some basic primers on the rise and influence of mechanical philosophy in the second half of the seventeenth century, see Marie Boas Hall, "The Establishment of the Mechanical Philosophy," *Osiris* 10 (1952): 412-541; J.A. Bennett, "The Mechanic's Philosophy and the Mechanical Philosophy," *History of Science* 24 (1986): 1-28; Otto Mayr, *Authority, Liberty, and Automatic Machinery in Early Modern Europe* (Baltimore: Johns Hopkins University Press, 1986); Derek J. de Solla Price, "Automata and the Origins of Mechanism and Mechanistic Philosophy," *Technology and Culture* 5 (1964): 9-23; Allan Gabbey, "The Mechanical Philosophy and Its Problems: Mechanical Explanations, Impenetrability, and Perpetual Motion," in *Change and Progress in Modern Science,* ed. Joseph C. Pitt (Dordrecht: D. Reidel, 1985), 9-84; and idem., "The Case of Mechanical Philosophy: One Revolution or Many?" in *Reappraisals of the Scientific Revolution*, ed. David C. Lindberg and Robert Westman (Cambridge: Cambridge University Press, 1990), 493-528, among many others.

[26] Jole Shackleford, "Seeds with a Mechanical Purpose: Severinus's Semina and Seventeenth-Century Matter Theory" in *Reading the Book of Nature: The Other Side of the Scientific Revolution*, Allen G. Debus and Michael T. Walton, eds. (St. Louis: Truman State University Press, 1998), 15-44.

(*mechanicus processus*) meant a literal workman, or craft-like process, which was presumed to take place at the microscopic level. Even atomic theories of matter, integral to many versions of mechanical philosophy, had vitalist interpretations. For example, by the early 1650s, Robert Boyle had become a corpuscularian. Like atomists, corpuscularianists envisioned matter as composed of infinitesimally small particles, but unlike the atomists, corpuscularianists did not think that these particles were indivisible. In an attempt to reconcile this matter theory with his vitalist tendencies, Boyle asserted that corpuscles were endowed with seminal power.[27] While he seems to have given up on this theory for crystal and metal creation by the early 1670s, he continued to accept it as an explanation for plant and animal growth.[28] In contrast to Boyle, who never fully committed to vitalism but maintained that certain corpuscles contained seminal principles, Van Helmont was a fully committed vitalist who did not accept that anything vitalistic was intrinsic to the corpuscles themselves. In Helmontian chymistry, as it developed during his lifetime and among his acolytes after his death in 1644, *semina* existed not as miniscule physical bodies but as something akin to Aristotelian forms, from which life might spring, even if the corpuscles themselves were purely mechanical.[29] In short, there were a number of ways in which one could claim to be a vitalist, a mechanist, an atomist, or a corpuscularian in the seventeenth century that were not mutually exclusive.

Between the introduction of Paracelsian and Helmontian chymical and alchemical ideas into England around the turn of the seventeenth century and the decline of alchemy

[27] Clericuzio, *Elements, Principles, and Corpuscles*, 125-7.

[28] Peter Anstey, "Boyle on Seminal Principles," *Studies in the History and Philosophy of Biology and Biomedical Sciences*, 33 (2002): 597-630.

[29] William Newman, "The Corpuscular Theory of J.B. van Helmont and Its Medieval Sources," *Vivarium*, Vol. 31, No.1 (1993): 161-191.

as a serious scientific enterprise in the early eighteenth century, vitalism maintained a strong influence on the practice of alchemy, atomistic and corpuscularian matter theories, and the study of material change for those who strove to understand matter and motion in ways that were not dogmatically mechanical. As we shall come to see, the experimental quest for the vital principle inherent in matter—thought to be discoverable at the microscopic level—characterized much of the work performed by alchemically inclined agricultural reformers.

Baconian Science and the Hartlib Circle: Improvement, Cornucopianism, and the Vegetable Philosophy

By the early seventeenth century, several socio-political and scientific changes coincided in ways that prompted various reformers to believe that perfecting society, politics, education, and even religion was possible. This involved the active manipulation of nature and a direct, hands-on approach to problem-solving, which, when helmed by socially middling individuals, most of whom were neither aristocratic nor impoverished, drew together knowledge both from the world of educated, elite natural philosophers and from that of commonplace artisans and craftsmen. With utopian social objectives and cornucopian economic principles, these individuals proceeded with a research program loosely organized around the idea that through the proper investigation of nature, human welfare could be enhanced and society perfected. Epitomizing these notions were the ideas of the Hartlib Circle.[30]

[30] A number of members of the Hartlib Circle penned works making such cornucopian assumptions, particularly with regard to agriculture and alchemy. See, for example, Samuel Hartlib, *Cornu Copia: A Miscellanium of Luciferous and Most Fructiferous Experiments, Observations, and Discoveries, immethodically distributed; to be really demonstrated and communicated in all sincerity* (London, 1652); idem., *Samuel Hartlib,*

The Hartlib Circle—named after the Prussian émigré to England and pan-continental intelligencer Samuel Hartlib—was a correspondence network of natural philosophers and others who shared results of experiments and theoretical discussions on themes ranging from alchemy, mineralogy, and mathematics to pansophism, educational reform, and the English settlement of Ireland. From the early 1630s until the establishment of the Royal Society in 1660, the Hartlib Circle, which sometimes overlapped with the "Invisible College" that coalesced around Robert Boyle, was one of the primary informal institutional bodies for natural philosophers in England.[31] For the Hartlibians, solving the social ills that plagued seventeenth-century European society would be accomplished through this type of active engagement with the natural world. Though the full chronological range of this dissertation runs from the mid-sixteenth through early eighteenth centuries—largely because I explore the origins of intellectual trends in sixteenth-century alchemy and the development of trade and industrial manufacture of commonly used chymical goods—the main narrative follows this constellation of individuals most active from the 1630s through the 1660s. This is well-trodden ground, to be sure. However, my hope is that, like the agricultural reformers themselves who believed the same ground could be renewed of its fertility indefinitely, I have developed a novel

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His Legacy of Husbandrie… (London, 1655); Gabriel Plattes, *A Description of the Famous Kingdome of Macaria* (London: Samuel Hartlib, 1641); idem., *A Discoverie of Subterraneanall Treasure* (London, 1639); idem., *A Discovery of Infinite Treasure, Hidden Since the Worlds Beginning* (London, 1639); John Dury, *The Reformed Spiritual Husbandman* (?London, 1652); Jan Amos Comenius, *A Pattern of Universal Knowledge shadowing forth the largenesse dimension and use of the intended Worke* (London, 1651); George Starkey, *Natures Explication and Helmonts Vindication* (London, 1657); and John Webster, *Metallographia: or, An History of Metals* (London, 1671), among many others.

31 See, for instance, Charles Webster, *Samuel Hartlib and the Advancement of Learning* (London: Cambridge University Press, 1970); G.H. Turnbull, *Samuel Hartlib: A Sketch of His Life and His Relation to J.A. Comenius* (London: Oxford University Press, 1920); and Mark Greengrass, Michael Leslie, and Timothy Raylor, eds., *Samuel Hartlib and Universal Reformation: Studies in Intellectual Communication* (London: Cambridge University Press, 1994).

understanding of their chymical and alchemical worldview, particularly when it could be deployed in the service of a broader social reform.

This generation of reformers was heavily influenced by the thought of Francis Bacon.[32] With Bacon, we see at least three intersecting concepts about scientific knowledge, Biblical hermeneutics, and human power, which led to his philosophy of science regarding the proper uses of nature. First, Bacon argued in a number of his writings from the late sixteenth century until his death in 1626 that knowledge about nature could only be achieved through a combination of inductive reasoning, empirical research, and experimental methodology. In his *Advancement of Learning* and *Novum Organum*, he explored the deficiencies of traditional philosophy and scholastic knowledge, which he criticized as adversely mired in the stagnant logical syllogisms of Aristotelianism. True knowledge about nature, Bacon argued, would come not from the *scientia contemplativa* of philosophers but from the *scientia operativa* of those artisans, craftsmen, and mechanics who toiled in workshops and by those who actively sought to experiment with the natural world.[33] "Learning," he wrote, "should be referred to use and action." The end goal of this

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[32] The literature on Bacon's role in the rise of experimentalism and the origins of modern science is vast. For some important works that also demonstrate his influence after his death, see Antonio Pérez-Ramos, *Francis Bacon's Idea of Science and the Maker's Knowledge Tradition* (Oxford: Oxford University Press, 1988); Peter Urbach, *Francis Bacon's Philosophy of Science* (LaSalle, IL: Open Court Press, 1987); and Charles Webster, *The Great Instauration: Science, Medicine, and Reform, 1626-1660* (London: Duckworth, 1975). On the role of Baconian science in the development of the English state and empire, see Sara Irving, *Natural Science and the Origins of the British Empire* (London: Pickering and Chatto, 2008); and Matthew Underwood, *Ordering Knowledge, Reordering Empire: Science and State Formation in the English Atlantic World, 1650-1688* (PhD Dissertation, Harvard University, 2010).

[33] Jürgen Klein, "Francis Bacon's *Scientia Operativa,* the Tradition of the Workshops, and the Secrets of Nature," in Claus Zittel, Gisela Engel, Romano Nanni, and Nicole C. Karafyllis, eds., *Philosophies of Technology: Francis Bacon and His Contemporaries* (Brill: Leiden and Boston, 2008), 21–49. For examples of this *"scientia operativa"* in action among non-aristocratic actors, see, for example, Clifford D. Conner, *A People's History of Science: Miners, Midwives, and "Low Mechanicks"* (New York: Nation Books, 2005), esp. 248-261, 274-286, 291-305, and 318-336; Eric Ash, *Power, Knowledge, and Expertise in Elizabethan England* (Baltimore: Johns Hopkins University Press, 2004), 186-216; and Pamela H. Smith, *The Body of the Artisan: Art and Experience in the Scientific Revolution* (Chicago: University of Chicago Press, 2006), 95-127. For the classic work arguing that modern science originated when the barriers between the aristocratic, rationalist tradition of abstract

was not a simple understanding of the natural world but the ability actively to change it.

Secondly, Bacon's concept of dominion over nature was highly Biblical, and not just in regard to the regularly quoted passages from Genesis, in which God commanded men and women to "be fruitful and multiply; fill the earth and subdue it; [and] have dominion over the fish in the sea, over the birds of the air, and over every living thing that moves over the earth."[34] By reclaiming power and mastery over nature, Bacon believed that humanity could recover the initial conditions of the Garden of Eden. Knowledge of nature, Bacon wrote, is "a rich storehouse for the glory of God and good of humanity."[35] Technology and manufacturing, medical advancement, and new agricultural practices would combine to make what he called a "second creation." God had perfected nature in Eden, but humanity had sullied it through the original sin of rebelling against God. With a proper reform of natural philosophy, Bacon argued, humanity could emulate God's creation through its own ingenuity. "For man by the fall fell at the same time from his state of innocency and from his dominion over creation," Bacon wrote. "Both of these losses however can even in this life be in some part repaired: the former by religion and faith, the latter by arts and sciences."[36] For Bacon, religious conviction and practical sciences worked in tandem to fulfill humanity's utopian dreams.[37]

Finally, these notions of the power of properly employed human knowledge combined with his Biblical interpretation of dominion led to Bacon's belief in the

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theory and the artisan-craftsman techniques of quantitative, experimental practice broke down, see Edgar Zilsel, "The Sociological Roots of Science," *American Journal of Sociology*, Vol. 47, No. 4 (1944): 544-562.

[34] Genesis 1:28.

[35] Francis Bacon, *The Advancement of Learning* (London: Thomas Purfoot and Thomas Creede for Henrie Tomes, 1605), I.11.

[36] Francis Bacon, *Novum Organum Scientiarum* (London: John Bill, 1620), II.52.

[37] On the impact of Baconianism on Puritanism and their relationship with the utopian, social movements of the mid-seventeenth century, see, most notably, Webster, *The Great* Instauration; and idem., *From Paracelsus to Newton: Magic and the Making of Modern Science* (Cambridge: Cambridge University Press, 1982).

perfectibility not just of nature but of society as well. In his posthumously published *New Atlantis*, for example, Bacon envisioned a utopia in which a cadre of enlightened, scientifically knowledgeable, and religiously pure individuals governed society with benevolence. The ultimate goals of this cadre were the discovery of all natural knowledge, the ending of all material want, and the prolongation and enhancement of human life.[38] A political and religious utopia as much as a scientific one, the *New Atlantis* sheds light on Bacon's ideal reformed social order. With this newly perfected society, in which natural philosophers efficiently pursued political, religious, and scientific goals as part of the same interconnected research program, natural limits and material scarcity were irrelevant. Rather than seeing the supervening of such limits as distant and idealistic goals, Bacon argued that they were imminently achievable and rested only on the assumptions of human intellectual capacity, Biblical sanction, and the potential cornucopian bounty of the natural world. In the end, the ultimate goal was not only the "Second Creation" but also the "Second Coming," which Bacon and a number of other early moderns believed God had providentially ordained in their time. As Bacon wrote in his *Novum Organum*:

> Nor should the prophecy of Daniel be forgotten, touching the last ages of the world: —"*Many shall go to and fro, and knowledge shall be increased*;" clearly intimating that the thorough passage of the world (which now by so many distant voyages seems to be accomplished, or in course of accomplishment), and the advancement of the sciences, are destined by fate, that is, by Divine Providence, to meet in the same age.[39]

Bacon clearly believed himself to be living in the Last Days, and he observed that science as reformed by his program delivered evidence of this fact. In this reform movement in natural philosophy, the passive, disinterested study of the natural world no longer sufficed.

[38] Francis Bacon, *The New Atlantis* (London: William Rawley, 1628).
[39] Bacon, *Novum Oranum*, I.93. Emphasis in the original. The Biblical quote comes from Daniel 12:4, which famously graced the frontispiece of the first edition of the Latin version of Francis Bacon's *Novum Organum.*

For the Hartlib Circle and their associates, particularly those interested in using the operational knowledge of alchemy and the theoretical knowledge of chemical philosophy to make agricultural yields more productive, soil more consistently fertile, and botanical growth more intelligible, this Baconian reform was redirected toward the particular concept of "improvement," which in seventeenth-century England referred to the process of making land more agriculturally productive and ecomically valuable.[40]

In a Baconian sense, agriculturally improving land worked in parallel with religious, social, political, and economic improvement. While Bacon had separated the authority of science and religion based on divergent methodologies, he also believed in a unity of knowledge, meaning that given enough time and effort the findings of the empirical sciences would, if not confirm, at least not contradict either revealed or natural religion. For the husbandman, this meant that one who cultivated proper Christian character gained the moral fortitude also to cultivate his land profitably. Social change, including more a equitable distribution of land, universal education, and governance by those with expertise—all of which were overarching goals of Hartlib and many of his associates—necessarily required this moral fortitude and justified a radical shift in the goals and methods of husbandry.[41] Referring to Bacon's interpretation of the Book of Daniel, they imagined that the end times were upon them because of the rapid expansion of European

[40] For the concept of the "improvement" of land as the ultimate goal of agriculture, horticulture, botany, and other natural sciences, see, for example, Paul Slack, *The Invention of Improvement: Information and Material Progress in Seventeenth-Century England* (Oxford: Oxford University Press, 2015), esp. 91-128; Richard Drayton, *Nature's Government: Science, Imperial Britain, and the 'Improvement' of the World* (New Haven, CT: Yale University Press, 2000), esp. 50-81. For a broader discussion of "improvement" in environmental history and historiography, see, for example, John F. Richards, *The Unending Frontier: An Environmental History of the Early Modern World* (Berkeley: University of California Press, 2003), esp. 193-241.

[41] Francis Bacon, *Instauratio Magna*, preface [unpaginated]. For the historical context of this vision of improvement and the Hartlib Circle's role, see Matei, "Macaria, the Hartlib Circle, and Husbanding Creation," 8-11; and Andrew McRae, "Husbandry Manuals and the Language of Agrarian Improvement," in *Culture and Cultivation in Early Modern England: Writing and the* Land, ed. Michael Leslie and Timothy Raylor (Leicester: Leicester University Press, 1992), 35.

power around the globe and the sudden upsurge of new scientific knowledge about the natural world. In part, it was in terms of the belief in humanity's Fall from Grace that these reformers sought domination over nature and interpreted the grand purpose of natural philosophy, natural history, and agriculture as improvement.[42] This included improvement in political structure, in the political economy, in the arability of land, and in scientific knowledge, as well as in the personal spiritual improvement that would prepare humanity for the End Times, which were presumed to be imminent.[43]

Among the typical methods of agricultural improvement in seventeenth-century England, historians have identified a plethora of developments. These include new schemes of crop rotation, the introduction of adjustable-depth swing plows, wide-scale enclosure of common pastureland, the development of a national grain market, enhancements to the transportation infrastructure on land and water, the drainage and reclamation of sea and swamp land and its conversion into cultivable cropland, and an increase in the selective breeding of livestock.[44] To be sure, these were all exceptionally important developments and in the long run profoundly contributed to what is sometimes called the second

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[42] See, most again, Webster, *The Great Instauration*; and idem., *From Paracelsus to Newton: Magic and the Making of Modern Science* (Cambridge: Cambridge University Press, 1982). Though interest in this thesis has waned in recent years, I believe the fusion of socio-political, spiritual, and agricultural improvement remains integral to understanding their notions of reform.

[43] For the concept of the "improvement" of land as the ultimate goal of agriculture, horticulture, botany, and other natural sciences, see, for example, Paul Slack, *The Invention of Improvement: Information and Material Progress in Seventeenth-Century England* (Oxford: Oxford University Press, 2015), esp. 91-128; Richard Drayton, *Nature's Government: Science, Imperial Britain, and the 'Improvement' of the World* (New Haven, CT: Yale University Press, 2000), esp. 50-81. For a broader discussion of "improvement" in environmental history and historiography, see, for example, John F. Richards, *The Unending Frontier: An Environmental History of the Early Modern World* (Berkeley: University of California Press, 2003), esp. 193-241.

[44] On these, see Mark Overton, *Agricultural Revolution in England: The Transformation of the Agrarian Economy, 1500-1850* (Cambridge: Cambridge University Press, 1996); Joan Thirsk, *Agrarian History of England and Wales*, Vol. 5, *1640-1750*, Pt. 1, *Rural Farming Systems* and Pt. 2, *Agrarian Change* (Cambridge: Cambridge University Press, 1984 and 1985); and Eric Kerridge, *The Agricultural Revolution* (Lodon: Allen Unwin, 1967), though these works come to very different conclusions about the chronology and relative importance of each innovation.

agricultural revolution. It is not my intention, however, to weigh in on the debates over when or whether such a revolution occurred. Nor is it my intention to upend the historiography of agriculture by suggesting that these methods of improvement were of secondary importance. Rather, I aim to show that a particular philosophy of improvement informed by Baconian science, vitalist interpretations of alchemy, and cornucopian expectations of return holds a small but crucially important place in the histories of agriculture and the life sciences.

Seventeenth-century cornucopian ideology rested on the assumption that human ingenuity, within prescribed divine parameters, could create agricultural and economic bounty irrespective of any natural limits. Drawing, in part, from the dominionist religious license and technological optimism of Francis Bacon and his devotees, alchemists, agricultural reformers, and projectors believed they could apply these basic premises to eradicate the need for war, the existence of hunger, and the fear of crop failure. Religiously and politically speaking, many of them were utopians who asserted that the world needed science because Christianity—the universal religion—was still riven by internecine and sectarian strife. As they came to view nature as eventually knowable in its entirety and leading toward complete knowledge of the physical world, they also came to believe this would result in a complete vindication and verification of true Christianity, thus obviating the need for military conflict.[45] Economically speaking, many assumed that the end point of their efforts would be in such extreme bounty that the perils of international trade and the

[45] What constituted true Christianity was, of course, up for vigorous debate and often violent conflict. Nevertheless, most professed that it would be revealed as obvious to all once complete knowledge existed. On this interpretation, particularly of the Baconian influence of mid-seventeenth-century social reformers, see Jerry Weinberger, "Introduction to the Revised Edition," in Francis Bacon, *The New Atlantis and the Great Instauration* (Wheeling, IL: Harlan Davidson, 1989), xxix-xxxii; and more generally, idem., *Science, Faith, and Politics: Francis Bacon and the Utopian Roots of the Modern Age* (Ithaca, NY: Cornell University Press, 1985).

extractive nature of empire, food shortages, the lack of bullion, the debasement of coinage, and scarcity of material goods would be things of the past. In short, cornucopianism entailed the belief that there were no serious ecological, economic, or environmental problems that did not have technical or scientific solutions and that growth could, theoretically, be boundless.[46]

These newfound notions of reforming husbandry drew from multiple deep and sometimes untapped wells. They included ancient Greek and Roman works on agricultural topics, classical and Renaissance natural histories, herbals and botanical textbooks, artisanal manuals, humanist encyclopedias, texts on natural magic and rediscovered occult traditions, Baconian experimentalists, and contemporary alchemists. Although there is no discrete and seamlessly definable category into which we can place these disparate sources and approaches to husbandry reform, there have been some recent efforts by historians of science to describe the mid-seventeenth-century experimental methodologies and general theories of growth among Baconians, Hartlibians, and members of the early Royal Society as a "vegetable philosophy."[47]

Vegetable philosophy is difficult to define. According to Oana Matei, vegetable philosophy was "technological and antispeculative, experimental and operational," and was oriented "toward the production of specific results" with "technologies transferable from

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[46] See Fredrik Albritton Jonsson, "The Origins of Cornucopianism: A Preliminary Genealogy," *Critical Historical Studies*, Vol. 1, No. 1 (2014): 151-168. On Baconian utopianism and its economic corollary cornucopianism, see James Delbourgo and Nicholas Dew, *Science and Empire in the Atlantic World* (London: Routledge, 2007). 1-4; Pamela Smith, *The Body of the Artisan: Art and Experience in the Scientific Revolution* (Chicago: University of Chicago Press, 2004); esp. 95-127 and 238; Drayton, *Nature's Government:* esp. 50-81; Carolyn Merchant, *The Death of Nature: Women, Ecology, and the Scientific Revolution* (San Francisco: Harper Collins, 1980); and Jerry Weinberger, "Science and Rule in Bacon's Utopia: An Introduction to the Reading of the *New Atlantis*," *American Political Science Review*, Vol. 7, No. 4 (1976): 865-885.
[47] Oana Matei, "Husbandry Tradition and the Emergence of Vegetable Philosophy in the Hartlib Circle," *Philosophia*, Vol. 16, No. 1 (2015): 35-52.

one domain to another."[48] It was not just botanical because its objects of study were diverse and included metals, stones, and mineral ores; not "just agricultural because it had a manifested inclination for alchemical experiments;" and "not simply natural philosophy," because it had a "practical and operative side, concerned with technological advancement and amelioration."[49] "Vegetable," in this case, did not necessarily equate to "plant," but rather took on an adjectival meaning denoting anything that was capable of growth.[50] Thus, its material objects of study included plants, but also animals, metals, minerals, and people, and so it bled into the botanical, biological, agricultural, metallurgical, and economical. The common denominator seems to have been—to borrow a metaphor from modern theoretical physics—an interest in a "grand unified theory" of growth. In this way, vegetable philosophy may be seen as an addition to the various philosophies that emerged in the sixteenth and seventeenth centuries to challenge the primacy of scholasticism and Aristotelianism (e.g., chemical philosophy, magnetic philosophy, experimental philosophy, mechanical philosophy, etc.) with the ultimate aim of resolving disputes over how best to describe the natural world.[51] Much of the more recent literature examining the Hartlib Circle has painted a more complex picture of the heterogeneous nature of the goals of those within that circulation network. Still, members of the Hartlib Circle involved in alchemical

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[48] Ibid., 36.
[49] Ibid., 35.
[50] See the definitional differences between the two in "Vegetable, *n*," *OED*, v.1a, and "Vegetable, *adj*," *OED*, v.1a. Both, ultimately, share etymology with the Latin *vegetare*, "to enliven," and from that, the Late Latin *vegetabilis*, meaning "enlivening or animating" and evolving to mean "growing or flourishing" by the Middle Ages. The immediate source of the English word is the Old French cognate *vegetable*, which entered English in the early to mid fifteenth century, and meant, simply, "a plant," regardless of whether or not it was intended for human consumption.
[51] On the proliferation of these and other distinct "grand unified" natural philosophies, particularly as resolutions to a "crisis of knowledge," see Peter Dear, *Revolutionizing the Sciences: European Knowledge and Its Ambitions, 1500-1700* (Princeton: Princeton University Press, 2001); Steven Shapin, *The Scientific Revolution* (Chicago: University of Chicago Press, 1996); and David C. Lindberg, *The Beginnings of Western Science: The European Scientific Tradition in Philosophical, Religious, and Institutional Context, 600 B.C. to A.D. 1450* (Chicago: University of Chicago Press, 1992), 355-68.

interpretations of the vital properties of salts, the process of seed germination, the chymistry of seed steeps, the explanation of plant growth, and the creation of artificial fertilizers all stand as powerful examples of this wider reform in action, which was directed toward agricultural improvement, cornucopian economics, vegetable philosophy, and a search for the vital principle of life itself.

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In fairness, not all histories of alchemy over the past two decades have been so tightly focused on elite, laboratory alchemy. The historiographical redefinitions between the 1980s and 2000s, and particularly those posited by historians such as Owen Hannaway, Deborah Harkness, Bruce T. Moran, and Pamela Smith have emphasized not just the proto-chemistry of early modern alchemy, but also many other aspects of its history. These historians have highlighted how the sites of knowledge production affected its practice, how patronage dynamics governed its approach, how economic concerns moderated its zeal, how the down-to-earth orientation of merchants and tradesmen shaped its "business practices," how the didacticism of chemical texts informed its practitioners, and how local political cultures and social interests dictated its reception.[52] Hannaway's research on Oswald Croll and Andreas Libavius, for example, has shown that many early modern alchemists and chymists drew significant distinctions between the textual culture of laboratory alchemy and the chemical philosophy that pervaded Hermetic, Paracelsian, and

[52] See Owen Hannaway, *The Chemists and Word: The Didactic Origins of Chemistry* (Baltimore: Johns Hopkins University Press, 1975); idem., "Laboratory Design and the Aim of Science: Andreas Libavius versus Tycho Brahe," *Isis* Vol. 77, No. 4 (1986): 584-610; Deborah Harkness, *The Jewel House: Elizabethan London and the Scientific Revolution* (New Haven: Yale University Press, 2008); Smith, *The Business of Alchemy*, esp. 173-176, 206-214, and 226-227; Bruce T. Moran, *Distilling Knowledge: Alchemy, Chemistry, and the Scientific Revolution* (Cambridge: Haravard University Press, 2005). This historiographical direction was, in part, an echo of the "internal versus external" debate prevalent in mid-twentieth-century history and philosophy of science.

natural magical tracts describing material change.[53] My research suggests that many of those involved in agricultural improvement explicitly sought the commonalities between these theories. In the early 1990s, Pamela Smith's work on Johann Joachim Becher illuminated the often-overlooked links between the practice of alchemy and the political and economic consequences of patronage dynamics.[54] Becher's interest in practical projects and cameralist policy, and the input alchemical theory had on their implementation—from the production of fine porcelain and chemical medicines to fabric dyeing and glass manufacturing—mirror the practical, utilitarian concerns of many of my historical subjects, and Becher's contemporaries, in seventeenth-century England. Most recently, the work of Walter Woodward has provided a compelling example of the degree to which early modern alchemical culture permeated the agricultural, economic, religious, and political practices of early modern Puritans on both sides of the Atlantic. His case study of the influence of John Winthrop, Jr.—Hartlib Circle intelligencer, founding member of the Royal Society, and colonial governor of Connecticut—demonstrates that the practice of alchemy reached far past the laboratory, that it was considered an applied science, and that its applications extended well into the realm of the life sciences.[55] It is in this historiographical vein that I proceed.

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[53] Hannaway, *The Chemists and the Word*, esp. xi-xii, 75-91, and 117-151. Hannaway compares chemistry textbooks, such as Jean Beguin, *Tyrocinium Chymicum* (Paris, 1610), Nicolas Lemery, *Cours de Chymie* (Paris, 1675), and most especially, Andreas Libavius, *Alchemia* (Frankfurt, 1597), which contained step-by-step technical instructions on chemical and alchemical laboratory procedures, with Oswald Croll, *Basilica Chymia* (Frankfurt, 1609), whose work dealt with Paracelsian and Hermetic chemical philosophy, very different fields entirely according to Hannaway. For a more recent investigation of the topic, see Bruce T. Moran, *Andreas Libavius and the Transformation of Alchemy: Separating Chemical Cultures with Polemical Fire* (Sagamore Beach, Mass.: Science History Publications, 2007).
[54] Smith, *The Business of Alchemy*, esp. 56-92 and 173-227.
[55] Walter W. Woodward, *Prospero's America: John Winthrop, Jr., Alchemy, and the Creation of New England Culture, 1606-1676* (Chapel Hill: University of North Carolina Press, 2010).

The chapters that follow are, by turns, synthetic efforts to reknit some of the seams of these disparate historiographical traditions and close, analytical readings of alchemical recipe manuscripts, chymistry treatises, botanical texts, husbandry manuals, projector reports, government documents, and correspondences among members of the Hartlib Circle. In different ways, these all demonstrate how vitalistic theories and alchemical practice influenced agricultural reform. I begin by detailing the growing knowledge of saltpeter's chymical properties in the mid sixteenth century, acquired mostly through the mining, metallurgical, and gunpowder industries, and the suspicion that salts in general, and saltpeter in particular, held the key to understanding the vital potentials of matter. This contributed to the origins of the so-called *sal nitrum* school of alchemy, a quasi-Paracelsian branch of chemical philosophy that sought the underlying vital principle, which developed in the late sixteenth and early seventeenth centuries and became highly influential among several members of the Hartlib Circle. Then, I examine a number of projects among this group in the 1640s and 1650s to produce saltpeter. This was originally motivated by a desire to supply Commonwealth forces with ample gunpowder but morphed into attempts to create artificial fertilizers as part of a broader reform movement intended to boost agricultural productivity. Focusing on Benjamin Worsley's efforts to undergird these endeavors with cutting-edge chemical philosophy and sophisticated alchemical techniques, I track the multifarious nature of these projects, which sought not only to improve agriculture through niter-based soil enrichment, but also to deliver poor relief, capitalize on new markets, provide state security, and seek the vital seat of life via alchemical means. The following chapter continues the investigation of agricultural improvement by examining the uses of seed steeps and fructifying waters, chymical mixtures (much like the one described in Ferguson Manuscript 274) designed to promote more rapid germination and generate more fertile seeds with robust protection from disease, pests, and the elements. The recipes for these steeps and waters possessed striking similarities to the substances used in various alchemical recipes, and I show some of the ways that alchemical techniques informed their production. The natural sources of soil fertility and the alchemical explanation for their genesis and regeneration are the next subjects I consider. I interrogate the thought of Gabriel Plattes, a writer on mineralogy and husbandry, who argued that the same natural process accounted for the growth of both underground mineral seams and plants. His work on the properties of soil proved integral to husbandry reform within the Hartlib Circle. Finally, I scrutinize the meanings of transmutation and other alchemical operations in agricultural, horticultural, and botanical settings by conducting an in-depth analysis of the work of country parson and gentleman farmer John Beale, whose short, unpublished tract "On the Transmutation and Improvements of Plants" provides a paradigmatic example of the uses of alchemy in these domains. I argue that, for these reformers, every step in the life cycle of a plant—from germination, to budding and flowering, to death and the reabsorption of its nutrients into the soil—had an alchemical explanation. Alchemical change was something that was happening all around us, and therefore alchemical experimentation could happen anywhere. Explaining and more importantly *controlling* these processes became a crucial objective for agricultural reformers and their allies.

In spite of their criticisms of what they have considered erroneous interpretations of historical alchemy, scholars like Newman and Principe have nevertheless professed hope that the historiographical future of alchemy will "elucidate the spectrum of notions, attitudes, and pursuits generally grouped under the wide umbrella 'alchemy' and portray it as a vastly more dynamic field than has hitherto been presumed."[56] A broader notion of what constituted alchemy in the past and a more generous allowance for what historians should focus on when they study it are necessary to gain a fuller perspective on how historical actors approached the subject. Even if they were not practicing laboratory alchemists, the study of "armchair," amateur, and field alchemists is an overlooked aspect of the history of alchemy and will contribute to a richer and more multifaceted picture of the practical and intellectual content of the work of these historical figures.

[56] Principe and Newman, "Some Problems with the Historiography of Alchemy," 420.

CHAPTER 1

THE "HERMAPHRODITICAL SALT": SALTPETERMEN, THE CHYMISTRY OF SALTS, AND THE TEXTUAL ORIGINS OF THE *SAL NITRUM* SCHOOL

"Every grain offering of yours, moreover, you shall season with salt, so that the salt of the covenant of your God shall not be lacking from your grain offering; with all your offerings you shall offer salt."

--Leviticus 2:13

Introduction

If one were to look up descriptions of saltpeter from the later Middle Ages through the late eighteenth century at random, one would find consistent accounts of the enigma of its origins, generation, and nature. This was especially the case during the sixteenth and seventeenth centuries, when the natural history enterprise focused on what William B. Ashworth has called the "emblematic" character of plants, animals, and minerals, meaning a complex, interwoven system of embedded symbols about natural objects informed by their social and cultural history.[1] Saltpeter remained a significant conundrum, not least because of the peculiar fact that it was both a source of destruction through its use in gunpowder and a wellspring of life through its apparent nourishment of plants. It was responsible for life and death as well as growth and destruction. It could be extracted from earth, air, and water; produced fire; looked like a mineral; propagated like a vegetable; and seemed to be an integral component in animal blood. As early as the thirteenth century, the

[1] William B. Ashworth, Jr.,"Natural History and the Emblematic Worldview," in *Reappraisals of the Scientific Revolution*, David Lindberg and Robert Westman, eds. (Cambridge: Cambridge University Press, 1990), 303-32.

friar Roger Bacon had remarked on the "violence of the salt called saltpeter," while the seventeenth-century chymist and expert on salts Johan Rudolf Glauber affirmed that "the Salt-Peter was a necessity in the Herbs, & the Grass, afore the Beasts feeding on them."[2] Well after the golden age of alchemy had passed, one chemistry professor in France confessed in the 1770s that he was very "much in the dark as to the origins and generation of saltpeter," calling it a "product of the elements [that] may not improperly be called the universal…mercury."[3] Even early twentieth-century agricultural chemists still commented on the lack of good studies explaining its biochemical development.[4]

Saltpeter's dichotomous nature—as a giver of life and a bringer of death—perplexed and troubled early moderns. Peter Whitehorne, whose 1562 book provided the first English account of its chymical properties, uses, and manufacture, epitomized the contemporary understanding of saltpeter when he wrote that he could not "tell how to be resolved what thing it properly is. It seemeth it hath the sovereignty and quality of every element."[5] The English physician William Clarke simply referred to it as the "hermaphroditical salt" for its shape-shifting indefinability.[6]

As one of the principal ingredients in gunpowder, mining, purchasing, manufacturing, or otherwise securing saltpeter became a national security issue by the fifteenth century. However, it had other practical uses, most notably as a fertilizer, a seed

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[2] Roger Bacon, *Opus Majus* [1267], trans. and ed. John Henry Bridges (Oxford: William and Norgate, 1900), 463; and Johan Rudolf Glauber, *The Works of the Famous and Highly Experienced Chemist, John Rudolph Glauber*, trans. by Christopher Packe (London: Thomas Milbourne, 1689), 309.
[3] Pierre-Joseph Macquer, *Elements of the Theory and Practice of Chymistry,* unknown English translation (Edinburgh, 1777), 182.
[4] John Walter Leather and Jatindra Nath Mukerji, *The Indian Saltpetre Industry* (Calcutta, 1911), 14.
[5] Peter Whitehorne, *Certaine Wayes for the ordering of souldiours in battelray… and moreouer, how to make saltpeter, gounpouder and diuers sortes of fireworkes or wilde fire….* (London, 1562), 22.
[6] William Clarke, *The Natural History of Nitre: or, a Philosophical Discourse of the Nature, Generation, Place, and Extraction of Nitre, with its Vertues and Uses* (London, 1670), 19 and 53.

steep, and an insect repellent in the agricultural and horticultural industries.[7] By the seventeenth century, projectors, and particularly members of the Hartlib Circle, had developed dual interests in both the utilitarian aspects of industrially produced saltpeter—for gunpowder, fertilizers, and more—and the more conjectural search for the origins of life and growth in inert matter, which might lead to a mastery of agriculture and ensure stable, secure supplies of food for the nation. Its bewildering physical nature and countless practical uses led to many experiments on saltpeter and other materials from which saltpeter could be derived, in particular various types of decaying organic matter.

This chapter details the growing knowledge of saltpeter's chymical properties, the alchemical or otherwise technical means needed to uncover these properties, and the development of this knowledge though its trade, mining, and artificial manufacturing, mostly for the nascent process of gunpowder production, which began in the late fourteenth century and had grown into a full-fledged industry by the early sixteenth century. I focus on the separate but coinciding and often coalescing practices of early saltpetermen who mined or manufactured saltpeter, farmers who used it for fertilizer, and alchemists who saw it as the key to unlocking the vital principle of life in non-living matter. Texts that discussed these manifold sources transferred much of this knowledge, largely through plagiarized or surreptitiously translated Continental works, into England beginning in the late sixteenth century and accelerating after around 1600. After detailing some of the practical knowledge gleaned from the mining and metallurgy trades, I explore

[7] Brenda J. Buchanan, "'The Art and Mystery of Making Gunpowder': The English Experience in the Seventeenth and Eighteenth Centuries," in *The Heirs of Archimedes: Science and the Art of War through the Age of Enlightenment*, ed. Brett D. Steele and Tamera Dorland (Cambridge, MA: MIT Press, 2005), 233–74; Jenny West, *Gunpowder, Government and War in the Mid-Eighteenth Century* (Woodbridge: Boydell Press, 1991); and Bert S. Hall, *Weapons and Warfare in Renaissance Europe: Gunpowder, Technology, and Tactics* (Baltimore, MD: Johns Hopkins University Press, 1997), esp. xxiii-xxv and 42-3.

the attitudes of English saltpetermen from roughly the end of the reign of Henry VIII through the early Jacobean era. I conclude by discussing the origins of the so-called "*sal nitrum* school" of chemical philosophy, which sought the vital seat of life in salts and in particular saltpeter, and demonstrate the deep influence this had on seventeenth-century projectors and the members of the Hartlib Circle. This became an extremely important intellectual component of artificial saltpeter projects in the 1640s, which is a subject of the following chapter.

Much of this work on saltpeter was situated upon the foundation of a chemical philosophy known as the *sal nitrum* school. In the early modern era, chemical philosophers sought the principles of life in numerous substances, from water and soil to Paracelsus's *tria prima* of sulfur, mercury, and salt, to the unknown and unseen corpuscles of the early mechanists. Many believed that salt in general, and saltpeter in particular, held the key to understanding the genesis and growth of life, which within the alchemical tradition came to be known as the *sal nitrum* school of chemical philosophy. The division of separate traditions was first articulated by Georg Ernst Stahl in the 1710s and 1720s, who identified three "famous schools" of alchemy: the vitriol school, the mercury school, and the *sal nitrum* school, each named after the substance from which the philosopher's stone was supposed to be created. Among these, the mercury school was by far the most common and by Stahl's time had been around for a millennium.[8] In the Paracelsian tradition, the foundation of the material world was not the four Aristotelian elements of earth, air, water,

[8] See Georg Ernst Stahl, *The Philosophical Principles of Universal Chemistry*, trans. by Peter Shaw (London, 1730). See also, Newman, "From Alchemy to 'Chymistry,'" 513-17.

and fire, but the "three principles," or *tria prima,* of sulfur, mercury, and salt.[9] Those of the *sal nitrum* school simply elevated salt to the highest of these three, and sought, as Benjamin Worsley put it, "the seate of life et vegetation, et so the whole subject of nutrition" in salts.[10] Successors of Paracelsus—primarily Michael Sendivogius, Clovis Hesteau de Nuysement, and Blaise de Vigenère—became highly influential among early Hartlib Circle members. The history of saltpeter presents a compelling example of the fusion of practical arts, alchemical theory, the development of sophisticated industrial manufacturing techniques, and the growing importance of international trade for the scientific understanding of material substances.

Practical Knowledge of Saltpeter in Sixteenth-Century England: Mining and International Trade

Because of its array of uses, a number of different professions and laborers accounted for much of the early experimentation and innovation with saltpeter, most of whom toiled anonymously.[11] From the Central Middle Ages through the early modern era,

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[9] Paracelsus, *Sämtliche Werke* eds. Karl Sudhoff and Wilhelm Mattießen (Hildesheim: Georg Olms Verlag, 1996), Vol. 11, 349, and Vol. 13, 393. See also Bruce T. Moran, *Distilling Knowledge: Alchemy, Chemistry, and the Scientific Revolution* (Cambridge: Harvard University Press, 2005), 72-3.

[10] Benjamin Worsley to Samuel Hartlib, 16 May 1664, Harlib Papers Online (hereafter HP) 66/4/1B, M. Greengrass, M. Leslie, and M. Hannon, eds., *The Hartlib Papers*, published by HRI Online Publications, Sheffield, https://www.dhi.ac.uk/hartlib/context.

[11] Kelly DeVries, "Sites of Military Science and Technology," *The Cambridge History of Science*, Vol. 3, *Early Modern Science*, ed. Lorraine Daston and Katherine Park (Cambridge: University of Cambridge, 2006), 310. "Saltpeter"—now known as potassium nitrate (KNO_3)—once referred to a large body of salts containing nitrate or carbonate ions. Potassium nitrate is made of a potassium atom joined with nitrate ions, making it an alkali metal nitrate. It is a natural, solid, stable nitrogen source, hence its importance as a fertilizer; and its three oxygen atoms make it a combustible oxidizer, hence its importance in gunpowder. Before the modern period, the term was sometimes used interchangeably with "niter," making it difficult for historians to discern precisely what compounds are being discussed in historical documents. Niter is mentioned in Herodotus, Pliny the Elder, Strabo, and in the Old Testament books of Proverbs and Jeremiah, though much of the modern scholarship on niter suggests that these allusions refer to soda or sodium carbonate (Na_2CO_3), as well as other nitrate salts, rather than pure potassium nitrate. See, David Cressy, "Saltpetre, State Security and Vexation in Early Modern England," *Past and Present*, 212 (2011): 78; Joseph M. Levine, *Between the Ancients and the Moderns: Baroque Culture in Restoration England* (New Haven: Yale University Press, 1999), 28. For

people made use of it in a wide variety of ways, including as a fertilizer, a food preservative and curative, a meat tenderizer, a beverage cooler, and a remedy for sensitive teeth and certain types of breathing problems. It was even believed by some to act as an anaphrodesiac for men as a suppressant of "male ardor," and there is some evidence it was used in a number of European armies from the thirteenth through seventeenth centuries in an attempt to control soldiers' libido.[12]

By far saltpeter's most important use beginning in the early fifteenth century was as the prime ingredient in gunpowder.[13] In the fourteenth century, apothecaries, who both used it medicinally and supplied it to the militaries, typically controlled the largest supplies in the West. Cannons came into use in the Hundred Years' War by at least the 1370s and 1380s, and shortly thereafter gunpowder became a mainstay in most Western European armies. In the fifteenth century, it seems that the supply chain came under the control of various masters of artillery, and they obtained saltpeter from multiple sources, including

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early modern English interpretations of both the Biblical and classical references, see Thomas Chaloner, *A Shorte Discourse of the Most Rare and Excellent Virtue of Nitre* (London, 1584); Clarke, *The Natural History of Nitre*; George Hakewill, *An Apologie of the Power and Providence of God* (Oxford, 1627), esp. 261-2; and Edward Jorden, *A Discourse of Naturall Bathes, and Minerall Waters* (London, 1632), esp. 48.

[12] On these uses and other, see Alan Williams, "The Production of Saltpeter in the Middle Ages," *Ambix* 22 (1975): 125–33.

[13] Saltpeter's combustible properties and its importance in explosives and projectiles had long been known, having first been identified by at latest late-fifth-century China, where an alchemical text from 492 C.E. described the purplish fire it produced when ignited. Another Chinese reference to the constituents of gunpowder, including saltpeter, came from a Daoist text from the mid-800s called *Zhenuan miaodao yaolüe.* The earliest Latin text containing a description of saltpeter and its combustible attributes dates to the mid thirteenth century and comes from descriptions circulated by William of Rubruck, a Franciscan friar who visited the court of the Mongol *khagan* Möngke from 1253 to 1255. Contemporary fellow Franciscan Roger Bacon showed great interest in these accounts and noted them in his *Epistola de secretis operibus artiis et naturae, et de nullitate de magiae* (*Letter on the Secret Workings of Art and Nature, and on the Vanity of Magic*) of ca. 1248-1267, the first European text to explicitly discuss the ingredients of gunpowder. Similar works around the same time include *De mirabilibus mundi* (*Concerning the Wonders of the World*), of ca. 1275, attributed to Albertus Magnus, and the pseudonymous Marcus Graecus's *Liber ignium ad comburendos hostes* (*Book of Fires for the Burning of Enemies*), of ca. 1300. See Kenneth Chase, *Firearms: A Global History to 1700* (Cambridge: Cambridge University Press, 2003), 31 and 58; Joseph Needham, *Science and Civilisation in China* (Cambridge: Cambridge University Press, 1954), Vol. 5, 179-200; Bert S. Hall, *Weapons and Warfare in Renaissance Europe: Gunpowder, Technology, and Tactics* (Baltimore, MD, and London, 1997), xxiii-xxv and 42-3; and DeVries, "Sites of Military Science and Technology," 308.

domestic mining, international trade, government funded open-market procurement, and private subcontracting, in addition to independent entrepreneurs beginning in the sixteenth century, especially in countries that had fewer natural stores.[14] In England, the Ordnance Office—founded in the 1460s at the Tower of London and greatly expanded to include a number of gunpowder specialists in the 1540s—organized the purchasing, standardization, and security of national gunpowder holdings.[15]

England witnessed major changes in the social, economic, and scientific status of saltpeter in the sixteenth century. During what historian David Cressy has called the "gunpowder kingship" of Henry VIII, England began to promote a domestic saltpeter industry and acquire a number of Continental trading contacts.[16] Saltpeter, along with sulfur (known as brimstone) and carbon (usually in the form of pulverized charcoal), was one of the principal ingredients in gunpowder, making its production an issue of national security.[17] By weight, it accounted for around three-quarters of the constituents of

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[14] DeVries, "Sites of Military Science and Technology," 310, and idem., "Gunpowder and Early Gunpowder Weapons," in *Gunpowder: The History of an International Technology*, ed. Brenda J. Buchanan (Bath, UK: University of Bath Press, 1996), 125–7. DeVries mentions that for the mid-fifteenth century, we know remarkably few of these individuals. Though the names of several are known, only two are discussed in any detail in contemporary sources: the French brothers Jean and Gaspard Bureau, who worked in the tactical administration of artillery in the latter years of the Hundred Years' War in the armies of Charles VII and Louis XI. He cites H. Dubled, "L'Artillerie royale française à l'époque de Charles VII et au début du régne de Louis XI (1437–1469): Les frères Bureau," *Memorial de l'artillerie française*, 50 (1976): 555–637, though he cautions that much of the information in this article is speculative.

[15] Ibid., 310; Richard Winship Stewart, *The English Ordnance Office, 1585–1625: A Case Study in Bureaucracy* (London: Royal Historical Society), 1996; and H.C. Thomlinson, *Guns and Government: The Ordnance Office under the Later Stuarts* (London: Royal Historical Society, 1978).

[16] Cressy, *Saltpeter: The Mother of Gunpowder* (Oxford: Oxford University Press, 2013), 36. See also, Cressy, "Saltpetre, State Security and Vexation in Early Modern England," 73–111. Cressy directly compares England (on an admittedly smaller scale) to the contemporary "gunpowder empires"—the Ottoman, Safavid, Mughal, and, to a leeser extent, Ming—that expanded territorially, secured their borders, and transformed their militaries using cannons and small arms.

[17] Cressy, "Saltpetre, State Security and Vexation in Early Modern England," 73–111; Brenda J. Buchanan, "'The Art and Mystery of Making Gunpowder': The English Experience in the Seventeenth and Eighteenth Centuries," in *The Heirs of Archimedes: Science and the Art of War through the Age of Enlightenment*, ed. Brett D. Steele and Tamera Dorland (Cambridge, MA: MIT Press, 2005), 233–74; Jenny West, *Gunpowder, Government and War in the Mid-Eighteenth Century* (Woodbridge: Boydell Press, 1991); and Bert S. Hall,

gunpowder, and without it ignition was impossible. Compared to saltpeter, charcoal and sulfur were relatively abundant and inexpensive. Charcoal could be easily obtained from English forests, particularly from alder, oak, holly, willow, hazel, and beech trees, and from at least the sixteenth century, the English imported sulfur from volcanically active regions of Europe, especially southern Italy, though it too could be acquired from various mineral springs throughout the British Isles.[18] Before the late fifteenth century, most European nations mined enough saltpeter domestically to meet their military demands, but the rapid surge of firearms, cannons, and other projectile weapons using gunpowder led to a depletion of various local sources, including in England. According to one source, for instance, during the sieges of Thérouanne and Tournai in Henry VIII's invasion of France (1512-14), his army reputedly consumed thirty-two tons of gunpowder (or roughly twenty-four tons of saltpeter by weight) *per day*.[19] At this point, countries increasingly began to rely on international trade to fulfill their quotas.[20]

By this time, saltpeter had become more difficult to procure domestically. There were essentially three ways to secure saltpeter supplies: importing it from foreign sources; domestic mining or digging; and artificial saltpeter plants or beds, also called plantations or nitraries.[21] Natural saltpeter requires precise environmental conditions, humidity, and soil chemistry to develop. Only a handful of locations around the world possess the right conditions to produce it naturally in abundance and unadulterated by other nitrate salts:

Weapons and Warfare in Renaissance Europe: Gunpowder, Technology, and Tactics (Baltimore, MD: Johns Hopkins University Press, 1997), esp. xxiii-xxv and 42-3.

[18] Cressy, *Saltpeter*, 12-14.

[19] Ibid., 39. On these numbers, see C.G. Cruickshank, *Army Royale: Henry VIII's Invasion of France, 1513* (Oxford: Oxford University Press, 1969), 76.

[20] DeVries, "Sites of Military Science and Technology," 311; Hall, *Weapons and Warfare in Renaissance Europe*, 74–5; and Williams, "The Production of Saltpetre in the Middle Ages," *Ambix*, 22 (1975): 125–33.

[21] Cressy, *Saltpeter*, 130.

Egypt, parts of Spain, the Atacama Desert on the Pacific coast of South America, the Mediterranean coast of North Africa and the Middle East, and parts of northwestern India were well-known locations.[22] This fact was not lost on early European nations with colonial aspirations as they expanded into many of these parts of the globe, and India in particular became a battleground between the Portuguese, French, Dutch, and eventually English, in no small part thanks to its natural stockpiles of saltpeter.[23] Bengal, Jaunpur, and Bihar had established their own thriving, domestic saltpeter industry in the mid-fifteenth century, well before any permanent European presence on the Indian subcontinent.[24]

For the British Isles, however, and much of Northern Europe more generally, typical wet weather conditions made the environment highly unfavorable for the maintenance of natural saltpeter troves, because it dissolves easily in water. This natural property was problematic for storing saltpeter and gunpowder as well, and various unknown smiths, gunners, artillerymen, and ferriers experimented with assorted compounds and mixtures

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[22] Ibid., 132-149. For a reasonably comprehensive series detailing the basics of saltpeter mining, trading, and production from the later Middle Ages to the end of the nineteenth century by an amateur historian, but firearms expert, see "The History of Saltpeter," Parts I-XIX, February 26 – June 6, 2016, *Firearms History, Development, and Technology* (blog), http://firearmshistory.blogspot.com/. During the Middle Ages, the town of Montpellier in France was also regarded as a source, though the resources seem to have been depleted by the early modern era. In Spain, two specific locations are mentioned: a mountain in Aragon near the sea and the salnitre caves of Collbató in modern-day Catalonia.

[23] In fact, in Britain, isolated potassium nitrate was sometimes referred to as "Indian saltpetre." See Leather and Mukerji, *Indian Saltpetre Industry*, 2.

[24] On the development of the Indian saltpeter industry and its exploitation at the hands of European imperial powers, see, for instance, James W. Frey, "The Indian Saltpeter Trade, the Military Revolution, and the Rise of Britain as a Global Power," *The Historian*, Vol. 71, No. 3 (2009): 507-54; Sun Laichen, "Saltpeter Trade and Warfare in East Asia," in *Offshore Asia: Maritime Interactions in East Asia before Steamships*, eds. Fujita Kayoka, Momoki Shiro, and Anthony Reid (Cambridge: Cambridge University Press, 2013), 130-184; K.N. Chaudhuri, *The English East India Company: The History of a Joint Stock Company, 1600-1640* (London: Frank Cass, 1965); idem., *The Trading World of Asia and the English East India Company, 1660-1760* (Cambridge: Cambridge University Press, 1978); Murari Kumar Jha, *The Political Economy of the Ganga River: Highway of State Formation in Mughal India, c. 1600-1800* (PhD Dissertation, Leiden University, 2013), esp. 139-96; and for a slightly later era, Kumkum Chatterjee, *Merchants, Politics, and Society in Early Modern India: Bihar, 1733-1820* (Leiden: Brill, 1996). The cities of Patna and Chapra both possessed large saltpeter manufacturing centers by the 1460s, and Patna remained important in the seventeenth century, first as a Dutch trading depot and then, along with Surat and Ahmedabad, as an English East India Company outpost.

of saltpeter and other substances to preserve its structural integrity, including mixing it with potash or wood ash; transporting the saltpeter, sulfur, and charcoal separately and combining them into gunpowder on-site during military engagements; and blending saltpeter with other salts like lime saltpeter, norgressaltpeter, and "Chili" saltpeter that held up better in high moisture environments.[25] In any case, with the importance of firearms in warfare well established by the early sixteenth century, domestic production no longer sufficed for England.

In the first half of the sixteenth century, international trade became essential to securing saltpeter. Under Henry VIII, Mary, and Edward VI, the English developed a complex network of continental European suppliers from multiple countries and regions, as one piece of a strategic plan to ensure that conflicts with any one country of origin would not impede the flow of saltpeter into England. Suppliers between the 1510s and 1550s included, among others, Italian merchants and bankers like the Cavalcanti family in Florence and Benedict Morevelli and Frances de Bara of Lucca, steelyard matériel suppliers affiliated with the Hanseatic League in Bremen, Hamburg, and Lübeck, independent Sicilian

[25] DeVries, "Sites of Military Science and Technology," 310; idem., "Gunpowder and Early Gunpowder Weapons;" and Bert S. Hall, "The Corning of Gunpowder and the Development of Firearms in the Renaissance," in Branda J. Buchanan, ed., *Gunpowder*, 87–120. By the late thirteenth century, the term "saltpeter" had almost solely come to refer to modern potassium nitrate (KNO_3). However, other nitrates sometimes referred to as "saltpeter" included calcium nitrate ($Ca(NO_3)_2$), sometimes called "lime saltpeter" or "norgressaltpeter;" sodium nitrate ($NaNO_3$), sometimes called "sodium saltpeter," "Chilean saltpeter," or "Chili saltpeter;" and magnesium nitrate ($Mg(NO_3)$), all of which are often found naturally mixed with potassium nitrate. There is a trade-off: though less water soluble, none of these is nearly as combustible as potassium nitrate and thus too much will make the finished product useless as an ingredient in gunpowder. See also, Cressy, "Saltpetre, State Security and Vexation in Early Modern England," 78; J. R. Partington, *A History of Greek Fire and Gunpowder* (Cambridge: University of Cambridge Press, 1960), 298-314; and Dennis W. Barnum, "Some History of Nitrates," *Journal of Chemical Education,* Vol. 80, (2003): 1393.

merchants from Palermo, dealers from along the Baltic coast, and a number of middlemen based out of Antwerp, England's largest creditor from the 1540s through the 1570s.[26]

Despite the preeminence of trade in the mid sixteenth century, attempts to manufacture saltpeter artificially grew drastically beginning in the late 1550s. When Elizabeth took the throne in 1558, England was on the verge of bankruptcy, had accrued large debts due to trade imbalance, and faced significant threats from other nations hoping to take advantage of the perceived weakness of an unmarried queen with few geopolitical allies. It also faced a serious saltpeter shortage. William Cecil, Secretary of State and later Lord Burghley, immediately commenced a two-pronged approach, aimed at both developing a large, extended network of suppliers and promoting artificial production domestically on scales that dwarfed those of earlier in the century.[27] Noting in memoranda delivered to Sir Richard Southwell in late 1558 that substantial "quantities [were] required from abroad" for "provisions necessary for supply to the armory," Cecil cultivated a number of new contacts over the next several years to guarantee a steady supply of saltpeter. He did this by directly trading English goods for it, by turning a blind eye to English smugglers returning with it from Spanish Hapsburg lands, and by simply offering to pay more for it than competing buyers, which he funded by going even further into debt

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[26] Cressy, *Saltpeter*, 40-2 and 189 n.7-9. On these, see The National Archives, Kew (hereafter TNA), C 1/108/61; C 1/308/71; SP 1/4, f. 66; and SP 1/8, f. 1; *Letters and Papers, Foreign and Domestic of the Reign of Henry VIII*, Vol. 1, Part 1, 670 and Vol. 1, Part 2, 2, 6, 13, 18, 21-23, 206, 334, 400, 401, 404, 588, all cited by Cressy. The Spanish Hapsburgs controlled Antwerp in mid-century and this supply source corresponded, not coincidentally, with the temporary Anglo-Spanish alliance during the Italian Wars of 1551-59. On Antwerp's role in the holding of English foreign debt, see R.B. Ouithwaite, "The Trials of Foreign Borrowing: The English Crown and the Antwerp Money Market in the Mid-Sixteenth Century," *Economic History Review*, Vol. 19, No. 2 (1966): 289- 305.

[27] On Cecil's propensity for funding all manner of chemical and metallurgical projects, see Deborah Harkness, *The Jewel House: Elizabethan London and the Scientific Revolution* (New Haven: Yale University Press, 2007), 145-180, esp. 169-180.

with the extension of generous lines of credit from Antwerp.[28] One of Cecil's Continental proxies, the merchant and royal financier Thomas Gresham, spent time in Flanders, Germany, and the Netherlands negotiating with dealers whose networks extended far beyond those from the early sixteenth cenutry. In less than a year, Cecil and Gresham had secured over 200 tons of saltpeter and pushed the supply chain as far as Hungary, Morocco, Russia, and the Safavid Empire in Persia, where English dealers traded items like timber, wool, cannonballs, and iron for saltpeter.[29] "Sundry Parcels of powder, salt peter, and match" from an unnamed supplier flowed to the Ordnance Office in the fall of 1560.[30] The next year the crown granted a license to an Italian supplier by the name of Marco Antonio Errizo to "supply…the queen with 20,000 bow staves, 20,000 cwt. [hundredweight] of Brimstone and salt peter of Naples."[31] Cecil's gamble seems to have paid off, as state documents note that "the crown and ordnance office saved money from the international purchase of gunpowder and saltpeter" by the mid-1570s.[32]

Practical Knowledge of Saltpeter in Sixteenth-Century England: Domestic Production

Other than importing it from foreign locations or mining the scant natural reserves in the British Isles, the best way to secure supplies of saltpeter was to "mine" or dig it from

[28] *Calendar of State Papers Domestic* (hereafter *CSPD*), *Edward VI, Mary, and Elizabeth (1541-1580),* Vol. 1, ed. Robert Lemon (London: Public Records Office, 1856), 117; *Calendar of State Papers Foreign*, *Elizabeth, 1558-1559,* Vol. 1, ed. Joseph Stephenson (London: Her Majesty's Stationery Office, 1863), 201 and 582. See also Cressy, *Saltpeter*, 50-1.
[29] "The History of Saltpeter," Parts I-XIX, February 26 – June 6, 2016, *Firearms History, Development, and Technology* (blog), http://firearmshistory.blogspot.com/; and Cressy, *Saltpeter*, 51-2. The Persian connections were secured via the newly chartered Muscovy Company, which funded several sea voyages and overland travels to Persia between 1555 and the early 1580s. See, Jane Grogan, *The Persian Empire in English Renaissance Writings, 1549-1622* (London: Palgrave-Macmillan, 2014), esp. 112-49.
[30] *CSPD*, *Edward VI, Mary, and Elizabeth I (1547-1580)*, Vol. 1, 160.
[31] Ibid., 172.
[32] Ibid., 511.

artificial sources or to manufacture it domestically from the digging of raw materials that could then be used to produce it. This second form of mining gave rise to a particular occupation: the "saltpeterman" or saltpeter digger. Unlike the natural troves of saltpeter found in caves and salt flats, the raw materials, sometimes known as "saltpeter soil," were mined in very different locations. Under the right environmental conditions, animal excrement and decomposing plant matter will naturally produce saltpeter in a matter of months, so farms, pastureland, and latrines became major sources of saltpeter extraction.[33] If saltpeter had not yet been produced, the raw material found in these locations could be harvested and refined in saltpeter plants. Although saltpetermen had begun the process of "mining" in this manner in England in the early sixteenth century, their method of saltpeter production had all but disappeared by the middle of the 1500s.[34] It was revived in a major way in the second half of the sixteenth century, this time with the supplementary addition of saltpeter manufacturing centers.

Producing saltpeter in this manner was not an English innovation. The English obtained it via German engineers and metallurgists starting in the 1540s. In 1545, Henry VIII employed a man by the name of Stefan von Haschenperg who possessed the technology to create saltpeter plants. Very little is known of these trials, but the continued

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[33] The modern biochemical explanation for this process is that bacteria consume dung, urine, and decomposing organic matter, which produces ammonia (NH_3) that bonds with oxygen in the air and soil to produce nitrate ions ($NO\text{-}_3$). In locations with a great deal of plant matter, this forms a potent fertilizer, but in areas with little vegetation—and in places like pastures and barnyards where that vegetation is eaten by livestock—these nitrate ions combine readily with various carbonates (CO_3^{-2}), including calcium carbonate, magnesium carbonate, and potassium carbonate. Over time, the nitrates replace the carbonates and in the case of potassium carbonate, forms potassium nitrate, or saltpeter. See Dennis W. Barnum, "Some History of Nitrates," *Journal of Chemical Education,* Vol. 80, (2003): 1393; and "The History of Saltpeter," Parts I-XIX, February 26 – June 6, 2016, *Firearms History, Development, and Technology* (blog), http://firearmshistory.blogspot.com/.

[34] Though novel in England, this process is known to have existed in China, India, Persia, and the Ottoman Empire by the fourteenth century, and in Germany, the first place in Europe to employ it, by at least the 1410s and possibly earlier. See Partington, *A History of Greek Fire and Gunpowder*, 314.

reliance on foreign trade during this time suggests little came of them. In 1561, Cecil's agents in central Europe informed him that various principalities in the Holy Roman Empire possessed similar technology. Inquiries into these sources came to fruition later that year in Cecil's acquisition for £300 of the methods of a German engineer named Gerard Hoenrich, who claimed to know "the true and perfect art of making saltpetre grow in cellars, barns, &, or in lime and stone quarries."[35] Hoenrich's ingredients included manure from horses fed with oats, urine from "those persons which drink either wine or strong beer," black earth from cool, dry places, especially if it was rich with decaying plant matter, lime made from crushed oyster shells or plaster of Paris, and fuel for a fire, for which he recommended sea-coal, as it was cheaper than charcoal, which should be preserved for gunpowder anyway.[36] Two months after divulging his trade secrets, he protested that he had never received his payment, but it appears the English government granted licenses to English saltpeter producers instead.

Beginning in the early 1560s and accelerating in the early 1570s, the crown appears to have granted many more of these contracts to English subjects than their foreign counterparts. There are several possible reasons for this. It was perhaps a result of the growing impetus of international English commercial ambitions. It was also perhaps a result of the rise of the Elizabethan privilege system of "letter patents" for promoting domestic commercial activities, increasing income, and rewarding courtiers with lucrative monopolies on household goods.[37] It may also have been a concerted effort on the part of

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[35] *CSPD*, *Edward VI, Mary, and Elizabeth (1547-1580)*, Vol. 1, 172.
[36] TNA, SP 12/16/28, f. 55, quoted in Cressy, *Saltpeter*, 54. The importance of using the urine of someone who consumed ample quantities of alcohol bore some resemblance to recipes for making saltpeter less water-soluble. See Hall, "The Corning of Gunpowder and the Development of Firearms in the Renaissance," 94-107.
[37] Joan Thirsk, *Economic Policy and Projects: The Development of Consumer Society in Early Modern England* (Oxford, UK: Clarendon Press, 1979), 51-56 and 58-60; Christine McacLeod, *Inventing the Industrial*

the Elizabethan government to achieve gunpowder independence, cease trading with foreign merchants who also sold to their adversaries, and protect themselves from disruption due to the caprices of international alliances. In part because of England's foreign debts, problems with debased currency, and a relative paucity of mineral wealth compared to the silver that flowed into Spanish and German coffers from Potosí and Saxony, respectively, William Cecil became known for promoting all sorts of homegrown metallurgical, mineralogical, and alchemical projects from the 1560s onward.[38] After declining to pay Hoenrich for his techniques, the Elizabethan government granted a ten-year monopoly on saltpeter digging to the English duo Philip Cockerham and John Barnes, who were licensed to search, dig for, and remove any and all saltpeter found throughout the country, even if it meant rampant trespassing and wanton destruction of private property.[39] Following them were the Master of the Ordnance, the Earl of Warwick and a lieutenant William Pelham, who were granted licenses "for the making of saltpeter" in 1573; John Bovyat, who was granted an "exclusive privilege of manufacturing gunpowder [from] stone minerals" for a twenty-one year term beginning in 1575; Christopher Hudson, who was granted a sum of £20,000 to make or purchase saltpeter or gunpowder by whatever means necessary in 1577; and John Grange, who in 1589, petitioned William Cecil, by then Lord High Treasurer, to grant him the right to produce saltpeter within the city of London after he had been "bereaved of his employment of making saltpeter…[by]

Revolution: The English Patent System, 1660-1800 (Cambridge: Cambridge University Press, 1988), 10-19; and Adrian Johns, *The Nature of the Book: Print and Knowledge in the Making* (Chicago: University of Chicago Press, 1998), 248-9.

[38] Harkness, *Jewel House*, 169-79.

[39] Cressy, 54-55. On Cockerham and Barnes's grant, see TNA, SP 12/16/30 f. 59. On the regulations meant to curb the wanton destruction of property, see British Library (hereafter BL), MS Lansdowne 5, f. 98.

Ralph Hockenhull, who for his own gain, employed unskillful persons to carry on the work."[40]

These saltpeter diggers—or, more likely, their employees, about whom we know very little—became a thorn in the side of country farmers because they ranged across the countryside to extricate saltpeter wherever it could be found or to gather the dried manure of cattle, oxen, horses, donkeys, mules, and sheep from stables, pastures reserved primarily for mixed husbandry, urban streets and gutters, chicken coops, pigeon dovecotes, and even latrines and outhouses (Figure 1.1). This manure was called "saltpeter soil" or "nitrous

Figure 1.1, Saltpeterman digging under stable, mid-16th century (Source: Wikimedia Commons).

[40] *CSPD*, *Edward VI, Mary, and Elizabeth I (1547-1580)*, Vol. 1, 461, 511, and 553; and *CSPD, Elizabeth I (1581-1590)*, Vol. 2, 612.

earth." There were even reports from Wales in the early 1650s of saltpetermen "digging vp dead bodies in some Churches, where they make saltpeter of their dust."[41] Unfortunately for landowners, the crown backed up these diggers because saltpeter's use in the production of gunpowder, an issue of national security.[42] The domestic production of saltpeter had also become such a lucrative practice that tensions developed between the crown—which heavily promoted entrepreneurial production and extraction of saltpeter all over the country—and the populace, whose farms, lands, and property often became damaged as a result of the often rapacious and exploitative nature of these saltpetermen.[43] By law, saltpetermen were instructed to reimburse landowners for any property damage or loss of income, but in practice this seemed rarely to have been the case, and there is evidence of farmers negotiating with, bribing, and even violently confronting saltpetermen when they made their rounds.[44]

[41] Samuel Hartlib, *Copy of Extracts in Hartlib's Hand*, 12 October 1653, HP 39/1/14A. I have been unable to find other references to this. Hartlib may have been referring to a similar incident that occurred in 1627-8, where one saltpeterman named Nicholas Stephens had overturned pews at a church in Chipping Norton to dig for saltpeter. After being castigated for his "sacrilegious abuses," he reportedly claimed, probably in crude jest, "women piss in their seats" during particularly charismatic sermons, which creates the best saltpeter. On these reports, see *CSPD, Charles I, 1629-1631*, ed. John Bruce (London, 1860), 206 and 386. For later prohibitions against this activity, see BL, MS Harley 1576, f. 164*v*.

[42] Cressy, *Saltpeter*, 166-173. This was not just an English law. Many European countries enacted similar ordinances, including, for instance, the French "*droit de fouille*" or "right to search" or "dig," enacted in the mid-sixteenth century by Francis I and remaining effectively unchanged until some easements from Louis XIV in the 1670s. See Surirey de Saint-Rémy, "The Manufacture of Gunpowder in France (1702), Part I: Saltpetre, Sulphur, and Charcoal," trans. D. H. Roberts, *Journal of the Ordnance Society* 5 (1993): 47–55; and Jack Kelley, *Gunpowder: Alchemy, Bombards, and Pyrotechnics—The History of the Explosive that Changed the World* (New York: Basic Books, 2004), 164.

[43] Ibid., 88-120. See also, Buchanan, "'The Art and Mystery of Making Gunpowder,'" in *The Heirs of Archimedes,* 233–74.

[44] Ibid., 42-54. This was, reportedly, quite a common phenomenon with patentees in different industries from the mid sixteenth to mid seventeenth centuries. For the epitomic example, see the affair of Giles Mompesson, Sidney Lee, rev. Sean Kelsey, "Mompesson, Sir Giles (1583/4-1651x63)," *Oxford Dictionary of National Biography* (hereafter *ODNB*), Oxford University Press, 2004, last accessed 26 October 2018, https://doi.org/10.1093/ref:odnb/18932.

Three major trends characterized the English saltpeter industry in the second half of the sixteenth century: the heavy promotion of domestic mining from these mostly agricultural sources at the expense of foreign imports; the preference for this to be conducted by English subjects; and the increasing profusion of artificial saltpeter plants to supplement—and sometimes consume raw materials from—these domestic mining projects. Domestic production became so successful that by the turn of the seventeenth century, perhaps *half* of all saltpeter consumed by the Ordnance Office was English in origin. Most of this came from roving saltpetermen.[45]

Saltpeter Plants, Nitraries, and the Development of Chymical Knowledge

What were saltpeter plants like? These artificial production centers offer some of the best evidence of the cross-pollination of chemical philosophy, the operative techniques of alchemy, and the practical, industrial methods of largely non-elite, often entirely anonymous, historical actors. Saltpeter boilers relied on techniques honed over decades through trial and error.[46] However, there is some evidence to suggest that many of the elite administrators of these projects, as well as the literate manual labors, had read various chymical and alchemical texts describing how to distill, crystallize, and synthesize assorted salts and other saline products, and there is even more evidence to suggest that later

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[45] Ibid., 72. Cressy cites TNA, SP 12/286/42, and SP 16/275/76, though I have been unable to verify this specific estimate. For this number, see also, "The History of Saltpeter," Parts I-XIX, February 26 – June 6, 2016, *Firearms History, Development, and Technology* (blog), http://firearmshistory.blogspot.com/, though Cressy appears to be his source as well.

[46] On saltpeter "boilers," which seems to have become a state position in Sweden ("*pannelag*"), see Bengt Åhslund, "The Saltpetre Boilers of the Swedish Crown," in Brenda J. Buchanan, ed., *Gunpowder*, 163-81; Thomas Kaiserfeld, "Chemistry in the War Machine: Saltpeter Production in Eighteenth-Century Sweden," in *The Heirs of Archimedes*, 275-92; Cressy, *Saltpeter*, 100 and 104; and *CSPD, Edward VI, Mary, and Elizabeth I (1547-1580)*, Vol. 1, 658.

alchemists drew on information gleaned from these practical efforts to substantiate their own matter theories.

Various techniques for the industrial production of saltpeter seem to have developed in either China or India sometime in the later Middle Ages. They had spread to Persia and the Ottoman Empire by the fifteenth century.[47] Venetian merchants with eastern Mediterranean and Black Sea trading depots were likely the first to receive and disseminate this knowledge.[48] The first unambiguous mention of nitraries in Europe comes from a 1405 German manuscript that may describe a technique in use a decade or two earlier than that. After that, numerous references began to appear, and between 1420 and 1480 saltpeter manufacturing centers arose in Vienna, Magdeburg, Frankfurt, and Heidelberg.[49] Shortly after this, information began to filter into the rest of Europe, and more technical descriptions of saltpeter production were committed to manuscript and print. As part of a broader tradition of describing metal and mineral works, saltpeter production often sat side-by-side on the page with other industrial processes and technological descriptions important for military, state security, and the industrial manufacture of merchantable products.[50]

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[47] On these developments and geographical diffusions, see Kenneth Chase, *Firearms: A Global History to 1700* (Cambridge: Cambridge University Press, 2003), 58-65 and 84-7.

[48] See, in general, Walter Panciera, "Saltpetre Production in the Republic of Venice from the Sixteenth to Eighteenth Century," *Icon* 3 (1977): 155-66.

[49] Partington, *A History of Greek Fire and Gunpowder*, 314-15.

[50] DeVries, "Sites of Military Science and Technology," 311; Hall, *Weapons and Warfare in Renaissance Europe*, 74–9; and Williams, "The Production of Saltpetre in the Middle Ages," 125–33. Although Cressy's work is the most recent book-length treatment of the role of saltpeter in early modern England, it focuses mostly on trade, mining, and military uses, rather than manufacturing and scientific study. For works covering these issues, though not necessarily specific to England, see Panciera, "Saltpetre Production in the Republic of Venice from the Sixteenth to Eighteenth Century," 155-66; Stephen Bull, "Pearls from the Dungheap: English Saltpetre Production, 1590–1640," *Journal of the Ordnance Society*, 2 (1990): 5–10; Saint-Remy, "The Manufacture of Gunpowder in France," 47–55; Thomas Kaiserfeld, "Chemistry in the War Machine: Saltpeter Production in 18th Century Sweden," 275–92; and Seymour H. Mauskopf, "The Crisis of English Gunpowder in

There is evidence of early niter beds being produced in England as early as the 1510s. Henry VIII, for example, had employed a German named Hans Wolf to scout for locations across England for raw materials to produce saltpeter.[51] However, published descriptions of these productions, and particularly the step-by-step instructions for making saltpeter beds, date only from the 1540s, and they appeared in Italian and German sources a generation before surfacing in English.

The chymical and technical knowledge of saltpeter first trickled into England largely through various translations and plagiarized writings of continental alchemists, saltworkers, and metallurgists. These included the Italian Vannoccio Biringuccio's posthumously published *De la pirotechnia* (*On the Practice of Metallurgy*) of 1540. Biringuccio had become the sole saltpeter producer in the city of Siena beginning in 1524, suggesting that he had gained possession of knowledge of its artificial production sometime before then.[52] The last few years of his life were spent as the head of the Papal foundries and munitions office in Rome. Peter Whitehorne's *Certaine Wayes for the ordering of souldiours in battleray…and moreover how to make saltpeter, gunpouder, and diuers sortes of fireworks and wilde fire…* of 1562, which first established the procedures for making saltpeter in English, drew heavily from this source.[53]

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the Eighteenth Century," in *Materials and Expertise in Early Modern Europe: Between Market and Laboratory,* ed. Ursula Klein and Emma C. Spary (Chicago: University of Chicago, 2010), 288-320.

[51] "Henry VIII: February 1514, 21-28" and "Henry VIII: April 1514, 21-30," in *Letters and Papers, Foreign and Domestic, Henry VIII, Volume 1, 1509-1514*, ed. J. S. Brewer (London, 1920), 1163-1179 and 1229-1248; and "Henry VIII: April 1515, 16-30," in *Letters and Papers, Foreign and Domestic, Henry VIII, Volume 2, 1515-1518*, ed. J. S. Brewer (London, 1864), 104-118, *British History Online,* last accessed 18 July 2018, http://www.british-history.ac.uk/letters-papers-hen8/vol1/pp1163-1179.

[52] Cressy, *Saltpeter,* 15-16; "The History of Saltpeter," Parts I-XIX, February 26 – June 6, 2016, *Firearms History, Development, and Technology* (blog), http://firearmshistory.blogspot.com/; and Erwin F. Lange, "Alchemy and Metallurgy in the Sixteenth Century," *Ambix* Vol. 13, No. 2 (1966): 92-5.

[53] The full title of Whitehorne's work is *Certaine Wayes for the ordering of souldiours in battelray, and setting of battailes, after diuers fashions with their manner of marching: and also fugures of certaine newe plattes for fortification of townes: and moreouer, how to make saltpeter, gounpouder and diuers sortes of fireworkes or*

Though *De la pirotechnia*'s primary function was as an instructional manual for miners, assayers, smelters, and casters, it also contained a wealth of information on the natural histories of metals and minerals, and humanistic musings on the purposes of wealth and labor and the appropriate commercial pursuits of princely states. Based on the similarities between his discussion of saltpeter and the following century of saltpeter manufacturing, he was considered a trustworthy source. He described the origins of saltpeter, which is "generated in moist caves, [and] easily generates under thick and calcareous walls, attached and congealed above like icicles."[54] The composition of saltpeter confounded Biringuccio, however, even as he wrote an entire chapter on its production. He called it a "mixture composed of many substances extracted with fire or water from arid or manurial soils," but confessed that he did "not know how to decide and say exactly what the nature of saltpeter is."[55] Quoting Pliny the Elder, he noted that some distinguished between "natural" and "artificial" saltpeter, the former of which was mined from underground like any other mineral, while the latter developed in or on topsoil, usually in the presence of organic material. Miners or diggers "commonly extracted [this second type] from certain dry manures and from a certain earth that has been dug up a long time and has been covered in a dry place so rain cannot wash out this substance."[56] Pliny had given "Armenia, Africa, and Egypt" as plentiful sources for natural saltpeter, where it was mined

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wilde fire, with other thinges appertayning to the warres (London, 1562). Abridged editions were published in 1574 and 1588, the latter appended to an English translation of Niccolò Machiavelli's *Arte of Warr*. See Cressy, "Saltpetre, State Security and Vexation in Early Modern England," 76 and n.17.

[54] Vannoccio Biringuccio, *The Pirotechnia of Vannoccio Biringuccio: The Classic Sixteenth-Century Treatise on Metals and Metallurgy*, trans. and ed. by Cyril Stanley Smith and Martha Teach Gnudi, 2nd edition (New York: Dover Publishing, 1990), 110.

[55] Ibid., 404.

[56] Ibid., 110-11. On Pliny, see *Historia Naturalis* 14.26 and 31.46.

in the form of mineral stone, which he referred to as "niter" (*nitro*).[57] Artificial saltpeter—what would become most familiar to saltpeter boilers—Pliny referred to simply as "saltpeter" (*salnitro*).[58] This distinction became important as later projectors touted the greater potency of this latter version, and *sal nitrum* theorists' understanding of the source of vitality depended on its presence in the soil or near the surface of the earth.

What were the steps to making saltpeter at one of these plants (Figure 1.2)? There were a plethora of ways to construct them, but a common one, from Georgius Agricola's *De re metallica* (*On the Nature of Metals*) of 1556, derived at least in part from Biringuccio's earlier work, went as follows:

> Saltpetre is made from a dry, slightly fatty earth…. This earth, together with a powder, are alternately put into a vat in layers a palm deep. The powder consists of two parts of unslaked lime and three parts of ashes of oak…. Each vat is filled with alternate layers of these to within three-quarters of a foot of the top, and then water is poured in until it is full. As the water percolates through the material it dissolves the saltpetre; then, the plug being pulled out from the vat, the solution is drained into a tub and ladled out into small vats. The…solution is poured into the first vat, the next into the second, the third into the third vat…As soon as there is an abundance of this solution it is poured into the rectangular copper caldron and evaporated to one half by boiling; then it is transferred into a vat covered with a lid, in which the earthy matter settles to the bottom. When the solution is clear it is poured back into the same pan, or into another, and re-boiled. When it bubbles and forms a scum, in order that it should not run over and that it may be greatly purified, there is poured into it three or four pounds of lye, made from three parts of oak or similar ash and one of unslaked lime. But in the water, prior to its being poured in, is dissolved rock-alum, in the proportion of one hundred and twenty *librae* [about 39.5 kg] of the former to five *librae* of the latter. Shortly afterward the solution will be found to be clear and blue. It is boiled until the waters, which are easily volatile (*subtiles*), are evaporated, and then the greater part of the salt, after it has settled at the bottom of the pan, is taken out with iron ladles. Then the concentrated solution is transferred to the vat in which rods are placed horizontally and vertically, to which it adheres when cold, and if there be much, it is condensed in three or four days into saltpetre. Then the solution which has not congealed, is poured out and

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[57] Ibid. By "Africa," Pliny presumably meant the Roman province of Africa, which covered parts of the Mediterranean coasts of modern-day Libya, Tunisia, and Algeria.

[58] Ibid. Smith and Gnudi note that Pliny's *nitro* was almost certainly not modern potassium nitrate, but rather some type of alkaline carbonate.

put on one side or re-boiled. The saltpetre being cut out and washed with its own solution, is thrown on to boards that it may drain and dry. The yield of saltpetre will be much or little in proportion to whether the solution has absorbed much or little; when the saltpetre has been obtained from lye, which purifies itself, it is somewhat clear and pure.[59]

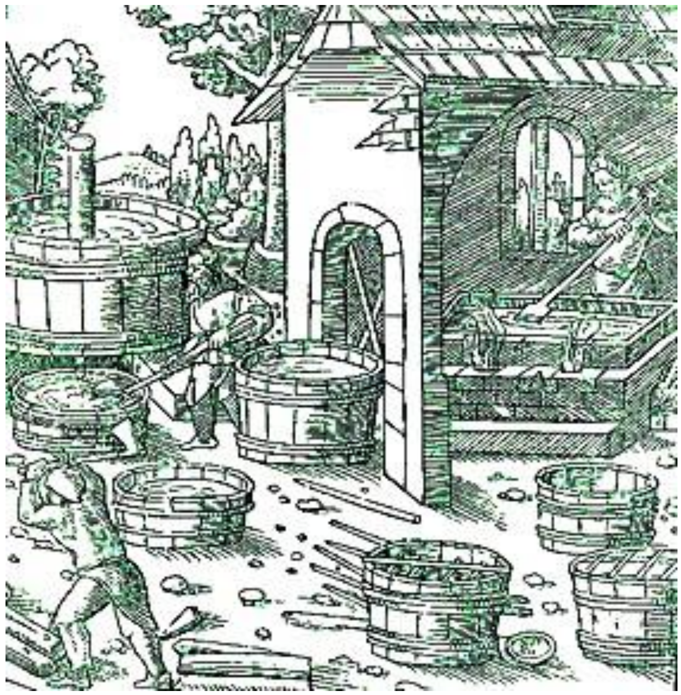

Figure 1.2, Woodcut of a saltpeter workshop, from Georgius Agricola, *De re metallica,* (Basel, 1556), 456 (Source: Wikimedia Commons).

Other, similar techniques existed, too. In another, after the original mixture had been mixed with the ash and leached with lye, the saltpeter boilers added egg whites or some other thickening agent; this solution would clump, and particulates would begin to coagulate (a process known as "flocculation"). After the precipitation had settled, the cleared saltpeter solution was scooped into a flat, copper reduction pan on a hearth and the solution boiled

[59] Georgius Agricola, *De Re Metallica*, trans. and ed., Herbert Clark Hoover and Lou Henry Hoover, 2nd ed. (New York: Dover, 1950) 561-3. The original publication is Georgius Agricola, *De re metallica* (Basel: Hieronymus Froben and Nicholas Episcopius, 1556). I have referred to the Hoovers' edition throughout. In modern chemical terms, this process allows decomposing organic matter containing nitrate ions produced by bacteria, in the presence of calcium carbonate (in this case, the lye and lime), to convert into calcium nitrate. The addition of wood ash, containing potassium carbonate, then changed calcium nitrate into potassium nitrate. The highly water-soluble potassium nitrate is absorbed by the water, which is distilled until only the potassium nitrate remains, now crystallized. The formula is $Ca(NO_3)_2 + K_2CO_3 = CaCO_3 + 2KNO_3$. See the Hoovers' footnote, 561 n.9.

down into concentrated saltpeter brine. The hot brine was poured into smaller, crystallization vats, which were then stirred with copper, rather than iron, ladles, as these were believed to aid in crystallization. After crystallization, the saltpeter was scratched off the sticks and the rest of the brine went back to the reduction pan again. The process continued until all the saltpeter had been extracted from these vats.[60]

Saltpeter boilers and others who developed these projects could begin with nitrous earth, various quantities of dung and urine from different animals, including people, or decaying plant matter, and there was some disagreement over what to use and when. Biringuccio claimed that pig dung worked best.[61] For the ash, he recommended olive-bush, cerris, or oak; while for the oak, Agricola specified holm oak, Italian oak, or Turkish oak.[62] For Biringuccio, the ratio of water to alum was 24:1; for Agricola, it was 25:1. Others dispensed with the alum solution altogether.[63] Both Biringuccio and Agricola mentioned another refining method that involved setting the mixture of nitrous earth and lime on fire, which immediately created saltpeter, though this method was rarely used because it produced only very small quantities.[64] Few other manuals mentioned this method after the 1550s. Taste and smell were also important testing methods for the original dried nitrous

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[60] Cressy, *Saltpeter*, 15-29. It should be noted here that William Newman and Lawrence Principe have suggested that these some of these processes may have been more akin to alchemical attempts to transmute metals than successful chymical procedures for producing large quantities of saltpeter. See, especially, William R. Newman and Lawrence M. Principe, *Alchemy Tried in the Fire: Starkey, Boyle, and the Fate of Helmontian Chymistry* (Chicago: University of Chicago Press, 2002), 207-272. For modern efforts to recreate these attempts, see Haileigh Robinson, "Reworking Seventeenth-Century Saltpetre," *Ambix* Vol. 63, No. 2 (2016): 145-61, which details the historical reenactment of these experiments with the Medieval Gunpowder Research Group at the University of Leeds and demonstrates just how difficult it is to isolate pure potassium nitrate without carbonate, sulfate, and other nitrate byproducts.
[61] Biringuccio, *Pirotechnia*, 405.
[62] Ibid., and Agricola, *De re metallica*, 561. Among trees that would have been available to saltpeter boilers, oak has among the highest potassium content.
[63] The addition of alum does not, in fact, affect the outcome.
[64] In this method, the calcium nitrate converted to calcium sulfate ($CaSO_4$) in the fire, which left behind only a few free nitrates to combine with potassium from the original organic matter.

earth, which needed to be "biting" or "acrid," as well as the distilled brine, which should be sufficiently salty. In one English recipe from a mid-seventeenth-century manuscript containing notes and translations of a 1624 book called *Neu reformierter Heldenschatz…* (*Newly Reformed Hero's Treasure…*) by Johannes Staricius, the author stipulated "unquickened lime," liquid filtration with "raynewater which falleth with the Northwind," and preparatory ingredients with a ratio of "three parts lime, one part sheep's urine, and three parts sheep's dung" to make a "vault in which saltpeter Groweth of itself."[65] In any case, any recipe might require ad hoc, on-the-spot changes depending on the material conditions of the ingredients at any given step.

The most complete and wide-ranging European saltpeter manual was the textbook *Beschreibung allerfürnemisten mineralischen Ertzt und Berckwercksarten* (*Description of Leading Ore Processing and Mining Methods*), published in 1574 by the Bohemian metallurgist Lazarus Ercker, chief master of mines in Rudolph II's Holy Roman Empire. This work, which also covered chemical, metallurgical analyses of a number of other minerals, saw several German editions in the 1570s and 1580s, though no full English edition would

[65] Wellcome Library, MS 763, f. 56*b*. This appears to be an unpublished English translation of the German work of 1624. I have been unable to locate a published version in English. The author translated the full work as *The newly reformed warrioures treasure. That is, a Nature-knowing consideration upon and about the Vulcan: as also naturall-magicall preparation and fabrefaction of that warriour Achilles his armour in Greece. Out of which besides many secrets, is to be seen what belongeth chiefely for the warlike setting out of a warriour. Whereby also is discovered a false copie, which John Burkner, in the Authors name hath deceitfully published….* The manuscript discusses a semi-magical attempt to create armor as strong as Achilles' and contains numerous chemical and medical recipes, designs for various military devices, and "secrets" and "experiments" to make such things. The original work is Johannes Staricius, *Nue reformierter Heldenschatz: das ist, Naturkündliches Bedencken, uber und bey Vulcanischer auch natülich-Magischer Fabrefaction und zubereitung der Waffen deß Helden Achillis in Grieschland: Darauß neben vielen Secretis zu vernehmen was zu Martialischer außrüstung eines Kriegshelden vornemlich gehörig; Auch das betrügliche Exemplar von Hans Bürcknern von Erffurt sub Autoris nomine fälschlich in Quarto spargirt entdecket wirdt* (Frankfurt-am-Main: Johan Niclas Stoltzenberger auf Kosten von Johan Berner, 1624).

appear until a century later.[66] Nevertheless, portions of the book appeared in England around this time, often without crediting Ercker. Even with this transfer of knowledge from continental sources, most English saltpetermen worked "blindly and without knowledge," as Bohemian mining expert Joachim Gaunze, who had been acquainted with Ercker, wrote.[67]

If one did not have ready access to saltpeter soil, or nitrous earth, from farms, this too could be manufactured to provide the starting material for these large boiling projects. To do this, one needed the same matter that eventually produced nitrates naturally—animal feces, urine, or decaying organic materials—to "plant" in niter beds, most of which existed at the site of the industrial production of saltpeter. Laborers filled long trenches with the animal and plant waste and lined it with clay or dense soil to prevent absorption into the ground. They also added twigs, branches, straw, or other materials to make the beds permeable enough for easy circulation of air and water. Periodically, workers added liquid to keep the mixture moist, and this was usually done with human and animal urine, wastewater, rainwater, or any other standing water that was available. The moisture level had to remain consistent—too little and the decomposition would not produce nitrates, too much and the highly water-soluble saltpeter would not be able to crystallize. The entire

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[66] For a modern, English edition, see Anneliese Grünhaldt Sisco and Cyril Stanley Smith, trans. and eds., *Lazarus Ercker's Treatise on Ores and Assaying translated from the German Edition of 1580* (Chicago: University of Chicago Press, 1951). The first edition was published in Prague in 1574 and further editions appeared in Frankfurt in 1598, 1629 and 1672. The first published English translation appeared in John Pettus, *Fleta Minor. The Laws of Art and Nature* (London, 1683). For other seventeenth-century works that either owed heavy debts or were outright plagiarized from the likes Biringuccio, Agricola, and Ercker, see John Rudolph Glauber, *The Works of the Highly Experienced and Famous Chymist* (London, 1689), 345-59, which also reproduced Ercker's treatise on "the manner of boiling salt-petre;" Thomas Henshaw's "History of the Making of Salt-Petre," in Thomas Sprat, *The History of the Royal Society of London, for the Improvement of Natural Knowledge* (London, 1667), 260-76, was heavily plagiarized from Ercker. On these, and others, see See Cressy, "Saltpetre, State Security and Vexation in Early Modern England," 77; idem., *Saltpeter*, 21-5; and R. J. W. Evans, *Rudolf II and His World: A Study in Intellectual History, 1576-1612* (Oxford: Oxford University Press, 1984), 215.

[67]Whitehorne, *Certaine Wayes for the ordering of souldiours in battelray…*, 22.

process took upwards of a year before the base matter was sufficiently filled with nitrous material to be boiled (Fig. 1.3).[68] Because of the incredible fertility of the material in the niter beds, it was common for plants of all sorts to grow up from the mounds, which would have to be weeded periodically or the plants would absorb all of the useful nitrates. This led to an increased understanding of the uses of saltpeter in the agricultural industry and

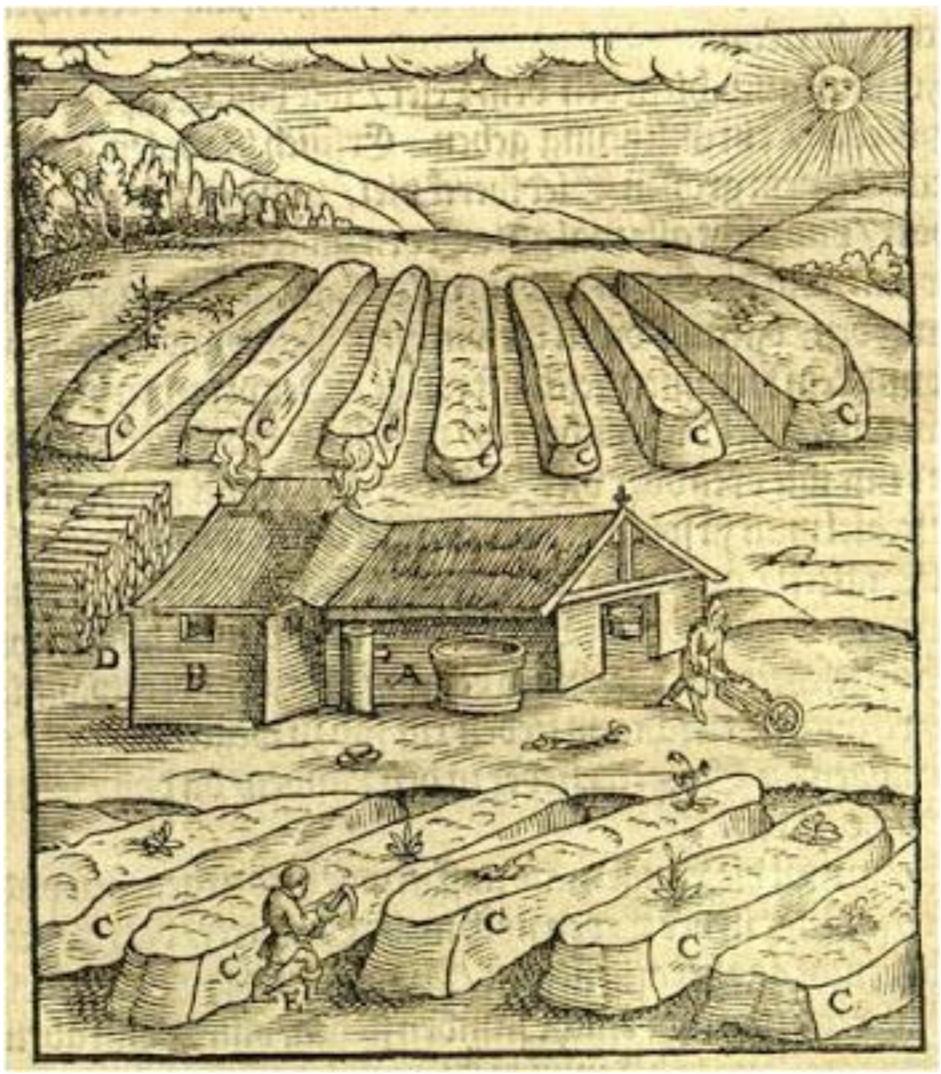

Figure 1.3, Niter beds or nitraries. Notice the plants growing out of the very fertile soil. These would have to be regularly weeded or their roots would absorb the valuable nitrates necessary for saltpeter production. Woodcut from Lazarus Ercker, *Beschreibung allerfürnemisten mineralischen Ertzt und Berckwercksarten* (Frankfurt, 1598), f. 134 (Source: Wikimedia Commons).

[68] Sisco and Smith, trans. and ed., *Lazarus Ercker's Treatise on Ores and Assaying*, 291-310.

the belief that saltpeter might possess something vital for the existence of life and its growth.

Metallurgical and mineralogical texts, alchemical recipe manuscripts, and the more theoretical writings of natural philosophers provide ample evidence of the reciprocal nature of these sources of knowledge. In spite of their often-obstreperous protestations, the writers of practical manuals like Biringuccio, Agricola, Ercker, and Whitehorne tended to be dismissive of alchemy, or at least of the more grandiose claims of transmutational alchemists. This belies the sheer quantity of techniques, material knowledge, and equipment design borrowed from late medieval alchemical texts.[69] During the sixteenth century, small artisanal manuals (*Kunstbüchlein*) proliferated and circulated in Germany among both literate laborers who used them as practical resources and elite figures who often used them as empirical sources for their published materials on alchemical theory.[70] One of the first—entitled the *Rechter Gebrauch d'Alchimei* (*The Proper Use of Alchemy*)—explained that "true" alchemy was not about transmutation or creating the philosopher's stone, but rather the industrial processes of "skilled workmen," including the extraction of "spirits" from metals, the distillation of liquids to extract useful matter within, and the "fixing" of various substances, like mercury, sulfur, and ammonia, that were often lost when materials were heated.[71] Compiled from workshop notes, oral transmission of artisanal procedures, and earlier unpublished treatises, these small booklets provided instructions

[69] Newman, "From Alchemy to 'Chymistry,'" 515.
[70] Ibid. On these texts, Newman cites Ernst Darmstaedter, "Berg-, Probir- und Kunstbüchlein," *Munchener Beitrage zur Geschichte und Literatur der Naturwissenschaften und Medizin*, Vol. 2, No. 3 (1926): 101–206.
[71] On this and others, see William Eamon, *Science and the Secrets of Nature: Books of Secrets in Medieval and Early Modern Culture* (Princeton: Princeton University Press, 1994), 112-134.

for operational techniques, standardized many trades, and provided foundational access for apprentices.

Biringuccio and Agricola exhibited both debts to and disdain for alchemists. Biringuccio remained agnostic about their grander claims, though he demarcated fruitful alchemy from the fraudulent variety. The former "[gave] birth everyday of its new and splendid effects, such as the extraction of medicinal substances, colors, and perfumes, and an infinite number of compositions of things," while the latter was "sophistic, violent, and unnatural," practiced only by criminals, and founded on "illusions" and "deceit" only.[72] Still, he argued, even charlatans produced demonstrable physical change through knowledge of the chemical reactions of metals. Agricola noted that very few had written on the subject of metals, except for "so many alchemists…who would compound metals artificially and who would change one into another."[73] Claiming to limit himself "only to famous ones," he proceeded to list over thirty names—some mythical, including Hermes and Merlin—though he complained that they "employ[ed] obscure language," cloaked their meaning in poetry, and were "difficult to follow, because the writers upon these things use[d] strange names, which do not properly belong to metals."[74] Though he claimed to be "undecided" whether or not transmutational alchemy was true, he noticed that the lack of any fabulously wealthy alchemists made the matter "highly dubious."[75]

Contemporaneous English manuscripts with alchemical recipes revealed borrowings from these more conventional texts and it is clear that there was a sizeable

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[72] Biringuccio, *De la pirotechnia*, 337.
[73] Agricola, *De re metallica*, xxvii.
[74] Ibid., xxvii-xxviii. This was quite the claim considering that Agricola was also known for inventing terminology, including for saltpeter, which he referred to as "*halinitrum*," though in this he was distinguishing Pliny's niter from saltpeter (or the German near-cognate *salpeter*). His list of alchemists was derived from an unnamed work of the Paduan lecturer in natural philosophy Hermolaus Barbarus.
[75] Ibid., xxviii.

intersection of knowledge about the chymical preparation of metals and salts. One author discussed saltpeter as a byproduct of the use of vermilion—a red pigment derived from cinnabar, used in printing and painting—in alchemical recipes for separating gold from silver or aquafortis: a small amount of vermilion added to lye could reputedly be boiled until only saltpeter remained.[76] Beginning in the seventeenth century especially, short recipes to produce saltpeter and other rock salts, or longer recipes in which they were byproducts, clearly appropriated many of the best techniques from metalworkers, salt smiths, and other industrial or military-oriented occupations. One manuscript containing a recipe to create the vegetable stone, or a substance reputed to stimulate growth, began with practical instructions explaining how salts were to be "drawn out of metals and to be turned into oyle and thereof to make the stone" in what appears to be a method for creating various types of vitriol.[77] Another from around the same time containing instructions on making the "great stone" started by taking the "clearest and cleanest sea salt as is made by the sea itself such as is brought by shipping from Spain…"[78] Other manuscripts containing alchemical recipes covered how to distinguish various types of salts from one another and their "chemical definitions," and techniques for extracting salts from various plants.[79] All of these recipes and instructions came from after the development of a domestic saltpeter industry in England and revealed descent from both the late medieval alchemical tradition and the short metallurgical manuals of the sixteenth century.

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[76] See Pamela H. Smith, "Vermilion, Mercury, Blood, and Lizards: Matter and Meaning in Metalworking," in *Materials and Expertise in Early Modern Europe: Between Market and Laboratory*, 42. Smith quotes the anonymous *Goldsmith's Storehouse* (ca. 1604), f. 55*r.*
[77] BL, MS Sloane 1723, ff. 70*b*-93. This appears to be a recipe for producing various metallic sulfates.
[78] BL, MS Sloane 3632, ff. 121-132. The recipe is titled "*De lapide magna*."
[79] On these, see BL, MS Sloane 1386, ff. 1*b*-2*a*, 5*b*, 6*b*, 9*a*-10*a*, 22*b*, 24*a*-*b*, and 29*b*-30*a*; and Wellcome Library, MS 4755, ff. 277-321.

The Textual and Theoretical Roots of the **Sal Nitrum** *School*

Despite an increased knowledge of its uses from the reign of Henry VIII onward, the composition and nature of saltpeter remained an enigma to English alchemists, natural philosophers, and saltpetermen. The substance seemed to defy strict categorization and thus was a prime candidate for those vitalist alchemists who sought to study the dividing line between living and non-living matter and who searched for the chemical or material substance that housed the seminal principle of life. Saltpeter seemed to contain properties of vegetable, animal, and mineral depending on how it was manipulated.[80] It could be made both acidic and alkaline, both stable under certain conditions and volatile under others. Those who subscribed to the Empedoclean-Aristotelian position of four elements could detect in it qualities of earth, water, air, and fire. It occurred naturally in the physical world, could be seen "growing" in caves and on cow pats in fields, but could also be produced artificially.[81] A combination of the rise in practical knowledge about salts, an infusion of Neoplatonism into alchemy and natural philosophy, and challenges to the existing alchemical corpus, especially from Paracelsus, helped inaugurate what is sometimes referred to as the "*sal nitrum*" school of alchemical theory.[82]

The *sal nitrum* theory, in short, was the belief that the key to understanding animal, plant, and mineral growth; the vital principle that made life possible; and the physical substances required to create the philosopher's stone lay in an understanding of salts. Its origins are complex. Their upsurge in usefulness in industrial processes, agriculture, food preservation, medicine, and most importantly gunpowder manufacture made a variety of

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[80] Cressy, *Saltpeter*, 10-11
[81] Ibid., 4-5.
[82] Newman, "From Alchemy to 'Chymistry,'" 512-15.

salts much more familiar material to manual laborers, physicians, soldiers, and natural philosophers by the beginning of the sixteenth century. Around the same time, late fifteenth-century Neoplatonist philosophers, like Marsilio Ficino, had argued for a universal life spirit extant in all matter and casually suggested that alchemists might isolate this.[83] Changes in alchemical theory helped to integrate these two developments.

Although *chrysopoeian* alchemy had long been the most common version of laboratory alchemy and the transmutation of base metals into gold remained the most typical alchemical goal, understanding of the composition of metallic ores, minerals, and crystalline substances had developed into an important aspect of the experimental process. As Newman and Principe have demonstrated, this dated back to the eighth-century works of the Arab alchemist Abū Mūsā Jābir ibn-Ḥayyan, usually Latinized in the West as Geber, and the thirteenth-century works of pseudo-Geber, which persisted well into the early modern era, when the Geberian mercury-sulfur theory of metallic composition became the cornerstone of alchemy.[84] In Geberian and pseudo-Geberian writings, all metals were composed to varying degrees of "philosophical" mercury and sulfur, which combined naturally underground to form copper, iron, tin, lead, and physical mercury (base metals) and silver and gold (noble metals). The precise ratio of the two determined which metal arose. This theory likely emerged, in part, because certain metals give off a sulfurous smell

[83] Ibid., 514-15.
[84] Lawrence Principe, *The Secrets of Alchemy* (Chicago: University of Chicago Press, 2013), 35-37. Due to the obscurity, anonymity, and secrecy of a great many alchemical writings, it is difficult to trace the origins of these ideas with any real certainty. These notions do not arise *sui generis* in Jābir or pseudo-Geber, and Principe notes liberal borrowings from Pythagoras, Aristotle, Galen, the ancient Greek alchemists Zosimos of Panopolis and Apollonius of Tyana, and a number of Muslim alchemists and physicians from the eighth century, including Jābir's "master," the sixth Shi'ite Imam, Ja'far al-Ṣādiq. Jābir himself may have been many different people writing under the same name or may not have existed at all. On Aristotle, who contrasted the "dry and smoky" (i.e. sulfurous) and "wet and steamy" (i.e., mercurial) "exhalations" of the earth, see Aristotle, *Meteorologica* 3.6.378*a*17-*b*6.

when burned and many metals heated to the point of liquefaction possess similar appearance and physical properties to mercury. The transformation of metals required purified philosophical mercury and philosophical sulfur, which when recombined in the proper proportions, could create any of these metals, including gold.[85] Somewhat confusingly, both philosophical principles possessed inherent qualities resembling the chemical substances of mercury and sulfur, respectively, but were not necessarily equivalent to them. By the early sixteenth century, the physician and alchemical theorist Paracelsus had added salt to the Geberian dyad of mercury and sulfur to create what he called the *tria prima*, or "three principles," the combination of which accounted for the components of all matter.[86] Most of those who subscribed to the *sal nitrum* school adhered to some version of Paracelsian matter theory and simply elevated salt to the highest of these principles.

This theory received its fullest and most coherent expression in Michael Sendivogius's *Novum lumen chemicum* (literally *New Chemical Light*, usually translated into English as *New Light of Alchemy*).[87] In this work, Sendivogius, a devotee of Paracelsian

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[85] Newman, *Alchemy Tried in the Fire,* 249; and idem., *Gehennical Fire: The Lives of George Starkey, an American Alchemist in the Scientific Revolution* (Cambridge: Harvard University Press, 1994), 95-8. On Geber and Pseudo-Geber, see William R. Newman, *The* Summa Perfectionis *of Pseudo-Geber: A Critical Edition, Translation, and Study* (Leiden: E.J. Brill, 1993). For a concise presentation of Jābir, Geber/pseudo-Geber, and the alchemical theory derived from their works, see Principe, *Secrets of Alchemy*, 33-45 and 54-58.

[86] Principe, *Secrets of Alchemy*, 128.

[87] Michael Sendivogius, *Novum lumen chemicum* (Frankfurt and Prague, 1604). This was work was simultaneously published under the title *De Lapide Philosophorum Tractatus duodecim e naturae fonte et manuali experientia depromti*. There are numerous English translations and manuscript editions, many appended to other works or included in compilations of alchemical compendia. At least thirty editions appeared between 1608 and the end of the eighteenth century. The most well-known English edition was John French, *A New Light of Alchymie: Taken out of the fountaine of Nature, and Manuall Experience, to which is added a Treatise of Svlphvr* (London: Richard Coates for Thomas Willis at the Bible in Little Britain, 1650). I have quoted from French's translation throughout. For more on Sendivogius's theories regarding saltpeter, philosophical niter, and the *sal nitrum* school, see Paolo Alves Porto, "Michael Sendivogius on Niter and the Preparation of the Philosopher's Stone," *Ambix* Vol. 48, No. 1 (2001): 1-16; Zbigniew Szydlo, "The Alchemy of Michael Sendivogius: His Central Nitre Theory," *Ambix* 40 (1993): 129-46; idem., "The Influence of the Central Nitre Theory of Michael Sendivogius on the Chemical Philosophy of the Seventeenth Century," *Ambix* 43

tenets, explained mineral growth, plant and animal life, and the generative properties of matter more generally, by using saltpeter as a model.[88] In this, he could be grouped in with vitalist alchemists who sought the *semina rerum* or *spiritus vitalis*, or particular vital principles usually described as "seeds," or in Sendivogius's case *sperma*, to create what Thomas Leng has called a "sexualized organic cosmology."[89] Sendivogius argued that physical saltpeter was not the equivalent of the *spiritus vitalis*, but contained the *sperma* within it, which were responsible for generating all other growing matter. According to Sendivogius, the philosophical sulfur of Geber was simply a more mature form of the philosophical mercury, which itself was a solid manifestation of an aerial philosophical niter. In *Novum lumen chemicum*, he described how the *sperma* traveled to the center of the Earth, which was a hollow place much like a womb, where a second, inner sun (*sol centralis*) digested the *sperma* contained within the elements and vaporized them, after which they rose back through a semi-porous Earth to the surface.[90] During its upward ascent, these *sperma* combined with the philosophical sulfur in the soil, which accounted for both the formation of metals and minerals and the fertile properties of topsoil. "The

(1996): 80-97; and Włodzimierz Hubicki, "Michael Sendivogius' Nitre Theory: Its Origins and Significance for the History of Chemistry," *Actes du Xe Congrès International d'Histoire des Sciences*, Vol. 2 (Paris: Hermann, 1964), 829-33. For Sendivogius more generally, see Rafał T. Prinke, "Beyond Patronage: Michael Sendivogius and the Meanings of Success in Alchemy," in *Chymia: Science and Nature in Medieval and Early Modern Europe*, Miguel Lopéz Pérez, Didier Kahn, and Mar Rey-Bueno, eds. (Newcastle-upon- Tyne, UK: Cambridge Scholars Publishing, 2010), 175-231; and Zbigniew Szydlo, *Water Which Does Not Wet Hands: The Alchemy of Michael Sendivogius* (Warsaw: Polish Academy of Sciences, 1994), translated out of the later published Polish edition, *Woda, która nie moczy rąk. Alchemia Michała Sędziwoja,* (Warszawa: Wydawnictwa Naukowo-Techniczne, 1997).

[88] William R. Newman, "Geochemical Concepts in Isaac Newton's Early Alchemy," in *The Revolution in Geology from the Renaissance to the Enlightenment*, edited by Gary D. Rosenberg (Boulder, CO: The Geological Society of America, 2009), 42; and idem., *Gehennical Fire*, 87-90.

[89] Thomas Leng, *Benjamin Worsley (1618-1677): Trade, Interest, and the Spirit in Revolutionary England* (Woodbridge, UK: Boydell Press, 2008), 97.

[90] This was not unlike the Geberian theory for the formation of metals and minerals. Paracelsus and (at least in the case of *sperma*) Sendivogius had expanded this to include all other matter as well. See Principe, *Secrets of Alchemy*, 128.

sperm of metals doth not differ from the sperm of all things," Sendivogius wrote, "*viz.,* the moist Vapor: therefore, in vain, do artists look after the reducing of metals into their first matter, which is only a vapour."[91]

Once airborne, these vaporous *spermae* traveled through the atmosphere. There, the sun's rays imparted their own vital power, which combined with the *spermae*, after which they congealed and returned to the Earth in various liquid forms, including rainwater, snow, and dews. At this point, they had been revitalized, and after mingling with a fattened soil, they produced ordinary saltpeter. As Sendivogius wrote,

> when there is rain made, it receives from the air that power of life, and joins it with the salt-nitre of the Earth…which in it is resolved into water: such attractive power hath the salt-nitre of the earth, which also was aire, and is joined to the fattness of the earth, and by how much the more abundantly the beams of the sun beat upon it, the greater quantity of salt-nitre is made, and by consequence the greater plenty of corn grows, and is increased, and this is done daily.[92]

An investigation of saltpeter, thus, would yield empirical evidence for the existence of the *spiritus vitalis* in nature.[93]

Though most saltpetermen and agricultural laborers had experience with the physical substance of saltpeter, alchemists, later projectors, and agricultural experimenters with some alchemical experience acquired various techniques to extract it from air and theories about why this was possible. This became an integral component of the *sal nitrum* school since it was thought that the secret to producing saltpeter artificially—and the explanation for its natural growth—lay in an airborne, nitrous substance that, upon interacting with matter at the surface of the earth, congealed into the fixed, crystallized, solid form of saltpeter with which most of them were familiar.

[91] Sendivogius, *A New Light of Alchymie*, 11.
[92] Ibid., 43-4.
[93] Newman, "Geochemical Concepts in Isaac Newton's Early Alchemy," 43.

The concept of an airborne, nitrous spirit, sometimes referred to as the "aerial niter," "the nitro-aerial spirit," the "celestial fire," or the "*flamma vitalis*," seems to have originated with Paracelsus.[94] He had argued that common saltpeter was produced from the "union of urine and the universal nature of balsam," but he claimed it was unique among all salts and connected it with an airborne, gaseous form known as aerial niter.[95] With reference to the thirteenth-century alchemist pseudo-Ramon Lull's definition, Paracelsus described four known qualities of saltpeter and aerial niter and described what he believed them to cause: in conjunction with "aerial sulfur," aerial niter caused thunder and lightning, contributed to bodily maladies involving burning sensations, delivered the necessary nutrients for the movement of muscles, and cooled the "Cagastric soul," or the post-Fall soul of humans that overwhelmed the pre-Fall "Iliastric soul."[96] The first conclusion likely resulted from the observed effects of combining saltpeter and sulfur in gunpowder. The second through fourth demonstrated some iatrochemical knowledge of saltpeter's possibly harmful qualities as well as its medical uses. Saltpeter's multifarious chemical qualities as well as its equally destructive and beneficial uses characterized the approach toward it that vitalist alchemists like Johan Rudolf Glauber and Benjamin Worsley would take in the seventeenth century.[97]

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[94] On the various terms used for this concept, see Debus, *Chemical Philosophy*, esp. 87-8, 107-9, 220-24, 231-36, 494-99, and 530-45.

[95] Paracelsus, *Of Chymical Transmutation, Genealogy and Generation of Metals & Minerals. Also of the Urim and Thummim of the Jews. With an Appendix of the Vertues and Use of an excellent Water made by Dr. Trigg. The second part of the Mumnial Treatise. Whereunto is added Philosophical and Chymnical Experiments of that famous Philosopher Raymund Lully* (London, 1657), 121-2. For an integration of these theories into prevailing notions of saltpeter at the time, see also Allen G. Debus, "Paracelsian Aerial Nitre," *Isis* Vol. 55, No. 1 (1964): 46.

[96] Paracelsus, *Liber azoth* in *Opera* (1616), Vol. 2, 525. For a fuller explanation of Paracelsus's interpretation of saltpeter, see Debus, "Paracelsian Aerial Nitre," 46, and idem., *Chemical Philosophy,* 109 and 109 n.103.

[97] For more on Paracelsus's concept of salts, and the influence that this had in the late sixteenth and early seventeenth centuries, see Anna Marie Roos, *The Salt of the Earth: Natural Philosophy, Chemistry, and Medicine in England, 1650-1750* (Boston: Brill, 2007), 10-46.

The only other direct mention of aerial niter in the context of alchemy, chemical philosophy, or matter theory between Paracelsus's death in 1541 and the early 1590s comes in Blaise de Vigenère's *Discourse of Fire and Salt…*, which was not published until 1608. De Vigenère—a contemporary of Sendivogius with a nearly identical chemical philosophy of salts—maintained a notion of the chemical composition of everyday matter similar to Paracelsus's in that he saw alchemical change in the laboratory as a pale reflection of the chemical changes observed in nature and ultimately wrought by God. Like Paracelsus, De Vigenère stressed the difference between humanity's knowledge of these changes before and after the Fall as well as the different effects aerial niter had on people's "natural" and "spiritual" bodies.[98] Regarding saltpeter and the aerial niter, De Vigenère wrote that saltpeter is "…full of aire and winde…," noting that

> Saltpeter is appropriated to the Aire; because it is of a meane disposition of nature, betwixt Sea water and the Fire, or Sulphur, whereof it participates, for that it is so inflamable, and saltish, on the other side, resolving it selfe into moisture, and water, as the Salts do; from whence it hath bitternesse and acuity; and as the inclined and retained aire, within the clouds, doth breake and lighten by the impetuosity of Thunder, the same doth Saltpeter.[99]

That is, saltpeter had both a sulfurous and saline nature, the former because it ignited, the latter because it dissolved in water. The nature and properties of saltpeter, still little understood, clearly remained an important facet of the second and third generation Paracelsians as they attempted to understand chemical change and the search for a vital seat of life in inert matter.

As Allen Debus has demonstrated, a number of Paracelsian-inspired vitalistic

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[98] Debus, "Paracelsian Aerial Nitre," 49.
[99] Blaise de Vigenère, *Discourse of Fire and Salt, Discovering Many Secrets as Well Philosophicall and Theologicall*, trans. Edward Stephens (London, 1649), 41. This quote comes from the first English translation in 1649. The original French edition was published in Paris in 1608, though the work was likely written in the 1590s. See Blaise de Vigenère, *Traicté du feu et du sel* (Paris, 1608).

theories coalesced around the turn of the seventeenth century, and this point seems to be supported by the works of the next generation of matter theorists, including Sendivogius. Another example is the French alchemist Joseph Duchesne, who often published under his Latinized name Josephus Quercetanus.[100] Duchesne emphasized both Paracelsus's general chymical approach to understanding all matter and his *tria prima* of salt, sulfur, and mercury, which he sought observationally in his own chymical experiments. The Neoplatonic influence of the microcosm-macrocosm analogy—in which the larger cosmos had parallels in world of humans—led him to the chemical understanding that "the soule of the body and the world are knit together by meanes of the Aetherial Spirits going betweene, joyning each part to the whole into one substance."[101] These so-called "Aetherial Spirits" were "vital forces," which, in connection with "Astrall seeds" found in all matter, provided evidence for the existence of philosophical mercury, sulfur, and salts in everything, as manifest most prominently in the physical substances bearing those names.[102] Like Sendivogius, Duchesne raised salt to the highest prominence among the triumvirate and emphasized the importance of saltpeter for vegetation.

Salt, and in particular saltpeter, was directly involved in the generation and growth of life. According to Duchesne, given the proper light and heat, saltpeter became aerial. Is it possible, he asked, that "these dewes arysing from the earth, and falling againe from the aire, [are] a cause of vegetation and growing?"[103] He answered that

> the dewe is the spirit of the foresaid Salt, and [imbued] with Salt, they which thinke themselves great Philosophers, against their wits and not without shame, do

[100] See, for instance, Debus, *Chemical* Philosophy, esp. 145-294. For England more specifically, see Debus, *The English Paracelsians*, esp. 86-136.
[101] Josephus Quercetanus [Joseph Duchesne], *The Practise of Chymicall, and Hermeticall Physicke, for the preservation of Health,* trans. Thomas Tymme, Minister (London, 1605), sig. B4*r*.
[102] Ibid., sig. G2*v*.
[103] Ibid., sig. O4*r.*

> confesse, when they see that the true Phylosophers doe extract out of the deawe a Salt, which dissolveth corall and pearles, no lesse then doth the Salt which is extracted out of common Salt, out of Salt-Peeter, out of Niter, or out of other Salts which are prepared for the same end.[104]

Just as all matter could be ultimately divided into three in the Paracelsian scheme, Duchesne argued that salt could be divided into three natures: the animal, the vegetable, and the mineral. Each of these in turn had sulfurous, mercurial, and saline manifestations, dependent upon how they behaved and where they could be found. This differed slightly from Sendivogius, who simply thought of saltpeter as the mature philosophical mercury that interacted with philosophical sulfur in the soil and air to produce its vital effects. Duchesne simply made all of these qualities intrinsic to the aerial niter.[105] The sulfurous part accounted for the "first mooving of nature" in animals, where it was "the hote and moyst radical: the true Nectar of life."[106] In plants, it was "a fyre…contempered, ful of life, which in Vegetables, wee cal the vegetating soule."[107] Saltpeter also contained a mercurial part that was "ayerie [in] nature, and which notwithstanding cannot take fyre, but is rather contrary thereunto…the which sowernesse is the general cause of Fermentation, and coagulation of al natural things."[108] As the *sal nitrum* school developed, adherents evoked the former aspect to explain saltpeter's combustible properties, while the latter was used to describe its fertilizing properties. This notion that saltpeter animated matter differently in different substances, and that it exhibited sulfurous, mercurial, and saline characteristics

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[104] Ibid.
[105] On these differences, see Debus, "Paracelsian Aerial Nitre," 56; and Henry Guerlac, "John Mayow and the Aerial Nitre: Studies in the Chemistry of John Mayow," *Actes du Septieme Congres International d'Histoire des Sciences* (Jerusalem, 1953), 339-41.
[106] Joseph Quercetanus [Joseph Duchesne], *Liber de priscorum philosophorum verae medicinae material….* (n.p.: S. Gervasii, 1603), 20, quoted in Debus, "Paracelsian Aerial Nitre," 54. The translation is Debus's.
[107] Ibid.
[108] Ibid.

that could be harnessed through chymical experimentation for practical endeavors is key to understanding how later members of the Hartlib Circle used this knowledge.

Unlike in Geberian alchemy or *chrysopoeian* alchemy more generally, followers of the *sal nitrum* school sought the key to understanding the sources of plant, animal, and mineral growth rather than the creation of the philosopher's stone or the transmutation of base metals into gold. They pursued the answer to the origins of metals and how to chymically manipulate them not in philosophical mercury, sulfur, or any unalloyed, base metal, but in a universal principle found in salts. Saltpeter's voluminous physical properties made it epecially attractive to those who held that the processes of growth and physical change could be directed and enhanced.[109] Sendivogius had written that those who strove "to produce a highly rarefied metallic substance by the vain solution and mixture of different metals" did so in folly. The secret to metallic multiplication lay in their seeds:

> What prerogative should all things in this world have before metals? Why should these alone by having seed without cause denied to them, be excluded from God's Universal blessing of multiplication, which holy writ affirms was put in, and bestowed on all created things presently on for the world was made. Now if they have seed, who is so sottish to think that they cannot bee multiplied in their seed?[110]

Also, unlike the alchemy of Geber and later of prominent practitioners like George Starkey and Isaac Newton, the *sal nitrum* school relied less on the highly technical operational alchemy most at home in the laboratory, even as it too developed its own experimental regime. There was a high degree of overlap among the followers of the school who worked in laboratory settings and other locations like fields, farms, and gardens. Among those laboring in these latter locations, the abstract notion of the vital principle and the importance of everyday substances like soil, water, manure, plant matter, and naturally

[109] Newman, *Alchemy Tried in the Fire*, 238
[110] Sendivogius, *New Light of Alchymie*, 37.

occurring chemicals used in agriculture, readily lent itself to common applications among agricultural reformers. Even among those who confined their studies to the laboratory, many of these everyday items were mentioned as potential starting points in recipes for the philosopher's stone.

One can see the potential botanical applications of these theories and Sendivogius's adaptation of Paracelsus's "sexualized organic cosmology" in letters he wrote while in Brussels in 1616 to a Rosicrucian secret society based somewhere in France.[111] In one letter, he described the sexuality of plants as necessarily different from that of animals and humans, both of whom had been given "a locomotive faculty by virtue of which they can come together and discharge their office."[112] Since neither plants nor minerals were capable of movement, God had endowed the world with intrinsic, seminal possibilities that did not require locomotion. For plants and minerals, "because the species of these families do want the same locomotive faculty, so that they cannot come, per se, together and copulate...God have given them one common Wife," which he called "our Spiritus Universalis."[113] Nature, Sendivogius suggested, could not always be expected to carry this

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[111] These letters, usually referred to in English as *The Philosophical Letters of Michael Sendivogius*, were published in Latin, French, and German, but there appear to be no published English versions from the seventeenth century. For the posthumous French edition, see Micahel Sendivogius, *Traitez du Cosmopolite nouvellement decouverts ou apres avoir donne unde idee d'une Societe de Philosophes, on explique dans plesieurs Lettres de cet Autheur la Theorie & la Pratique des Veritez Hermetiques* (Paris, 1691). The usual Latin title for the collective letters is *Apographum Epistolarum Michaelis Sendivogii seu J.J.D.J. Cosmopolitae vulgo dicti*. An abridged Latin version can be found in BL, MS Sloane 1724, ff. 1-36. These letters can be found in English in at least two separate manuscript sources: BL, MS Sloane 1800, ff. 1-111 and GUL, MS Ferguson 25, ff. 1-111. MS Sloane 1800 refers to these letters as English translations addressed to an unknown companion of "the new society of unknown Philosophers of Cabala" ("*novo Cabalae Philosophorum incognorum dignissimo sodali*"), while MS Ferguson 25 explicitly refers to the society as "the Rosey Crucian Society." The noted eighteenth-century collector of occult artifacts, Ebenezer Sibly, who came into their possession in 1791, translated these letters. For more on them, see Rafał T. Prinke, "Michael Sendivogius and the Christian Rosenkreutz: The Unexpected Possibilities," *The Hermetic Journal* (1990): 72-98, last accessed 27 July 2018, http://www.levity.com/alchemy/sendi.html#r35.

[112] Michael Sendivogius to M.S. [?], 21 June 1646 (1616?), GUL, Ferguson MS 25, f. 36. It is unclear why a later date is listed for these letters in this translation.

[113] Ibid.

out in the manner or quantity that alchemists or husbandmen might require. People and animals, he wrote, "copulate spontaneously by the impulse of Archeus without any other Artificial Industry, natural appetite being given them for that Purpose," whereas plants "permit the Seed of their ripe Fruits to fall into their everywhere, meeting Wife yet they do require Arts assistance to act well and surely."[114] What was agriculture if not art assisting nature for the benefit of humanity? While natural processes were preferable to human intervention, sometimes obtaining the desired results required artifice, which was precisely the attitude taken by projectors and reformers in seventeenth century England.

Interest in *sal nitrum* theorists, and especially Sendivogius, De Nuysement, and De Vigenère, remained high well into the seventeenth century. Numerous manuscripts from this time contain handwritten copies and commentaries of various translations of their works.[115] One anonymous, unpublished introduction to Sendivogius's *New Light of Alchymie* reads that "here unto a more noble and a better subiect [the reader] would not finde than…[the alchemical creation of] gold nor a more worthy or a more usefull arte than the Hermeticall fire…among all the treasures under the sunne."[116] Given the content of *New Light of Alchymie*, the implication was that to understand how to make gold, one first had to master Sendivogius's theories. Short tracts and excerpts from longer texts were often extracted and bound together in makeshift compilations of important alchemical works.[117]

[114] Ibid., f. 37.
[115] For abridgements of Sendivogius's *Novem lumen chemicum*, see, for instance, BL, MS Sloane 2175 ff. 96-113; Wellcome Library, MS 185, ff. 3-29. For commentaries on it, see GUL, MSS Ferguson 45 and 99, ff. 131-166*r*, along with hand-inked images on ff. 166*r*-167*v*. These were also published in Lazarus Zetner, ed., *Theatrum Chemicum*, Vol. 4 (Oberursel and Strasbourg, 1661), 397, and J.J. Manget, *Bibliotheca chemica curiosa* (Geneva, 1702), Vol. 2, 516.
[116] BL, MS Sloane 2175 ff. 96-7.
[117] For a comparison of Sendivogius and de Nuysement, see Wellcome Library, MS 3699. At least one manuscript copy of a possible English version of de Nuysement's *Traitté du Vrai Sel* exists before its

Handwritten portions of De Nuysement's *Traité du Vrai sel* were often compiled with Sendivogius's work, and Sendivogius regularly appears alongside discourses on the *tria prima* by Paracelsus and Van Helmont as well as alchemical recipes by figures like Basil Valentine, Roger Bacon, and George Ripley.[118]

The* Sal Nitrum *School in the Hartlib Circle

Members of the Hartlib Circle—especially those hoping to spearhead artificial saltpeter projects or foster a new nitrous-based fertilizer regime—made numerous references to *sal nitrum* theorists, and in particular the triad of Sendivogius, de Nuysement, and de Vigenère. For example, Henry Appelius, John Dury's brother-in-law and a physician with a professed interest in the activities of the alchemist Johan Rudolf Glauber, wrote to Hartlib in 1647 that he thought those who had "skill in Chymicall and Alchemysticall matters" would be best suited to judge whether or not Glauber had the capacity to "demonstrate *Artem transmutarium* [the art of transmutation]," and he cited Sendivogius as one such arbiter.[119] In notes on one of Worsley's discourses, Sir Cheney Culpeper tallied a list of questions that an alchemist should keep in mind when "putrefying Mettals," including whether by putrefaction one "meant the Philosophical Work" or the physical operations in "all of [Nature's] Metalline and Mineral productions."[120] Among these

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translated publication. See BL, MS Sloane 1720. The English edition was published in 1675, and it is unknown whether this manuscript predates that.

118 GUL, MS Ferguson 18, ff. 101-161. Versions by de Nuysement or about his work also appeared in verse, for example, in GUL, MS Ferguson 1 ff. 17-19; Oxford University, Bodleian Library (hereafter Bodl.), MS Ashmole 1446 ff. 1*a*-116; and BL, MS Sloane 690, ff. 43-68 and BL, MS Sloane 3681.

119 Henry Appelius to Hartlib, 26 August 1647, HP 45/1/33B. Sendivogius had written "*qui scit in* ☉ [symbol for gold] *convertere aliud metallum sive cum lucro, sive sine lucro, januam habet apertam in Naturam.*" ["He who can transmute some metal into gold, with or without gain, has opened the door into Nature."] For more on Appelius, see Young, *Faith, Medical Alchemy, and Natural Philosophy*, 187-193 and 198-202.

120 Cheney Culpeper, Notes on Worsley's Discourse in Hartlib's Hand, 10 July 1654, HP 39/2/14A.

questions, Culpeper asked, referring to the works of Sendivogius, whether "there is a real vegetative Life in Mettals equal to that in other Bodies…wherein this life principally consists…how to actuate this life, and how to make it a more living life," and whether this pertained not to particular lives but to a vital activator "that ought bee in Metals and Minerals as in other Bodies and Seeds."[121] He went on to agree with Sendivogius's assessment that atmospheric waters contained within them the *spiritus vitalis* that had been revitalized by the sun and that these accounted for growth.[122] In an anonymous tract in Hartlib's possession on "a question concerning fertility," the author placed Sendivogius alongside Aristotle, Van Helmont, Descartes, Digby, and Glauber as the foremost authorities on the question of whether "spermatic vapors [rose] from the center of the earth…or [came] from heavenly influence," whether "water was impregnated" by some vital seed, or whether the earth had "infinite strength" or the "infinite power of the prolific, fiery *semina*, whose wealth shall never be exhausted."[123] The diverse opinions of each of these figures showed that these were difficult questions to resolve.

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[121] Ibid., 15A.

[122] Ibid. In this, he was arguing against an unnamed philosopher who put the activating power in fire. He quoted Sendivogius as saying "*Ignis est quietissimum Elementum nec movet nisi excitetur.*" ["The element of fire is the quietest and does not move unless it is awakened."]

[123] Anonymous, "A Question Concerning Fertility," [*Quæstio de fertilitate Omnibus Naturæ serutatoribus indefessis proposita*], undated, HP 30/5/16A. The original Latin for this section reads: "*An per spermaticum vaporosum fumum, à Centro terræ ascendentem; an per Coeli influentias, an verò per solam Aquam imprægnatam, corruptam seu fermentatum* [altered from *fermentatam*]*? tandem an terra, ratione divinæ benedictionis, contineat infinitam virtutem, igneamseminalem, et prolificam, cujus Thesaursus nunquam exhauriri possit? Profectò Multiplicitas Opinionum doctissimorum Philosophorum (videlicet Aristotelis, Rupescissce. Sendivogij, Nortonij, Cartesij, Helmontij, Digbij, White, Glauberi) hanc quæstionem ~~et~~ concernentium, ostendit difficultatem Resolutionis.*" This tract closely resembles one section of Richard Weston's *Observations and animadversions upon the foregoing secrets or experiments: Written by the author of the large letter in the legacy of husbandry*, later published in Samuel Hartlib, *A discoverie for division of setting out of land....* (London: Printed for Richard Wodenothe, 1653), 16. The fact that this tract is undated makes it difficult to discern whether this was perhaps an early draft of the later English work or if it is a later Latin copy of that particular passage. See below, pages 174-5.

In his *Ephemeris* (collectively known as his *Ephemerides*)—a journal containing Hartlib's notes, recipes, ruminations, and memoranda on a number of scientific, philosophical, and technical subjects, which he kept annually from 1635 until 1660—he wrote approvingly of De Vigenère and Sendivogius and of efforts to put their theories to practical use.[124] In one of his 1648 *Ephemerides*, Hartlib wrote of the "many…admirable Optical and other Natural Experiments" recounted in the published works of De Vigenère and the "very hard to come by" unpublished manuscripts of which he had become aware that described new methods for making "gold and glasse," which were to be "much sought after."[125] According to an *Ephemeris* from the following year, Culpeper had come to possess both of these, one of which contained a recipe to make Van Helmont's alkahest.[126] In his notebook from April 1651, Hartlib noted that he had come to possess Sendivogius's *Novum lumen chemicum*—he may have been referring to John French's translation, which had just been published the previous year.[127] Demonstrating his evolution on the topic of the sources of fertility and the causes of generation, growth, and procreation, in notes on Cheney Culpeper's comments on "chemicals" and "fermentation" Hartlib quoted Sendivogius as saying that "movement causes heat and heat moves water," but questioned his axioms by asking "what causes movement?"[128] Admitting ignorance, Hartlib lamented that no one knew the answer and called "fermentation w*hi*ch doth specifie and multiply"

[124] For a fairly thorough rundown of the contents and nature of Hartlib's *Ephemerides*, see Stephen Clucas, "Samuel Hartlib's *Ephemerides*, 1639-1659, and the Pursuit of Scientific and Philosophical Manuscripts: The Religious Ethos of an Intelligencer," *The Seventeenth Century Journal* Vol. 6 (1991): 33-55; and Mark Greengrass, "An 'Intelligencer's Workshop': Samuel Hartlib's *Ephemerides*," *Studia Comeniana et Historica* Vol. 26 (1996): 48-62.
[125] Hartlib, *Ephemeris*, Part 2, June – July 1648, HP 31/22/26B.
[126] Hartlib, *Ephemeris*, Part 2, April – August 1649, HP 28/1/20B-21A.
[127] Hartlib, *Ephemeris*, Part 1, c. April 1651, HP 28/2/24A.
[128] Hartlib, *Ephemeris*, Part 1, January 1 – March 1, 1653, HP 28/2/52A. These sections were labeled "*Chymica*," "*Fermentatio*," and "*Sir Cheney Culpeper*."

the "Mystery of all mysteries."[129] In this context, by fermentation—a multivalent term with intersecting but subtly different meanings in alchemical, agricultural, and gastronomic contexts—Hartlib meant the natural processes that caused growth in plants, animals, and minerals.

In letters from Culpeper to Worsley, the text of which is likely the commentary on which Hartlib remarked, Culpeper compared the writings of Sendivogius and those of De Nuysement, a close follower of Sendivogius and one of the principal advocates of the *sal nitrum* school. Culpeper asked Worsley a series of questions, hoping to resolve the source of what seemed to be the perpetual and cyclical motion of the "exilation of *th*e Spirit of Nature againe and againe."[130] He recounted the familiar series of physical reactions from Sendivogius, in which movement created heat and heat moved water, but added that the movement of water generated air, and air contained the energizing material of all life.[131] Culpeper continued, "but were the question now asked what does *causare motum* [cause motion]; In this po[in]te are the philosophers very Sparinge."[132] He related the opinions of several natural philosophers, one of whom was the unnamed author of "*Traitte de Sel*," presumably meaning *Traité du Vrai sel* (*Treatise of the True Salt*) by De Nuysement, who had called the cause "Faeces," which in an alchemical context usually meant a residue left behind after a purification process such as distillation or sublimation.[133] Essentially,

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[129] Ibid.
[130] Culpeper to Worsley, undated [likely 1648/9], HP 13/223A.
[131] Ibid. The original Latin reads: *"…motus generat calorem, Calur movet* [altered from *mouet*?] *aquam Aquæ motus causat aerem Aer est omnium viventium vita."* Though he does not mention it by name, it appears that Culpeper meant a *spiritus vitalis* associated with the *sal nitrum* or saltpeter more generally.
[132] Ibid.
[133] Ibid. On the meaning of "faeces" or "feces" in an alchemical context, see William R. Newman, "Alchemical Glossary," last accessed 13 July 2018, http://webapp1.dlib.indiana.edu/newton/reference/glossary.do, derived in part from George Starkey, *Alchemical Laboratory Notes and Correspondence*, edited by William R. Newman and Lawrence M. Principe (Chicago: University of Chicago Press, 2004).

Culpeper suggested that the atmosphere was like a giant, natural alembic that had distilled the vaporous aerial niter, causing the *sperma* to return to "heat" or animate the water in some way, beginning the process that explained vegetative growth in all materials. In any case, study of the various *sal nitrum* theorists, their commentators, and their critics offered the best opportunity to understand these activities.

Many of these works were also well represented in Benjamin Worsley's *Catalogus*, the list of works in his library at his death. In this compilation we find listed three works by Paracelsus, several chymical and alchemical texts by Peter Severinus, Joseph Duchesne, Jean Beguin, Angelo Sala, and Johann Hartprecht, as well as the explicitly Sendivogian works, the *Traité du Vrai sel* by Clovis Hesteau, Sieur de Nuysement and the *Traicté du Feu et du Sel* (*Tract on Fire and Salt*) by Blaise de Vigenère, both of which had been translated into English in the mid seventeenth century.[134] Worsley was in turns deferential to and critical of these sources. More importantly, his engagement with them in letters and unpublished manuscripts establishes how thorough he tried to make his study of saltpeter.

Writing to an unknown recipient, for instance, Worsley commended the theories of Paracelsus, whom he called a "clear & Rationall man," but cautioned against blindly following his recipes or trusting his word on the records of his experiments, because he seemed "intoxicated now & then partly with *th*e sight of his owne knowledge, & partly through *th*e extraordinary opposition & reproach he [was] mett w*i*th."[135] Rather, he suggested other alchemical writers as clearer, more dependable, and less pompous, including earlier figures like Roger Bacon, Ramon Llull, and Nicolas Flammel as well as

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[134] For more information on Worsley's *Catalogus*, see Leng, *Benjamin Worsley*, 97; and Clericuzio, *Elements, Principles, and Corpuscles*, 35-47.
[135] Worsley to [?], 14 February 1655/6, HP 42/1/5A-6B.

contemporary ones like his own erstwhile correspondent Johan Moriaen, and Sendivogius, who had "writt much better."[136]

Worsley also saw in Sendivogius a way to recreate natural processes of transformation artificially. In *New Light of Alchymie*, Sendivogius had suggested that the seminal qualities of the *sperma* existed not just in physical materials that could grow, like metals and plants, but in "the Elixir of everything or quintessence or the most perfect decoction or digestion," which was produced flawlessly by Nature and which the adept alchemist could learn to replicate.[137] In fact, Worsley seemed to think that this was the ultimate task of the saltpeter projects. "For as mutch as in all mineralls and metals there is a participation of the same lyfe," he wrote in a letter, probably to Clodius,

> blessing vegitatiue and multiplicatiue virtue, as was given in the creation of two plants and other seed-bearing boddyes by reason the said vigitatiue virtue or spirritt is to *th*e outward sense imprisoned and not to bee diserned vntill brought forth in or by this Mercuriall substance hence the same substance before cald water is cal'd a Sperma or *Anima cuiuslibet Mettali* [a soul which pertains to a metal].[138]

Like Sendivogius, Worsley denied that philosophical mercury was to be identified with physical mercury, and instead argued that it was equivalent to what Aristotle had called *prima materia* and what Worsley accepted as the "basic ingredient of metals in general."[139] To dissolve matter and isolate this substance required putrefaction, which, while destroying the starting material, would "animate...the substance's spirit."[140] Using the metaphor of opening the door to a prison, Worsley claimed that putrefaction would make "manifest...the vertue & life" which had before been shut and would release the life energy

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[136] Ibid.
[137] Sendivogius, *New Light of Alchymy*, 6. For Worsley's use of these ideas, see Leng, *Benjamin Worsley*, 100.
[138] Worsley to ?Clodius, c. summer 1654, HP 42/1/26A.
[139] On this interpretation of Aristotle's *prima materia* and theory about the composition of metals, see Newman, *Gehennical Fire*, xiii.
[140] Worsley to ?Clodius, c. summer 1654, HP 42/1/27A.

within.[141] Attempting this process with saltpeter, first in the laboratory and then in the field, animated his professional life for much of the 1640s and 1650s.

Conclusions

The chymical knowledge and economic status of saltpeter continued to change in the early seventeenth century. By the time James I took the throne in 1603, enough of the previous international tensions with the Spanish had subsided and the domestic reserves were at a high enough level that the crown consented to the sale of saltpeter on the international market again. This coincided with attempts by the government to restrain the excesses of saltpetermen and limit their authority. However, these restrictions were short-lived, and the outbreak of the Thirty Years' War in 1618 once again made the demand for saltpeter rise steeply, after which all forms of production accelerated.[142]

Perhaps more importantly, the English East India Company (EIC), chartered in 1600, began importing saltpeter in small quantities during James I's reign. This proved extremely profitable. Once supply lines and refineries were secured in India, saltpeter became a major commodity traded by the EIC, which became an essential supplier leading up the English Civil Wars. Throughout the three and a half decades of the Thirty Years' War and the English Civil Wars, all methods of saltpeter procurement continued. During the Interregnum, however, due to the mounting dominance of the EIC, major saltpeter projects began to exhibit new characteristics and explore new dimensions of its properties and uses. While gunpowder production remained their overriding mission, projectors,

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[141] Worsley to Hartlib, c. autumn 1654, HP42/1/38B. For more on the Sendivogian influence on Worsley in particular, see Leng, *Benjamin Worsley*, 95-102.
[142] For a brief overview of these events, see Cressy, *Saltpeter*, 76-87.

agricultural and social reformers, and common alchemists all saw these as opportunities to apply saltpeter to other equally important undertakings—the production of artificial agricultural fertilizers, the creation of chymical medicines, the enhancement of vegetable nutrition, and the employment of the poor in these duties. In mid-seventeenth-century England, the Hartlib Circle, led largely by the labors of Benjamin Worsley, became the driving force behind these efforts.

CHAPTER 2

"RUSTICALL CHYMISTRY": BENJAMIN WORSLEY, HARTLIB CIRCLE SALTPETER PROJECTS, AND THE SEARCH FOR ARTIFICIAL FERTILIZERS

"And that is was a great pity, so it was,
That villainous saltpeter should be digg'd
Out of the bowels of the harmless earth,
Which many a good tall fellow had destroyed
So cowardly; and, but for those vile guns,
He would himself have been a soldier."

--William Shakespeare, *Henry IV Part I*, Act I, Scene iii

Introduction

In his final, extended discourse on saltpeter in 1654, Benjamin Worsley recommended to Samuel Hartlib the work of "a Captaine of the Army," described as "a Kinde of ingineer," who after "hearing much complaint for want of [gun]Powder," made a proposal to the Lord General and commissioners in Ireland for the "artificial breeding and increasing" of saltpeter. He claimed to be able to accomplish this "without any Vrine or Dung or the like," which were typical starting points for saltpeter manufacture.[1] Along with an unnamed Auditor General of the Army, the commission called upon Worsley's expertise in the subject to determine its feasibility. With over a decade of experience with saltpeter projects, Hartlib, the central hub of a sprawling correspondence network of intelligencers, counted Worsley as his foremost expert on the subject, and he regularly requested from Worsley any and all information on the production of saltpeter. His great

[1] Copy Extract in Scribal Hand ?, Worsley to Hartlib, 16 May 1654, HP 66/15/1A.

hope was the eventual discovery of an alchemical recipe to create it, like the army captain was promising, without the use of animal feces and urine.

By the mid-1650s, Worsley had gained experience in the alchemical study of saltpeter through textual scholarship, laboratory practice, and work in the fields of farms in England and Ireland. Although the making of saltpeter for gunpowder remained a priority, Worsley and many members of Hartlib's correspondence network considered themselves utopian social reformers, and they became much more interested in its agricultural capacities. Worsley believed he could demonstrate that the vital seat of life itself inhered in saltpeter and that through a material knowledge of its chymistry, he and his associates could irrevocably alter agriculture, medicine, the plight of the poor and hungry, and the knowledge of human nutrition. Though he had considerable training in alchemical pursuits, Worsley committed himself to the cause of agricultural improvement, writing to Hartlib that this was

> the point of Husbandry. In the ignorance of any of which I thinke a man knowes satisfactorily very little. They are rudely…sett downe, but may afford ground of larger discourses. If you shall please eyther to cherish or excite this humor in me by laying or propounding of something further for promoting of vegetation upon these comprehensive grounds, I shall not refuse to deale very freely with you…[2]

In his report on the army captain, Worsley heartily approved of his methods, but claimed his request of a £1000 loan to accomplish it was far too high. After he offered to spearhead the project for £250, the commissioners immediately consented.[3]

This project was to be Worsley's last in a series of increasingly elaborate endeavors to apply cutting-edge chymical knowledge to the reformation of agricultural productivity

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[2] Ibid., 4B.

[3] "Commonwealth State Accounts, 1653-56," in *Analecta Hibernia,* ed. E. MacLysaght (Dublin, 1944), 249, quoted in Leng, *Benjamin Worlsey*, 95.

and the improvement of soil fertility via saltpeter, and it represented the pinnacle of these types of projects that flourished in the 1640s and 1650s. They began as small-scale, local, practical trials to enhance long-tested, traditional methods at making saltpeter. They eventually morphed into much larger state-, military-, and nobility-sponsored collaborations (and usually boondoggles) that combined manual agricultural labor and mineralogical engineering with alchemical experimentation, as well as a desire to apply the material knowledge gained within the context of deeply complex and contested early modern chemical philosophies.

For the Hartlib Circle in the 1640s and 1650s, saltpeter appeared to be the most promising material substance to probe for the secret of botanical growth and the prospect for chymical agricultural improvement. But unlike many of the Paracelsian and Helmontian chemical writings of the previous century, their approach was neither abstract, text-based theory nor the applied, experimentalism of the laboratory. Rather, it was what might be called "field work"—both literally and figuratively—in that the work was done primarily through applied "projects," in the economic, reformative, and scientific sense of that word, and much of it occurred in agricultural settings.[4] This resembles what some scholars of science studies have referred to as a "living laboratory," in which many of the most important scientific activities took place neither in the laboratory nor in the pages of books

[4] By "projects," I mean coordinated money-making ventures into which the wealthy could invest and from which the poor could expect to gain employment. These could be anything from the development of cottage industries—such as button-making or wool production—into large-scale enterprises or colonial plantations to alchemical projects with the objective of turning manure into fuel. For the origins of the term and concept, see Daniel Defoe, *An Essay Concerning Projects* (London, 1697). For the classic, modern study on projects and "projectors" in England, see Joan Thirsk, *Economic Policy and Projects: The Development of Consumer Society in Early Modern England* (Oxford, UK: Clarendon Press, 1979). For a more recent reevaluation of projects, see Maximillian E. Novak, ed., *The Age of Projects* (Toronto: University of Toronto Press, 2008). For a critique of the role of projectors in mid-seventeenth-century England in general, and among the Hartlib Circle in particular, see Koji Yamamoto, "Piety, Profit, and Public Service in the Early Financial Revolution," *English Historical Review,* Vol. 126, No. 521 (2011), 806-834; and idem., "Reformation and the Distrust of the Projector in the Hartlib Circle," *Historical Journal,* Vol. 55, No. 2 (2012), 375-397.

but in the field.[5] Like the saltpeter boilers of the sixteenth and early seventeenth centuries—but with a more conscious and perspicuous combination of knowledge drawn from textual, experimental, and artisanal sources—the members of the Hartlib Circle engaged in practical projects deeply informed by current chemical philosophy.

Crucially, the chemical philosophy underlying both laboratory work and fieldwork was the same. Many times, the same individuals conducted both types of work, and agricultural reformers regularly shared experimental results with alchemists and vice versa, particularly when material substances, like saltpeter, were involved in both. There was intellectual content to this sort of agricultural labor that was neither simply reacting to environmental conditions nor blindly following husbandry manuals but rather complex problem-solving that deployed the most current information, much of it alchemical. It also included realistic aspirations to understand fertility and the multiplication of mineral and vegetable matter in nature. In this post-Baconian world, practice and theory fused and combined with an urgent interest in economic, social, and spiritual reform through the

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[5] It is difficult to trace the terminological origins of this concept. One starting point is Bruno Latour's description of Louis Pasteur's "laboratory" on the farm at Pouilly-le-Fort, where his anthrax vaccine was first tested on sheep, goats, and cows in 1881. See Bruno Latour, "Give Me a Laboratory and I Will Raise the World," in *Science Observed: Perspectives on the Social Study of Science*, ed. Karen Knorr-Cetina and Michael Mulkay (London: Sage Publishing, 1983), 141-70, esp. 144-49; and idem., *The Pateurization of France*, trans. by Alan Sheridan and John Law (Cambridge: Harvard University Press, 1988), 87-9. For the notion of a historical "living laboratory" and the application of this concept in science studies, see for example, Helen Tilley, *Africa as a Living Laboratory: Empire, Development, and the Problem of Scientific Knowledge, 1870-1950* (Chicago: University of Chicago Press, 2011); Rom Harré, *Pavlov's Dog and Schrödinger's Cat: Scenes from the Living Laboratory* (Oxford: Oxford University Press, 2010)—though the metaphor is interpreted differently in this work—Rebekah Lemov, *World as Laboratory: Mice, Men, and Mazes* (New York: Hill and Wang, 2005); Robert E. Kohler, *Landscapes and Labscapes: Exploring the Lab-Field Border in Biology* (Chicago: University of Chicago, 2002); and Amelia M. Moore, "Life in the Living Laboratory: An Anthropological Investigation of Environmental Science, Tourism, and Design in the Contemporary Bahamas," Unpublished PhD dissertation, University of California, Berkeley, 2010, last accessed 27 January 2016, http://digitalassets.lib.berkeley.edu/etd/ucb/text/Moore_berkeley_0028E_10610.pdf. To my knowledge, there has been no explicit use of the "living laboratory" concept in the study of seventeenth-century European scientific practice, with the possible exception of Fabrizio Baldassarri, "Manipulating Flora. Gardens as Laboratories in Renaissance and Early Modern Europe," *Rivisita de Storia della Filosofia,* Vol. 72, No. 1 (2017): 175-78, though I believe the metaphor is applicable, especially for non-laboratory-based alchemical studies.

application of the basic premises of alchemy to create economic and ecological conditions that would eradicate the need for war, the existence of hunger, and the fear of crop failure, and presage a future era of abundance. Understanding vitalist alchemy, chymical agricultural improvement, and the practical projects that they influenced is paramount to understanding this reform movement.

Following from the previous chapter, this chapter extends the investigation of early saltpeter projects into the seventeenth century, as undertaken primarily by the Hartlib Circle between the late 1630s and the early 1660s. These projects, though originally motivated by a desire to supply Commonwealth forces with ample supplies of gunpowder, morphed into attempts to create artificial fertilizers, particularly during the Interregnum. Focusing, in large part, on the efforts of Benjamin Worsley to undergird these endeavors with up-to-date chemical philosophy and the most recent alchemical techniques, I track the multifarious nature of these projects, which sought not only to create artificial fertilizers for the purposes of agricultural improvement, but also to provide poor relief, to capitalize on new domestic and international markets, to contribute to social reform, and to seek the vital seat of life via alchemical means. The last section of the chapter will take these issues past the Interregnum into the 1660s through 1680s, as domestic saltpeter projects collapsed due to the large, relatively inexpensive influx of saltpeter from the East India Company. Following this, interest in the chemical philosophy of saltpeter became largely speculative and more concerned with its medicinal and agricultural properties, particularly within the institutional context of the Royal Society and the Royal College of Physicians. There was also an increase in the attention paid to desalination attempts, and I examine some of the ways that these earlier projects influenced these new trials.

Benjamin Worsley, Johan Rudolf Glauber, and Salts in the Field and Laboratory

Why did Hartlib and his associates land on the idea of "growing" their own saltpeter? One reason was cost. Hartlib noted the prohibitive expense of purchasing saltpeter on the open market on several occasions, and he suggested that members of his circle could produce it domestically for a fraction of the cost. Another reason was the lack of a reliable supply. The volatility of international relations made domestic production far preferable. In notes from May of 1653, for example, he wrote of a former supplier from Wallachia that charged "an excessive rate" and lamented that there was "none comming from any place besides that, soe that now there is like to come none this year."[6] Yet another reason, due to the Hartlibian's interest in social and political reform, was poor relief, ideally in which the destitute would act as both suppliers and refiners of saltpeter. In principle, these plans entailed constructing workhouses in which the poor would live, containing large vaults below for the collection of their urine and feces to produce the raw materials for the saltpeter plants in which they would work. According to one calculation, the value of the saltpeter would exceed the cost of paying and feeding the workers and maintaining their lodgings. One hundred and fifty people "will afford matter for ten tun of Peeter in a year," Hartlib wrote, amounting to potential profit of £700.[7] A final reason for their interest in saltpeter projects was the influence of vitalist alchemical theory and the belief that saltpeter was the key to discovering the seat of life in matter.[8]

[6] Samuel Hartlib, *Copy of Extracts in Hartlib's Hand*, 28 May 1653, HP 39/1/14A.
[7] Samuel Hartlib, *Copy Memorandum on Provision for the Poor in Hand B*, "About Ye Poore Advertisement," undated, HP 15/2/5A-6B. For other Hartlib Circle papers concerning saltpeter and poor relief, see HP 53/26/2A and 7A and HP 71/11/12A.
[8] For an exposition of the "theory over practice" thesis with regard to the Hartlib Circle's interest in saltpeter and saltpeter projects, see Newman and Principe, *Alchemy Tried in the Fire,* 239-244; and Cressy, *Saltpeter*, 130-33. For evidence of this attitude, see HP 39/1/11A and 25A.

The earliest direct reference to the matter theory and possible artificial production of saltpeter among Hartlib's papers comes from his 1639 *Ephemeris*. In the 1639 notebook, Hartlib described agricultural improver Richard Weston's acquaintanceship with Gabriel Plattes and the former's inquiries into seeking a patent for the production of saltpeter. "In Sussex hee [Weston] hase bought abundance of barren ground, w^ch^ hee hase enclosed, and tried all manner of experiments vpon it."[9] Apparently little came of this, as neither Hartlib nor Weston mentioned it again to one another. It was not until the 1640s that serious discussion of projects to create saltpeter in greater quantities emerged once more.

Among the Hartlib Circle, the most ardent proponent of research into saltpeter was Benjamin Worsley. Born in 1618 and originally trained as a surgeon, Worsley managed to take advantage of the social and political turbulence in England in the 1640s and rose from fairly modest origins to a career in civil service, first as secretary of the Commonwealth's Council of Trade, then as a surveyor in Ireland. Historians of early modern England have characterized the mid-seventeenth century as a revolutionary period, not only because of the political and religious revolutions of the 1640s and 1650s, but also because of the so-called commercial or financial revolutions.[10] Worsley was emblematic as someone involved

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[9] Samuel Hartlib, *Ephemerides from 1639*, HP 30/4/26A.

[10] The literature on the English Civil War and the Glorious Revolution is too voluminous to mention. For some representative, fairly comprehensive works that also include discussions of the relationship of the politico-military and social revolutions with the commercial, financial, and scientific revolutions, as well as the conceptual links between the English Civil War and the Glorious Revolution, see Hugh Trever-Roper, *From Counter-Reformation to Glorious Revolution* (Chicago: University of Chicago Press, 1992); Tim Harris *Restoration: Charles II and His Kingdoms, 1660-1685* (London: Penguin, 2005); idem., *Revolution: The Crisis of the British Monarchy, 1665-1720* (London: Penguin, 2006); Derek Hirst, *England in Conflict, 1603-1660: Kingdom, Community, Commonwealth* (Oxford: Oxford University Press, 1999); Jonathan Scott, *England's Troubles: Seventeenth-century English Political Instability in European Context* (Cambridge, 2000); Christopher Hill, *The World Turned Upside-down: Radical Ideas during the English Revolution* (London: Penguin, 1975); idem, *The Century of Revolution: 1603-1714* (London: Norton, 1982); James Sharpe, *Early Modern England: A Social History 1550-1760* (London, 1997); Steven Pincus, *1688: The First Modern Revolution* (New Haven: Yale University Press, 2013), among many others. For the financial and commercial "revolutions" see, for example, R.G.M. Dickson, *The Financial Revolution in England: A Study in the Development of Public Credit 1688-1756*

in all three. He was instrumental in crafting the Navigation Acts of 1651—which stipulated that no non-English ships were allowed for trade between Britain and its colonies—beginning over a century of state-sanctioned mercantilist protectionism.[11] Despite his flourishing during the Interregnum, he vehemently turned against Protectorate rule in 1659 and weathered the early Restoration due, in part, to his expertise in commercial and administrative affairs.[12]

Worsley became intimately connected to the Hartlib Circle in 1644. He met Hartlib through their mutual acquaintance Gerard Boate, after both were imprisoned following the capture of their ship by Parliamentary forces on 25 April 1644. Upon their release in May, Worsley remained with Boate and traveled with him to his brother Arnold's house in London, where he became acquainted with Hartlib himself.[13] After this time, Worsley carried on correspondences about alchemy in general and saltpeter in particular with Robert Boyle, Frederick Clodius, Johann Moriaen, and Gabriel Plattes, among others.[14] These figures, along with Hartlib, had become highly interested in developing a method of creating saltpeter without the unpalatable work of digging in latrines and coops or working directly with animal dung and urine. This was partially out of their mutual interest in chemical philosophy and vitalistic alchemy, partially out of a simple desire to make money, and partially due to recent acts of Parliament limiting the locations saltpetermen could dig,

(London, 1967); and Carl Wennerlind, *Casualties of Credit: The English Financial Revolution, 1620-1720* (Cambridge: Harvard University Press, 2011).

[11] Leng, *Benjamin Worsley*, 53-79.

[12] Ibid., xi. For more details of Worsley's early life, see Charles Webster, "Benjamin Worsley: Engineering for Universal Reform," in *Samuel Hartlib and Universal Reform: Studies in Intellectual Communication*, edited by Mark Greengrass, Michael Leslie, and Timothy Raylor (Cambridge: Cambridge University Press, 1994), 213-15; G.E. Aylmer, *The State's Servants: The Civil Service of the English Republic, 1649-1660* (London: Routledge, 1973), and John T. Young, *Faith, Medical Alchemy, and Natural Philosophy: Johann Moriaen, Reformed Intelligencer, and the Hartlib Circle* (Aldershot, UK: Ashgate Press, 1998), *passim.*

[13] Ibid., 19.

[14] Ibid., 80-96.

now denoted as "Barnes, Stables, Pigeon-houses, and all other Outhouses, [but] not elsewhere."[15] By the summer of 1644, Worsley was collaborating with Hartlib and other members of his circle on a project to supply Parliamentary forces with saltpeter to make gunpowder.

Within less than a year, discussions of saltpeter proliferated. They treated it both as the vital seat of life in matter and as the most potent chemical substance for the creation of an artificial fertilizer, especially in conjunction with Helmontian chymistry. In a letter from Sir Cheney Culpeper—a Kentish landowner and supporter of all manner of agricultural improvement projects—to Samuel Hartlib dated 17 July 1645, Culpeper requested several titles by Van Helmont and eagerly anticipated several new titles mentioned in his *Opuscula*.[16] As Antonio Clericuzio has demonstrated, this is likely the first mention of Van Helmont amongst the Hartlib Circle, but it would not be the last.[17] Culpeper was especially interested in Van Helmont's idea of "natural spirits" (*spiritus naturalis*) and their relationship with the "spirit of the world" (*spiritus mundi*), which Culpeper believed to be the cause of all generation in the natural world among both living and inert matter.[18] He called saltpeter "rather like single sparks buried in deepe ashes," and he likely sought the path to that discovery through saltpeter projects and experimentations, as numerous

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[15] Anon., "News," *A Perfect Diurnall of Some Pasages in Parliament*, October 16, 1643 – October 23, 1643, Issue 43 (London, England), 12; "April 1644: An Ordinance of the Lords and Commons in Parliament assembled, for the making of Salt-petre, &c.," in *Acts and Ordinances of the Interregnum, 1642-1660*, ed. C H Firth and R S Rait (London: His Majesty's Stationery Office, 1911), 418-420, *British History Online*, last accessed July 18, 2018, http://www.british-history.ac.uk/no-series/acts-ordinances-interregnum/418-420. These acts ultimately gave saltpeter diggers the authority to dig on any property and allowed courts to prosecute individuals who refused to let them. It also licensed saltpetermen to commandeer any carts, wagons, etc. for transportation and exempted them from taxes and tolls on roadways.

[16] Cheney Culpeper to Samuel Hartlib, 17 July 1645, HP 13/98A. Antonio Clericuzio has noted that Van Helmont never, in fact, published the list of works that Culpeper so coveted. See Antonio Clericuzio, "From Van Helmont to Boyle: A Study of the Transmission of Helmontian Chemical and Medical Theories in Seventeenth-Century England," *British Journal for the History of Science,* Vol. 26, No. 3 (1993): 310-11.

[17] Clericuzio, "From Van Helmont to Boyle," 311.

[18] Cheney Culpeper to Samuel Hartlib, 17 July 1645, HP 13/96A-B.

letters just before and after acquainting himself with Van Helmont's works demonstrate.[19] He made multiple requests through Hartlib regarding information concerning Gabriel Plattes's work on developing saltpeter through his study of pigeon dung. At least eight such requests were made between November 1644 and November 1645.[20] Worsley began writing about saltpeter in earnest around this time, and it is possible the impetus for this was the exuberance of Culpeper, with whom Worsley had corresponded.[21]

In March 1646, Worsley submitted a project proposal to a committee of London aldermen, which by November had found its way to the House of Lords. This document provided no specific information about Worsley's methods, so the aldermen "demaunded many particulers about the said subject."[22] According to copies of the proposal among Hartlib's papers dated a month later, they discussed it with him personally. Newman and Principe have suggested that the proposal reveals Worsley knew little of the process of saltpeter production or the chemistry of salts at this point, and they provide convincing evidence that Worsley's actual plans were to purchase the rights to the methods of a saltpeterman named Francis Joyner through the intermediary of his "mistress" after securing the approval of the aldermen.[23] However, Worsley clearly believed that this was a viable project with a sound scientific basis and may have expected to acquire the technical

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[19] Culpeper to Hartlib, undated, HP 13/279B-280A.

[20] Culpeper to Hartlib, 20 November 1644, HP 13/55B; Culpeper to Hartlib, 4 January 1645, HP 13/59A; Culpeper to Hartlib, 21 January, 1645, HP 13/66B; Culpeper to Hartlib, 28 January 1645, HP 13/69A; Culpeper to Hartlib, 20 May 1645, HP 13/88B; Culpeper to Hartlib, 12 November 1645, HP 13/122A; Culpeper to Hartlib, 17 July 1645, 13/95A; Culpeper to Hartlib, c. November 1645(?), HP 13/278A. I am indebted to Oana Matei for pointing this out. See Oana Matei, "Husbanding Creation and the Technology of Amelioration in the Works of Gabriel Plattes," *Society and Politics,* Vol. 7, No. 1 (2013): 98 n.14.

[21] Charles Webster first suggested this connection, and more recent work by Newman and Principe has upheld it. See Webster, "Benjamin Worsley: Engineering for Universal Reform," 213-15; and Newman and Principe, *Alchemy Tried in the Fire*, 239. For Culpeper's letters, see M.J. Braddick and M. Greengrass, *The Letters of Sir Cheney Culpeper (1641-1657)*, Camden Miscellany 33 (Cambridge: Cambridge University Press, 1996), 135-37, 332-34, and 363-67.

[22] *Copy Report in Scribal Hand (?), Worsley's Proposal for Saltpeter,* 7 April 1646, HP 71/11/1A-1B.

[23] Newman and Principe, *Alchemy Tried in the Fire*, 239.

details once in progress.[24] Culpeper and Hartlib expressed some misgivings about the proposal, but the aldermen reputedly favored the project and "received so much satisfaccion as seemeth probable to vs of his abillity to make (after a yeare or two) some quantity of Salt Peter without digging vpp of houses or Cellers."[25] It is likely that their eagerness reflected a longstanding desire to meet gunpowder demands, which had become a growing difficulty as the price of saltpeter skyrocketed during the First English Civil War.[26] In any case, the aldermen either eventually lost interest in the project or Worsley never secured the funds; nor was he able to procure Joyner's recipe. By the time the case was brought before the House of Lords on 21 November 1646, Worsley had all but abandoned the project.[27]

After this opportunity dissipated, Worsley embarked upon a project to develop the requisite technical skills to accomplish his saltpeter production goals. Following several false starts in the mid-1640s, he secured funds to travel to Amsterdam in late 1647 to study alchemy under the illustrious adept Johan Rudolf Glauber, who had set up an alchemical furnace and laboratory there three years earlier.[28] Worsley learned from Glauber about both the chemical and medicinal properties of alchemically produced substances, and he aided Glauber in collecting, extracting, and distilling various materials in the explicit

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[24] For support for this interpretation, see Leng, *Benjamin Worsley,* 24. Leng argues that, while Worsley may have exaggerated his chemical abilities, this was not an attempt to defraud his investors. Rather, it was to prove his business acumen to Hartlib and his associates to build a reputation for later projects.

[25] Copy Report in Scribal Hand (?), *Worsley's Proposal for Saltpeter,* 7 April 1646, HP 71/11/1A-1B.

[26] See Peter Edwards, *Dealing in Death: The Arms Trade in the British Civil Wars, 1638-1652* (Stroud: The History Press, 2000), 91-115; and Ben Coates, *The Impact of the English Civil War on the Economy of London, 1642-1650* (New York: Routledge, 2016), 90-108.

[27] *Journal of the House of Lords*, *1645-1647*, Vol. 8 (London, 1767-1830), 573-74. According to these records, an ordinance for this request was ordered, but there is no record of it having been carried out. See also Leng, *Benjamin Worsley*, 24-5 n.81; and Newman and Principe, *Alchemy Tried in the Fire,* 239 n.110.

[28] Leng, *Benjamin Worsley*, 20-1. It should be noted here that Worsley likely would have abhorred being called a "projector," yet at the same time, he also likely would have concurred with the long-term goal of projects to provide services to the poor and act as a leveling device against the monopolistic power of the crown and church.

pursuit of a universal, vital spirit. Distillation often reduced these chemical concoctions to condensed "sprits," which were usually in liquid form, but which many seventeenth-century alchemists, including Glauber, had learned how to crystallize into salts.[29] In an undated letter likely written around this time, Culpeper requested from Worsley any information he might have concerning which substance or substances might contain the "spirit of nature," referencing both Glauber's work with salts and the work Johann Moriaen had done with potential chemical fertilizers. A mutual acquaintance of Glauber and Hartlib, Moriaen served as Worsley's contact in Amsterdam. "The touch you give from Mr Morian concerning Saltpeter rayses my Chymicall thoughts," Culpeper wrote, "and wishes that you would give me leave to recommend too Chymicall Queries to you search in these your travels, The first is *th*e exilation of *th*e Spirit of Nature againe and againe into a reitared [reiterated?] motion as offten as *th*e Phillosophers pleases…"[30] Culpeper wrote to Worsley multiple times while he was in contact with Glauber and Moriaen in Amsterdam during this time, mostly to interrogate him about everything he had learned from Glauber.[31]

Glauber's research into chemical salts, the spirit of nature, and its potential for harboring the vital properties of life influenced Worsey's notion of the nature and potential applications of saltpeter. Glauber's ultimate goal—one he thought he had achieved by the late 1640s—was the production of a *sal mirabile,* which could then be commercialized and put to medical or agricultural use.[32] At first, Glauber believed that he had identified the universal, vital spirit in a crystallized *sal mirabile*, which he originally believed to be a

[29] Chang, "Alchemy as a Study of Life and Matter," 326.
[30] Cheney Culpeper to Benjamin Worsley, undated, HP 13/223A.
[31] For Moriaen's connection, see Young, *Faith, Medical Alchemy, and Natural Philosophy*, esp. Chapter 5, "Curing Creation: Alchemy and Spiritual Alchemy," 151-82.
[32] For more detail on this plan, see Pamela Smith, *Body of the Artisan: Art and Experience in Scientific Revolution* (Chicago: University of Chicago Press, 2004), 165-181; and Chang, "Alchemy as a Study of Life and Matter," 326.

universal solvent, or alkahest, not just for metallic substances "but all stones and bones, yea, coal itself, which no other corrosive can dissolve."[33] He made this discovery while attempting to treat a stomach ailment by drinking water from a mineral spring near Neustadt. After recovering rapidly, he evaporated the water and discovered crystals similar to saltpeter, but concluded that they must be different, since saltpeter had no known laxative properties. He found similar salt crystals by producing a reaction with common salt and vitriol.[34]

In modern chemical terms, what Glauber had isolated was sodium sulfate (Na_2SO_4), also known as sulfate soda, and to this day colloquially referred to as "Glauber's salt."[35] This is important because Glauber acknowledged that his *sal mirabile* was distinct from saltpeter even though at times he had referred to *both* as the basis for the alkahest and the key to understanding the universal, vital spirit. Kathleen Ahonen has argued that Glauber simply held two irreconcilable ideas about these distinct salts in his head and never managed to clarify how each pertained to a universal, vital spirit.[36] In contrast, Anna Marie Roos has asserted that he simply posited two separate purposes for them: saltpeter was the alkahest and could be appropriated as a universal solvent to create potent medicines or synthetic fertilizers, while the *sal mirabile* undergirded the creation of all matter in nature,

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[33] Johan Glauber, *De natura salium,* 94, quoted in Young, *Faith, Medical Alchemy, and Natural Philosophy*, 196 and 196 n.100. The original German reads, "…*sondern alle steine und Beine ja die kohlen welche sonsten durch kein corrosiv zue solvirn, radicaler solvirt…"* Young's translation.

[34] Colin Russell, "Furnaces for Philosophers," in *Chemistry World* (September 2004), Royal Society of Chemistry, http://www.rsc.org/chemistryworld/restricted/2004/September/philosophers.asp, quoted in Roos, *Salt of the Earth*, 35. In modern chemistry, "vitriol" can refer to a number of sulfates and acids, especially iron (II) sulfate ($FeSO_4$).

[35] Roos, *The Salt of the Earth*, 35.

[36] Kathleen Ahonen, "Johan Rudolf Glauber: A Study of Animism in Seventeenth-Century Chemistry" (PhD Dissertation, University of Michigan, 1972), 95.

beginning with metals and minerals.[37] The solution to this apparent discrepancy lay in where the vital spirit was found—not in the salts themselves, but in the air, from which they could be condensed and crystallized.

Eventually, throughout the 1640s and 1650s, Glauber assigned these two different alchemical purposes to saltpeter and the *sal mirabile*. First, he argued that the air itself contained the vital spirit, which, when condensed in the proper way, would become a salt, the source of all growth and generation on earth. This he identified with saltpeter, which was the most powerful, adaptable, and versatile form of salt.[38] According to Glauber, it was the "*miraculum mundi*," containing within it the "fire or Sulphur," acting as a universal solvent, and it could be found in all elements, which, as he wrote in his *Tractatus de natura salium*, is a "reason that it may be called the *Materia Universalis* since no one can live without the elements."[39] Secondly, and perhaps more importantly, Glauber equated aerial niter—the supposed airborne substance from which solid saltpeter could be extracted—with the vital spirit, which originated in the stars, but through the air inseminated rain, snow, dew, and other atmospheric waters that eventually made their way to earth where saltpeter acted as a fertilizer and a possible catalyst for biological growth, while the *sal mirabile* induced the growth of metals and minerals.[40] During his two years in Amsterdam, Worsley seems to have accepted all of this as true.[41] These experiments and texts provided for him the evidence for the validity of the *sal nitrum* school.

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[37] Roos, *The Salt of the Earth*, 36-41.

[38] Johann Rudolf Glauber, *Pharmacopaeae spagyrica*, in *Opera chymica*, Vol. I (Frankfurt am Main, 1658), 15, and idem., *Tractatus de natura salium*, in *Opera chymica*, Vol. I, 441-2, both quoted in Debus, "Paracelsian Aerial Nitre," 59.

[39] Glauber, *Tractatus de natura salium*, 442; idem., *Pharmacopaeae spagyrica*, 97; idem., *Continuatio miraculi mundi*, in *Opera*, 163. See also Debus, "Paracelsian Aerial Nitre," 59.

[40] Glauber, *Continuatio miraculi mundi*, 163-5.

[41] Smith, *Body of the Artisan*, 165-181; and Chang, "Alchemy as a Study of Life and Matter," 326.

For Glauber, the laboratory production of saltpeter was not only integral to his study of its chemical composition but also provided evidence that it could be produced in a commercially viable way. His laboratory became a major source of manufactured products for industrial use. Worsley held similar notions of its economic importance and marketability, but for him, as for many other Hartlib correspondents, its possibilities as a both an ingredient in gunpowder and a highly potent fertilizer were paramount.[42] However, most Hartlib Circle chemical philosophers soured on Glauber's theories through the 1650s, in part due to the vagueness and inconsistency of his terminology, the secretiveness with which he guarded his supposed knowledge of the alkahest, and experimental results that appeared to refute his claims about saltpeter's solvent properties.[43]

In any case, Worsley's time in Amsterdam was short-lived. After repeated failure to accomplish these alchemical tasks, and with his own disillusionment with Glauber's alleged successes, he returned to England after fewer than two years with the hope of securing a state position.[44] By this point, according to Newman and Principe, his alchemical interests had become less utilitarian and more spiritual, which colored his later saltpeter experiments.[45] This is true with some caveats. On the one hand, it is clear from most of his

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[42] For Glauber's reception among English alchemists, chymists, and physicians, see Young, *Faith, Medical Alchemy, and Natural Philosophy*, 183-207. For his reception more specifically among the Hartlib Circle and the potential applications of chymistry to agriculture and other commercial activities see idem., esp. 198-207; and Roos, *The Salt of the Earth*, 34-43.
[43] See, for example, Samuel Hartlib, *2 Extracts & Notes on Glauber's Alkahest*, 30 December 1650, HP 31/8/6B; Robert Child to Samuel Hartlib, 2 February 1652, HP 15/1/18A; and Samuel Hartlib to John Winthrop the Younger, 16 March 1660, HP 7/7/3B. Ironically, Glauber undermined his own theory about the alkahest by demonstrating that recombining nitric acid and the "fixed salt" (in this case, potassium carbonate)—by-products of dissolving substances with saltpeter—could recreate saltpeter, meaning that nothing had been added or removed from the original material in the first place. Robert Boyle replicated this experiment and confirmed this result in 1660. See Robert Boyle, *Essay on Nitre* (London, 1661).
[44] Leng, *Benjamin Worsley*, 37-41.
[45] Newman and Principe, *Alchemy Tried in the Fire*, 241-2.

own writings and the criticism of others that Worsley was never able to master the technical aspects of alchemical laboratory work requisite for such a serious pursuit into the nature of life and matter. On the other, his later support for field- and farm-based chymical experiments into saltpeter and soil fertility suggests that he felt laboratory studies might have been superfluous for this particular task. It is apparent when comparing Worsley's writings on saltpeter in the mid-1640s to those in the mid-1650s, however, that he, in fact, *had* developed a more sophisticated chymical understanding of salts.[46]

The Projecting Impulse:
Benjamin Worsley and the Intellectual Foundations of Hartlib Circle Saltpeter Projects

After Worsley returned to England, Samuel Hartlib encouraged him to continue his research into the "vtopian designs…for [an] Artificiall way of breeding [&] increasing of Salt-Peter" without having to resort to the use of "Dung, Urine, and the like stuff."[47] Worsley claimed to be able to produce saltpeter without these substances after having worked with Glauber even as the vital principle of matter eluded him. Perhaps most importantly, Worsley believed that the research into saltpeter itself had led to knowledge not just of its chemical substance but "something also of…[all] vegeatation."[48]

A number of Hartlib Circle members also read the vitalistic works of the Paracelsians, Helmontians, and the succeeding generation of their followers invested in the *sal nitrum* theory, such as Duchesne and Sendivogius. However, it was not until the flurry of textual translation beginning in the early seventeenth century and accelerating around

[46] Compare, for example, his original 1646 proposal to the London aldermen (HP 71/11/1A-1B) with his *De Nitro Theses Quædem* (HP 39/1/16A-20B) and his extended 1654 letter to Hartlib on the topic (HP 66/15/1A-4B). With the exception of basic designs for the construction of workhouses, nothing is mentioned about saltpeter production in the proposal.
[47] Samuel Hartlib to Benjamin Worsley, 16 May 1654, HP 66/4/1B.
[48] Ibid.

1650, especially by John French and Thomas Tymme, that many of these continental works wound up in English hands. John French translated the alchemical works of Sendivogius, the natural magical tracts of Heinrich Cornelius Agrippa, and the experimental notebooks of Glauber. Thomas Tymme did the same for Duchesne. Edward Stephens translated one of the foundational works promoting the *sal nitrum* philosophy, Vigenère's *Discourse of Fire and Salt*, in 1649. All of their works circulated amongst Hartlib Circle members with an interest in applying alchemical techniques to agriculture, husbandry, and botany.[49]

Worsley read many of these texts around this time, including at least three works by Paracelsus, as well as John French's 1650 translation of Sendivogius's *New Light of Alchymie*, which provided a comprehensive theoretical construct for the *sal nitrum* school.[50] In Sendivogius's work, as we have seen, the energizing, vital principle found in

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[49] For some important works, see John French, *A New Light of Alchymie: taken out of the fountaine of nature, and manuall experience. To which is added a treatise of sulphur… translated out of the Latin into the English tongue, by J.F. M.D. Dictionarium Theophrasti Paracelsi.* (London: Printed by Richard Coates for Thomas Williams at Bible in Little Britain, 1650); idem., *Three books of occult philosophy, written by Henry Cornelius Agrippa, of Nettesheim, counseller to Charles the Fifth, Emperor of Germany: and judge of the Prerogative Court. Translated out of the Latin into the English tongue, by J.F.* (London: Printed by R.W. for Gregory Moule, 1651); idem., *A description of new philosophical furnaces, or A new art of distilling, divided into five parts. Whereunto is added a description of the tincture of gold, or the true aurum potabile; also, the first part of the mineral work. Set forth and published for the sakes of them that are studious of the truth. By John Rudolph Glauber. Set forth in English, by J.F. D.M.* (London: Printed by Richard Coats, for Thomas Williams, 1651); Thomas Tymme, *The practise of chymicall, and hermeticall physicke, for the preseruation of health. Written in Latin by Iosephus Quersitanus, Doctor of Phisicke. And translated into English, by Thomas Timme, minister*. (London: Printed by Thomas Creede, 1605); Blaise de Vigenère, *Discourse of Fire and Salt, Discovering Many Secrets as Well Philosophicall and Theologicall*, trans. Edward Stephens (London, 1649). For a later translated work on the same topics in the post-Hartlibian era, see John Webster, *Otto Tachenius, his Hippocrates chymicus, which discovers the ancient foundations of the late viperine salt and his clavis thereunto, translated into English by J.W.* (London: Printed for Thomas James, 1677). For works concerning Helmontian chemical theories about aerial niter and respiration, see Ralph Bathurst, *Praelectiones tres de respirations* (London, 1654); Malachi Thruston, *De respirations usu Primario Diatriba* (Cambridge, 1664); Kenelm Digby, *Discourse Concerning the Vegetation of Plants* (London, 1661). For a further discussion of these works, see Thomas Thomson, *Chemistry of Animal Bodies* (London, 1843), 606; Margaret Nayler, "Introduction," in William Crone, *De Ratione Motus Musculorum* [1664], edited and translated by Paul Maquet (Philadelphia: American Philosophical Society, 2000), 10; Henry Guerlac, "John Mayow and the Aerial Nitre: Studies in the Chemistry of John Mayow, I," *Actes du Septieme Congres International d'Histoire des Sciences* (Jerusalem, 1953), 332-349; idem., "The Poets' Nitre: Studies in the Chemistry of John Mayow, II," *Isis* 45 (1954): 243-255; J. R. Partington, "The Life and Work of John Mayow (1641-1679)," *Isis* 47 (1956): 217-230 and 405-417; and Debus, "Paracelsian Aerial Nitre," 58.
[50] Leng, *Benjamin Worsley,* 97-8.

saltpeter combined with the sulfurous soil to both produce metals and minerals and nourish the roots of all plant life. This substance was also found in the air—the *aerial niter* of Paracelsus expounded on by Duchesne—and when illuminated by sunlight or subjected to heat, it also contributed to the growth of plants. According to Sendivogius and Worsley, this explained, among other things, the variable properties of saltpeter.[51] Edward Jorden, whom Worsley also read, believed that very rich soil would give rise to saltpeter naturally when exposed to proper amounts of sunlight. In his *Discourse of Naturall Bathes*, saltpeter was referred to as an effective fertilizer that could bring "all plants to perfection far sooner than any other dung," and Worsley understood this not just as a superior soil enricher but also as a clue to the process of botanical growth itself.[52]

Nevertheless, Worsley's studies actually made him reticent to assign a single, universal structure to all matter. The underlying questions in the theory of material growth were

> What Principles we should thinke meete to assert in Nature to be the true causes of vegetation, & w*hi*ch beeing graunted, may clearly resolve, & fully Answer to all these both Naturall & Artificiall Phoenomena, Letting vs solidely & demonstratively see, whence all these variety comes, & how it must necessarily & vnavoidably arise, with the severall conseqvences of them. And here We inevitably fall to inquire: Whether all this may bee sufficiently cleared from Aristotles Hypothesis of the 4. Elements: Or from Paracelsus his 3. Principles of salt, Sulphur, & Mercury, or from Dr Cartes [Descartes] Doctrine of body figure or Motion; or whether by some Magnetick or Astrologicall supposition, Or whether without all these, by a plaine, direct, Analyticall Consideration & Examination of all & every particular body, concurring to Vegetation, & of the share, that each of them beareth from the very first Motion or Conception of Vegetation, to its ultimate Maturity or perfection.[53]

Worsley came to believe, using techniques and theories gleaned from studying the writings of Paracelsus, Van Helmont, and Sendivogius and the laboratory techniques of Glauber, that

[51] Ibid., 98.
[52] Edward Jorden, *A Discourse of Naturall Bathes, and Minerall Waters* (London, 1631), 57.
[53] Benjamin Worsley to Samuel Hartlib, c. April 1657, HP 8/22/2B.

the creation of saltpeter could be enhanced and accelerated: the practically useful substance that Worsley and others had been searching for was "the best and richest earth, that can bee got of Saltpetre, which being impregnated with its own Nitreous Spirit, will Multiply & increase itself vpon first matter."[54] By adding grass clippings, lime, and wood ash, and "planting" the mixture in rows, as had been done in earlier nitraries, Worsley believed that he could replicate the natural growth of saltpeter in an artificially controlled environment to coax out the "nitrous Vniversal spirit" in what Robert Boyle later lauded as the possibility of a "perpetual mine of salt-Petre."[55] In his *Sceptical Chymist,* Boyle promoted the theory that "the seminal principle of nitre, latent in the earth, does, by degrees, transform the neighbouring matter into a nitrous body," meaning fertile soil that could be continually replenished.[56] Later in his *Usefulnesse of Experimental Natural Philosophy*, he used this same theory to explain that God had not created all metals and minerals when He created the world and instead instilled generative powers in "Metalline bodies," which "have some of them a Power, though slowly to propagate their nature when they meet with a disposed matter."[57] According to Boyle, the intrinsic procreative powers of metals, minerals, and salts allowed for the possibility of self-sustaining, potentially unlimited natural stores.

Worsley's textual analysis of these saltpeter works and his field experiments on saltpeter led him to the conclusion in *De Nitro Theses Quædem*, his most extensive writing

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[54] Benjamin Worsley and Johann Moriaen (?), "Notes on salpetre…" 18 May 1653, HP 39/1/11B. See also Newman and Principe, *Alchemy Tried in the Fire*, 240, and Leng, *Benjamin Worsley*, 99, for alternate interpretations of the meanings of these passages by Worsley and Moriaen and the marginal notation by Hartlib.

[55] Leng, *Benjamin Worsley,* 98.

[56] See Webster, *The Great Instauration*, 380. Webster quotes Robert Boyle, *The Sceptical Chymist* (London, 1661), in *Works*, Vol. 1, 566, in regard to the idea of a "perpetual saltpeter mine."

[57] Ibid. See Robert Boyle, *Some Considerations Touching the Usefulnesse of Experimental Natural Philosophy* (London, 1664), in regard to metallic propagation.

on the topic, that "all Plants containe in them Salts" and that "nature's intent in the breeding of Salt-Peter in the Vpper Surface of the Earth is for the generation of Plants and by them for the præservation of Animals."[58] His final, experimental results in the field seemed to confirm this:

> It is found by certain and frequent experience that Salt-Peter is the very soule of Vegetation as may appeare by Corne or Seedes steeped in Water mixed with Salt-Peter, w*hi*ch by several trials is found to bee the best imbibition of any. As also by all the Earth rich in Salt-Peter, w*hi*ch is found fatter and richer in Spirit, then any other Compost in the World made by what Art soeuer, w*hi*ch is further confirmed by the ma*n*ner of Vegetation or Germination, w*hi*ch consists in the dissolution and apposition of Salt or any Salinous matter… It is found by the certainty of Experience that all such Earth as is once imprægnated or enriched w*i*th a nitrous Spirit, ceaseth not to generate and multiply its*elf* vpon all such fit matter as shall bee apposed to it, prouided shee bee not hindred.[59]

That is, regardless of whether or not it could singularly be pointed to as the material constituent of a universal spirit, as something that seemed to appear wherever life could be found growing, saltpeter remained the key to understanding all botanical growth and, through ingestion, animal growth as well.

Worsley's *De Nitro Theses Quædem* is his most comprehensive attempt to understand saltpeter's natural qualities and the possibilities for its production. This extended treatise, originally addressed to Hartlib, marks the height of his understanding of how artificial saltpeter production might be accomplished. Although the text is undated, Charles Webster originally suggested that Worsley wrote the work in or around 1646 at roughly the same time as his petition to Parliament for funds to create a saltpeter production project.[60] However, as Newman and Principe have noted, the contents of this thesis contain techniques of saltpeter production and knowledge of its chymical

58 Benjamin Worsley, *De Nitro Theses Quædem*, HP 39/1/16A-20B.
59 Ibid., 16A and 19B.
60 Webster, *The Great Instauration*, 378-79.

composition that Worsley did not have until after his time with Glauber in Amsterdam from 1647 to 1649. They argue that it was composed in 1654, or at least no earlier than mid-1653, since it contains references to the composition of saltpeter that had been discovered by Glauber and remained unpublished until it appeared in his *Miraculum mundi* of 1653.[61] It is likely that Worsley's first mention of these details came in an unpublished document titled *Observations about Saltpeter*, dated 18 May 1653, and he composed *De Nitro Theses Quædem* after this.[62] Though it is difficult to ascertain the exact year, his references to saltpeter's role as a plant fertilizer and the specificity of his descriptions of its natural history and uses make it likely that it was, at the very earliest, composed after Worsley's return to England in 1649. In any case, this work represents the most wide-ranging analysis of Worsley's understanding of saltpeter and the Hartlib Circle's interest in the chemical details of its production.

Worsley's *De Nitro Theses Quædem* was a systematic text that elaborated upon the formation, growth, nature, and potential production of saltpeter. It is both a brief instruction manual and a natural history, and it represents Worsley's most sophisticated understanding of the substance. It is structured as a numerical list of theses, each building upon the previous, to create a systematic understanding of the origins, growth, properties, and uses of saltpeter. These theses described the locations where saltpeter was likely to grow, why it was likely to grow there, why plant growth followed, which environmental conditions both helped and hindered this growth, the different material states that saltpeter took, and finally how a comprehension of this natural history led to a knowledge

[61] On these details, see Ahonen, "Johan Rudolf Glauber," vi-x, 102-3, 107, and 115.
[62] Newman and Principe, *Alchemy Tried in the Fire,* 240-43. See Benjamin Worsley, *Observations about Saltpeter*, 18 May 1653, HP 39/1/11A-12B.

of its production. Though it was originally conceived—like many earlier saltpeter projects—in the interest of supplying Commonwealth forces with saltpeter for gunpowder, Worsley eventually wrote far more about its uses as a fertilizer and, in fact, never mentioned saltpeter's role in gunpowder production in the text. Instead, he emphasized the alchemical convertibility of saltpeter into plant matter and plant matter into animal muscle as evidence that agriculture and mixed husbandry benefited from its use.

Worsley began by discussing how saltpeter naturally arose in the soil. He contended that emulating nature was the best way to model an artificial saltpeter production project. The logic for saltpeter's importance in plant growth came both from experiment and from experience. Worsley argued that saltpeter was rarely found where an abundance of plants were growing but was often found in arid locations where few plants grew. This suggested that saltpeter was "exhausted and consumed where plants and vegetables do grow," while saltpetermen had no trouble finding it in "plenty of places trod frequented and shaded where vegetables do not grow or are by these means hindred from growing."[63] Like saltpetermen and other projectors, Worsley noted that light, heat, moisture, time, and unwanted chymical substances had to be monitored precisely for consistent saltpeter production. Nature hampered the growth of saltpeter, he wrote, "either by too much moisture or by too much exclusion of the heat of the Aire and the Sun, or by anticipating its due time or by the continual springing of Co*m*mon Salt, or of some Mineral or Lapidescent juyce or by the germination or production of Plants."[64] By imitating the natural conditions that gave rise to saltpeter and meticulously monitoring these conditions, the artificial beds could be made to produce much higher yields.

[63] Worsley, *De Nitro Theses Quædem*, HP 39/1/16A.
[64] Ibid., 17A

The most novel aspect of *De Nitro Theses Quædem* compared to previous saltpeter projector techniques was Worsley's brief discussion of the different natural, material states in which one might find saltpeter and the multitude of chymical properties one might prompt it to adopt through alchemical transformation. "It is certaine," Worsley wrote, "that Salt-Peter hath Parts Volatill, infla*m*mable and spirituous and parts fixed exceedingly causticke fiery and wonderfully detersive."[65] This section provides the most compelling evidence that he composed this work after his time in Amsterdam, as Worsley clearly owed a debt to Glauber's work on the relationship between aerial niter and saltpeter.

The fifth thesis speaks of saltpeter as having a "double Nature and different parts" and composed of a "fixt and common Salt mixt with an aetherial heat and spirit."[66] As evidence of this, Worsley explained that saltpeter tasted much like common salt, that common salt could be separated via boiling, that it could easily be crystalized, and that the addition of unslaked lime would produce it. The fact that it was found in hotter and drier climates and grew readily on walls implied that an airborne substance affixed itself to these surfaces in warm, low-moisture environments, and Worlsey believed this was one of the keys to fully understanding its production.

Finally, the sixth thesis consisted of a recipe for creating productive saltpeter beds, and it is the most thorough unpublished work to be found among Hartlib's papers regarding these processes. In many ways, the recipe differed little from older instructions for traditional saltpeter beds or information found in Continental sources such as

[65] Ibid., 19A
[66] Ibid., 19B. This seems to suggest a certain awareness of the reaction between other nitrates and potassium carbonate.

Biringuccio, Agricola, and Ercker, or the heavily derivative works of Whitehorne and Jorden. But there were some novelties. The recipe, in full, is as follows:

> The Way of Generation is with good Earth in a deepe low dry ground exposing and turning of it to the Sune, preventing its being washed away and sub-strating to it a fit and volatil Matter. This is no other then a Consequence of that w*hi*ch hath beene already proued. That the Sun and the advention of moderate Raine and dewes will accelerate the fermentation and generation of the Matter, is evident by Walles and by the breeding of it sub dio plentifully in all hot Countries. That the Matter substrated is the better by how much the more Volatil is plaine, of w*hi*ch these are the chiefe
>
> Lyme of Chalke
> Lyme of Stones
> Lyme of Marle
> Fullers Earth.
> Tops and seeds of Plants greene.
> Leaves of Trees.
> Blood of Beasts.
> Vaults.
>
> First lay a lay of the best richest and most nitrous Earth, vpon that a lay of the same thicknesse of Lyme. Then a lay of Vegetables stratum super stratum. At top let store of Lyme or dung lye one foot high, that the Raine may wash downe the Saltnesse of it into the Earth. Let your first Earth bee laid 3. foot deepe. In stead of Vegetables you may vse Blood or Vaults. To the Lyme you may mixe Fullers Earth. This is to bee turned once in 3. or 4. Week's.[67]

Notable departures from prior recipes included the importance of sunlight in the fermentation of the vegetable matter, the plethora of natural materials other than urine and dung one might use as base matter, and the multiple sources of lime. The importance of light derived from Worsley's reading of Edward Jorden. The various material sources echoed Glauber's demonstrations of the differences between "fixed niter," created when saltpeter was burned, and "volatile niter" or "spirit of niter," created when saltpeter was distilled with fuller's earth. Glauber had concluded that saltpeter had at least two natures: a volatile, acidic one (volatile niter) and a solid, caustic one (fixed niter), which Worsley

[67] Ibid., 20B

noted.[68] To create productive saltpeter beds, Worsley argued, one must begin with volatile matter such as lime of chalk, limestone, or marl; Fuller's earth, an absorbent, clay substance made up of a number of minerals, which Glauber had used in distillation; decaying plant matter; or animal blood. This was the key to the genesis of saltpeter without resorting to dung, which had been Worsley's original goal, and *De Nitro Theses Quædam* marked his most sophisticated treatment on the topic before 1654.

"Rusticall Chemistry" and Experimental Fertilizers at the Height of Hartlib Circle Saltpeter Projects, 1650-1654

Throughout the early 1650s, in large part due to Worsley's work, Hartlib and many of his correspondents expanded their support for projects and experiments designed to create saltpeter artificially or precipitate its natural growth. In his January and February *Ephemeris* of 1650, Hartlib noted a number of secrets to growing saltpeter both from firsthand experience and from the testimony of others. On 1 January 1650, a minister from Seend in Wiltshire named Thomas Tomkins, an admirer of the education reforms of Hartlib's close friend Jan Comenius, visited him and described his knowledge of growing saltpeter. "A certain Mr Vnmussig," he wrote, referring to the alias of the Paracelsian physician Johan Brun, "related [to him] how the secret of Growing selt-peter had beene imparted vnto him as likewise der salte peter Garten Kaysers Rudolphi (the salt-peter garden of the Emperor Rudolphus)."[69] In the margins, where he summarized the contents of his notes, Hartlib described the meeting with Tomkins with the subheadings "Salt-peter," "Item: an Experiment for Pasturage to make Agriculture Husbandry," and "the Dunging of

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[68] Ahonen, "Johann Rudolf Glauber," 107 n.59. "Volatile niter" equates to modern nitric acid (HNO_3) and "fixed niter" to modern potassium carbonate (K_2CO_3).
[69] Samuel Hartlib, *Ephemerides 1650 Part I,* January-February, HP 28/1/39A-39B.

Land."[70] The tantalizing and ultimately unforthcoming passage claimed that Brun made "grasse growe thrice within three months" in "an Experiment for the dunging of Land without dunging…Hee saw also with his own ey's salt-peter which is never discovered in bookes."[71] Presumably, Brun was using a type of base matter other than manure, urine, or vegetable matter, such as one that Worsley had recommended in his *De Nitro Theses Quædem*.

In the same section, Hartlib discussed the association of his frequent correspondent Cressy Dymock with an unnamed man who worked with a projector named Francis Joyner, one of three men who petitioned Parliament in the early 1650s for a patent and monopoly on a saltpeter production venture. This was the same Joyner whose manufacturing techniques Worsley had attempted to purchase in 1646, and he clearly engendered respect on the topic. Hartlib referred to him as an "old salt-peeter Philosopher, [who] is supposed to know all the secrets of that mysterie."[72] In contrast to the enigmatic nature of Tomkins's report on the creation of saltpeter, Dymock's acquaintance Joyner, along with his business

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[70] Ibid.

[71] Ibid., 28/1/39B-40A. Due to the often-secretive nature of many alchemists, a number of their recipes, formulae, and instructions never made it to the page, or if they did, were written in coded or highly metaphorical language. For works on secrecy and alchemy, see especially, William Eamon, *Science and the Secrets of Nature: Books of Secrets in Medieval and Early Modern Europe* (Princeton: University of Princeton Press, 1994); Jan Golinski, "Chemistry in the Scientific Revolution: Problems of Communication and Concealment," in *Reappraisals of the Scientific Revolution*, ed. David C. Lindberg and Robert Westman (Cambridge: University of Cambridge Press, 1990), 367-396; Principe, *The Secrets of Alchemy*, esp. 137-172; idem., "Robert Boyle's Alchemical Secrecy: Codes, Cyphers, and Concealments," *Ambix*, Vol. 39, No. 2 (1992): 63-74; Newman and Principe, *Alchemy Tried in the Fire,* 156-206; Newman, "Alchemical Symbolism and Concealment: The Chemical House of Libavius," in *The Architecture of Science*, ed. Peter Gallison and Emily Thomson (Cambridge: MIT Press, 1999), 59-77; Tara Nummedal, *Alchemy and Authority in the Holy Roman Empire* (Chicago: University of Chicago Press, 2007), 119-146; Pamela O. Long, *Openness, Secrecy, Authorship: Technical Arts and the Culture of Knowledge from Antiquity to the Renaissance* (Baltimore: Johns Hopkins University Press, 2001); Lauren Kassell, "Secrets Reveald: Alchemical Books in Early Modern England," *History of Science*, Vol. 49 (2011): 61-87; and more generally Wouter J. Hanegraaf, *Esotericism in the Academy: Rejected Knowledge in Western Culture* (Cambridge: University of Cambridge Press, 2012), esp. 230-251.

[72] Ibid., 28/1/40A. Joyner is identified only by his surname in Hartlib's *Ephemeris* of 1650. M.J. Braddick and Mark Greengrass have identified him as the same "Joyner" who petitioned Parliament for a monopoly on artificial saltpeter production. See M.J. Braddick and M. Greengrass, eds., *The Letters of Sir Cheney Culpeper (1641-1657)*, Camden Miscellany 33 (Cambridge: Cambridge University Press, 1996), 251.

partners William Luckin and a “Mr. Woorrell,” claimed they were willing to share their knowledge of the chymical properties of various animal feces, particularly poultry, that could be better put to use for the creation of a saltpeter-based fertilizer.[73] By their account, pigeon dung was the best among animal manures as the basis for saltpeter manufacture, and since these animals were so often harmful to crops, capturing and cooping them to harvest their dung could solve two agricultural problems at once. Hartlib wrote that

> by hen, Turkies, etc and other Poultry’s dung as much may bee done as by pigeons-dung in reference to salt-peeter, by which meanes those most hurtful creatures to Corn might vtterly be destroyed…The inclosures of Land being thus made vp w*i*th fences of mudwales, certain liquors being continually flung vpon the fences, within a few y*ea*rs they would proove the richest salt-peeter Earth to supply the necessities of the whole kingd*om* w*hi*ch is a secret w*hi*ch hee did not expresse in those Papers.[74]

Poultry farming and enclosure had been added to the list of potential projects to produce a steady supply of saltpeter.

There were disputes among Hartlib’s correspondents concerning who had described the properties of saltpeter most accurately and how a correct understanding of these properties might be a factor in its most efficacious production. These notes, letters, and experimental trials almost all discussed salt, saltpeter, and *sal nitrum* in the context of both its practical applications and its theoretical implications, combining trial-and-error reports of saltpeter manufacture with frequent excursions into the matter theory of Aristotle, Paracelsus, Van Helmont, and others. In a 1650 letter to the clergyman and agricultural reformer John Beale, his nephew Peter Smith had suggested a middle ground between Aristotelian and Paracelsian traditions. He noted that Francis Bacon had

[73] William Luckin goes unnamed in Hartlib’s January-February 1650 *Ephemeris*, but he is mentioned in the undated *Acte for a new way of Making Salt peeter*, HP 71/1/2A-7B, identified internally within the manuscript as a “Draught of an Act of Parliament for the making of a corporation of Saltpeeter-makers in England Ireland and the Dominion of Wales to Sir William Luckin Mr Joyner and others.” See also Newman and Principe, *Alchemy Tried in the Fire*, 239-40.
[74] Samuel Hartlib, *Ephemerides 1650 Part I,* January-February, HP 28/1/40A.

recognized this in his own semi-Paracelsian chemical philosophy, "which now seemes like the middle region best to fixe the principles of Aristotle and Paracelsus, which without medium seems to fall into distempers."[75] In his own experiments in creating fertile cropland, which he had attempted after having read Virgil's *Georgics*, Smith argued that simply charring the ground was the best course of action and that if one started with reddish soil and "roasted unto blackness," the "fructify[ing]" power would be "a fowerfold proportion," adding that "*th*e obstacle to be removed seems to bee mercury or sulfur, & salt to be thereby fired…producing fertility."[76] By this process of "rusticall chemistry," as he called it, he hoped to increase soil fertility by isolating and separating salt from the rest of the matter found in the earth, and he equated this salt with that of Paracelsus's *tria prima*.

The next year, after the harvest, Smith wrote to Beale again to discuss his successes in fertilizing the land without saltpeter and noted that if one followed certain husbanding procedures, saltpeter would actually be a natural by-product, thus creating a potentially endless cycle of fertile ground in the same location. According to Smith, it was as simple as dunging the land with manure as usual but after harvesting the crop, returning to the field again to harvest the saltpeter that came from the manure. "I conceive that sheep-dung & pigeon mucke are much advanced in their worth by the shelter they have from moysture," he wrote,

> *th*e reason of my conceit is, because *tha*t drinesse conduceth much to *th*e increase of Niter (w*hi*ch Bacon calls *th*e Spiritt of earth) as may be demonstrated by *th*e Saltpeter works; And by experience I have knowne one *tha*t composed his dung

[75] Peter Smith to John Beale, 11 April 1650, HP 67/23/2A-2B. For more on Bacon's matter theory in this regard, see Graham Rees, "Francis Bacon's Semi-Paracelsian Cosmology, " *Ambix* Vol. 22, No. 2 (1975): 81-101; and *idem.,* "Francis Bacon's Semi-Paracelsian Cosmology and the *Great Instauration*," *Ambix* Vol. 22, No. 3 (1975): 161-173.

[76] Ibid. For Virgil's suggestions, see Virgil *Georgics* 1.71. It should be noted that this technique does not work for most types of soil.

> of *th*e stall in forme of a hayricke to have it thereby more fruitfull & sooner rotten then his neighbours.[77]

To make this process productive, at least in part because of the saltpeter content of the soil via the previous manuring, Smith suggested that "the best meanes I have found to spare compost" was by "burning the halfe of my tillage, w*hi*ch being thereby sufficiently manured, doth surrender its share of dung to *th*e other halfe, whereby I have some plenty of compost for orchards, garden & pasture."[78] Much like Boyle's "perpetual mine of saltpeter," this method seemed to provide a potentially limitless supply of fertile, arable ground, provided there was a steady stream of animal manure and proper management of the land at harvest time. These methods all depended on the belief—held by Worsley, Hartlib, Smith, Beale, and others who had attempted these projects—that through careful management designed to emulate nature, cornucopian quantities of saltpeter and fecund farmland could be produced. Bacon and Plattes's influence on natural economy intermingled with Paracelsian and Helmontian vital alchemy and coalesced to create a powerful worldview among these reformers.

Hardly a month went by in the early 1650s in which Hartlib did not receive news of some new process for creating saltpeter artificially, a better method of a known process, or a new location, either foreign and domestic, where it could be mined. Even as various alchemical schemes to create saltpeter failed, Hartlib continued to have faith that a chemical manipulation of the essential ingredients of saltpeter provided the best path forward to a universal, artificial fertilizer. In notes from February 6, 1652, Hartlib discussed the possibility that the seed of vegetable life cohered in saltpeter and that a

[77] Peter Smith to John Beale, 23 December, 1651, HP 67/23/3A-5A.
[78] Ibid.

sustainable, replicable production of it was the key to both understanding its nature and developing its use. He noted that it would be "useful to the human race if we could multiply corn [grain] artificially," and he suggested, based on work that had been done by various correspondents, that this could be "invigorated with a Lixivium," a solution containing alkaline salts extracted from wood-ash or leached from timber, usually using lye.[79]

This process was similar to ones noted in medieval Latin and Arabic texts, which suggests it had a long history. Thirteenth-century Arabic texts attested to the first chemical attempts to produce, isolate, and purify saltpeter to use in gunpowder and other explosive devices.[80] The Arab engineer Hassan al-Rammah's *Kitab al-Furusiyya wa al-Manasib al-Harbiyya* (*Book of Military Horsemanship and Ingenious War Devices*) (ca. 1270) described a process involving the distillation of mined, mineral saltpeter through boiling it in water, leaching it with wood ash, and drying it until it began to crystallize.[81] Similar European sources concerning its manufacture did not become common until the early sixteenth century.[82] Later on in the same section of his notes on saltpeter, Hartlib mentioned that Cressy Dymock had discovered a natural trove of saltpeter in Yorkshire and had begun to

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[79] Samuel Hartlib, *Notes on Saltpeter*, 6 February 1652, HP 39/1/4A. The notes, in the original Latin, read: "*Vtilissimum Generi Humano foret illud multiplicandi frumenti Artificium. Non dubito rem esse possibilem, et vegetari posse semen per Lixivium quædam corroborantia in quibus conficiendis principatus. Nitro debetur quod nec Antiqui ignorarunt. Sed an in copia magna, 108uails requiritur, idem successus scire velim.*" In modern chemical terms, this lixivium is sodium hydroxide (NaOH), also known as lye and caustic soda.

[80] Cressy, "Saltpetre, State Security and Vexation in Early Modern England," 78; J. R. Partington, *A History of Greek Fire and Gunpowder* (Cambridge: University of Cambridge Press, 1960), 298-314; and Dennis W. Barnum, "Some History of Nitrates," *Journal of Chemical Education,* Vol. 80, (2003): 1393.

[81] The main effect of this process is to separate potassium nitrate from other nitrate compounds like calcium nitrate and magnesium nitrate, both of which developed naturally alongside potassium nitrate. Removing these other compounds had the effect of making saltpeter less resistant to water but much more combustible. See above, pages 37-8.

[82] Ahmad Y. al-Hassan, "Potassium Nitrate in Arabic and Latin Sources," *Proceedings of the XXI International Congress for the History of Science*, Mexico City, 2001, last accessed 31 March 2017, http://www.history-science-technology.com/articles/articles%203.html; and idem., "Gunpowder Composition for Rockets and Cannon in Arabic Military Treatises in the Thirteenth and Fourteenth Centuries," *Icon* Vol. 9 (2003): 2-3.

conduct experiments on it, though the results of these experiments were never mentioned.[83]

Saltpeter's dual potential as fertilizer and ingredient in gunpowder disturbed a number of Hartlib's associates, even as earlier saltpeter projects during the Civil War were more concerned with the latter possibility. As utopian social reformers, many Hartlibians predicted and worked toward a future devoid of conflict in which abundant crops would far exceed abundant arms in importance. In a letter from February 18, 1653, Cheney Culpeper described a Spanish means of making saltpeter "by an artificiall mixture of some materialls fitted for that ende" that had kept King Phillip IV of Spain with a reliable stock of gunpowder for years, and he asserted that the same process could apply in England to create saltpeter for the purposes of fertilizer.[84] The "matter by which man is killed and fedde is but one & the same," he wrote—the difference was how it was manipulated.[85] Unfortunately, Culpeper did not know what was contained in such a mixture and averred that ultimately the key to fertilizer production was the ability to distinguish the deadly from the vital aspects. He remained confident it could be discovered.

By the mid-1650s, the idea that saltpeter "may be made to grown artificiallie" in a way unlike the earlier nitraries had become common among Hartlib Circle chemical philosophers and projectors. A great debate still lingered concerning the appropriate base matter, the necessity of dung or urine, the proper amounts of sunlight and moisture, and the amount of time necessary for its completion. In a letter to Hartlib on 29 March 1653,

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[83] Hartlib, *Notes on Saltpeter*, 6 February 1652, HP 39/1/4A. Hartlib commented on this Yorkshire source again the next year in his *Ephemerdes of 1653* (May through September), noting that "there is a kind of saltpeter coale observed only by Mr Dymock and to bee had in great plenty and cheape in Yorkeshire, which…is one of the richest mines on England." See HP 28/2/70A.
[84] Cheney Culpeper to Samuel Hartlib, 18 February 1653, HP 39/1/5A.
[85] Ibid.

Arnold Boate claimed to differ from Culpeper in his interpretation of the best way to grow it "both to the material, which should not be common earth, and as to the ferment, wherein the tops of grasse…will come wonderfull[y] short of [Girolamo Cardano's] speculations and expectations," which had promised multifold growth.[86] Boate preferred to continue using "the blood-urine, and other excrents of Liui*n*g creatures" in large quantities rather than plant matter or artificial chemical mixtures.[87] Where he agreed with Culpeper was on the troubling implication of the dual nature of saltpeter, which appeared both fully capable of creating life and taking it away, and on the point that the balance and differentiation between the two seemed to be significant in fully understanding its uses. "As to the nature of Niter," Boate wrote,

> Were [it] not *th*e work of a Letter, but of a whole Volume. [T]herefore content yourselfe for *th*e present with this short compendium of it, that fecunditie and nutriment, as well [in] vegetables as in animals doth whollie depend of niter [,] that both haue no greater enemie then nitre[,] which looketh like a riddle, but upon a right unfolding will appeare to be the plain truth. [N]either doe I in speaking of the enmitie haue anie regard at all to *th*e destructiue way wherein it is imployed for the making of gunpowder. Besides this use and its Medicinall Vertues, which are manie and great, it is of great utilitie…[88]

As Culpeper had argued, saltpeter required specific manipulation to produce the desired beneficial results. Boate showed little interest in saltpeter as a fertilizer and still less in its role in gunpowder, but rather hoped to understand its chemical properties for its medical applications.[89] Yet, given his affiliations with Hartlib, Worsley, and later Boyle, it seems

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[86] Arnold Boate to Samuel Hartlib, 29 March 1653, HP 39/1/6B. Boate was likely referencing Girolamo Cardano, *De subtilitate rerum* (Nuremburg: Johann Petreius, 1550), Book 5.
[87] Ibid.
[88] Ibid.
[89] Newman and Principe, *Alchemy Tried in the Fire*, 236-7 and 237 n.102. Newman and Principe argue that, in spite of the fact that both Arnold and Gerard Boate appear frequently among Hartlib's papers, only two documents demonstrate a clear interest in chymistry: the above quote from HP 39/1/6B and a note by Hartlib himself referring to an unnamed book by Etienne de Clave ("Estiene de Clauve"), which one brother had given to the other, that they and Robert Boyle had commended (HP 28/1/58B). This is true only if we

highly likely that both Arnold and his brother Gerard Boate had high hopes that if such a universal spirit of life in nature existed, it would be found in saltpeter.

In his March through May *Ephemerides* of 1653, Hartlib noted that a former Fellow of Trinity College, Cambridge, named "Mr. Jolly," whom he described as "a kind of Rosæcrucian or Adeptus," had been working with the well-known saltpeterman Mr. Worthington at Salisbury Court to create saltpeter artificially simply by adding small amounts of it to potash and allowing to it grow naturally. After an unnamed amount of time, "a certain quantity of salpeeter put amongst it…turns all the rest of the pot-ashes into salpeeter."[90] This process was similar to one described by Johann Moriaen, who had been the go-between for Worsley and Glauber in Amsterdam.[91] In the same way that Smith, Jolly, and Worthington had contended that saltpeter would multiply naturally given the proper medium in which to grow or with the addition of a single, simple ingredient, Moriaen claimed to have made his own observation about a certain "ferment," which, when added to an appropriate "fit matter…will cause the whole at lengtht [*sic*] to turne into the Nature of nitrium," in a manner that mirrored its natural growth.[92] This inexpensive and abundant

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consider a very narrow definition of chymistry to exclude iatrochemical medicine, commentaries on other chymical works, and the Boates's numerous correspondences with those involved in saltpeter projects. See, for instance, Samuel Hartlib to Robert Boyle, 28 February 1654, in Thomas Birch, ed., *The Works of the Honourable Robert Boyle*, 2nd edition, 6 vols. (London, 1772), Vol. 6, 80-81; HP 39/1/6A; Arnold Boate's interest in herbals and chymical medicines in W. Robertson, *The second gate, or the inner door to the holy tongue* (London, 1654) and H. Jessey, *The exceeding riches of grace, advanced by the spirit of grace* (London, 1647); Arnold Boate's annotations on husbandry in Samuel Hartlib, *His Legacy of Husbandry* (London, 1651), 189-216; and, at least generally speaking, Gerard Boate's own *Irelands Naturall History. Being a true and ample Description of its Situation, Greatnes, Shape, and Nature* (London, 1652), which discusses the composition of the soil, rocks, and minerals in Ireland, often in contemporary chymical terms. For more on the Boates's interests in chymistry, see also Stephen Clucas, "The Correspondence of a Seventeenth-Century 'Chymicall Gentleman': Sir Cheney Culpeper and the Chemical Interests of the Hartlib Circle," *Ambix* 40 (1993): 147-70; and Leng, *Benjamin Worsley,* 19-33 and 90.

90 Samuel Hartlib, *Ephemerides of 1653* (March – May), HP 28/3/62A.

91 For an overview of Moriaen's experience with saltpeter experimentation, see Young, *Faith, Medical Alchemy, and Natural Philosophy,* 196-206.

92 Johann Moriaen, "Notes on Saltpeter in Scribal Hand G, ? & Johann Morian," 18 May 1653, HP 39/1/11A. Internally, Hartlib had titled this with the simple heading "Observations on Saltpetre."

"fit matter" was composed of grass clippings and seeds, again sometimes mixed with a bit of lime or wood ash, while the ferment was the richest earth one could find, which was "impregnated with its own nitrous Spirit."[93] Unlike Worsley's recipe, Moriaen's technique conformed to more traditional sources with less regard for environmental conditions because "no season or weather shall hinder its fermentation."[94] Even covering it was unnecessary. Through this he promised "in a short time…a thousand hundred…as one of good and excellent Salt-Peter."[95] This ran counter to the trend in saltpeter experimentation—which tended to multiply the steps in search of the independent variable that would explain its efficacy—and instead sought multiple, simple recipes to compare against one another.

As Hartlib's intelligencer circle grew to include contributors from all over Europe and several in North America, new foreign sources with unique recipes increasingly contributed to the discussion. In April 1653 Boate wrote to Hartlib again with a lengthy description of how to grow saltpeter that he had learned from a French acquaintance named La Grange who had been paid a sum of ten thousand francs to conduct such an experiment. To begin, he wrote, take

> a parcell of good ground well digged, & well manured w*i*th dung, as for the richest corn, a couer is to be made ouer it, for to exclude *th*e sunne, & to hinder the growing of any hearbs, (:which would hinder the growing of Salpeter:) & then to sow salpeter on it, which might most comodiously be done by dissoluing it in water, & throwing *th*e water on the ground, the proportion he thinks to be a pound of salpeter for a footsquare of ground, after halfe a yeare you may pare away halfe a foot deep of your ground, & halfe a yeare after another halfe foot, & so from time to time, & you will haue an euerlasting mine of salpeter, & the deeper you come, the better it will be, but if at first you should pare it too deep, & cut away too much, you

[93] Ibid., 11B.
[94] Ibid., 11A.
[95] Ibid.

> would marr all. After the paring away of the uppercrust, *th*e ground must still be digged afresh.[96]

The precise proportions of each ingredient and the depth of burial remained a secret. Notably, this description also included instructions for weeding the ground, suggesting that La Grange was well aware of saltpeter's fertile properties. In the interest of knowledge sharing, Hartlib revealed this description—a "special, secret and ingenious speculation of [his] friend, the great experimenter"—verbatim to Robert Boyle the next year in 1654, claiming that he intended to write a book on the subject of saltpeter covering its "whole nature, intrinsical qualities, preparations, and all manner of uses." Hartlib related La Grange's recipe to Boyle in the hopes of receiving "a description concerning the *Hamburgh* saltpeter…under [his] own hands."[97] Here, Hartlib was referring to the work of Dr. Unmussig, the alias of Johan Brun, who was based in Hamburg and whose knowledge of saltpeter many within Hartlib's ambit coveted and frequently mentioned.[98] Of all the myriad figures cited by Hartlib with experience attempting to produce saltpeter artificially, none impressed Worsley, the Circle's resident saltpeter expert, more than Brun. "You will much oblige mee if you can learne any thing further about the Way of the Hamburg Man [Brun]," Worsley wrote to Hartlib in June of 1654, "bec*ause* [I] beleeve our Principles are

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[96] Arnold Boate to Samuel Hartlib, 12 April 1653, HP 39/1/6A.

[97] Ibid.

[98] Hartlib referenced "Dr. Unmussig" fourteen times in his *Ephemerides* between 1648 and 1654 and once again in 1657, almost all in reference to his saltpeter experiments. He also appeared in Hartlib's "List of Uses for Dymock's Inventions," undated, HP 56/12A, as an associate of Dymock who had aided in the construction of a waterwheel; Hartlib, "Notes to the Intelligencer of Health and Wealth," undated, HP 32/21/10A, where Hartlib listed a topic on which he commented ("*de fraxinus*" or "on ash"); Hartlib, "Copy Extracts on Saltpeter in Hartlib's Hand," undated, HP 39/1/25A; and ?Worsley to ?, 19 June 1649, Royal Society MSS, Boyle Letters 7.1, 1A. If this last one is, indeed, Worsley's letter, then he probably made Brun's acquaintance in Amsterdam (the letter's point of origin) while studying with Glauber. He wrote that is was a "favourable visit" and he believed him "of a good wit, free and open-hearted" and "judge[d] him an active and pleasant temper."

one."[99] Worsley then described the starting point of his own recipe and suggested that it was comparable to Brun's. However, this would be his last word on the topic of saltpeter.

The Decline of the **Sal Nitrum** *School among Projectors*: *Later Artificial Saltpeter Projects, 1655-1662*

In the second half of the 1650s, despite the repeated failure to produce large quantities of saltpeter artificially, interest in these projects continued unabated. According to Thomas Leng, Worsley's association with religious radicals in the Commonwealth army during this time caused him to adopt mystical interpretations of scripture and personal experience that demolished his once carefully erected barrier between human reason and divine revelation. His understanding of "spirit" in nature, which had previously compelled him to seek a vital force in physical matter, now took on entirely metaphysical and religious meaning.[100] With Worsley no longer engaged in saltpeter study or any other meaningful chymical pursuits, Hartlib turned to other alchemists and natural philosophers for the remainder of the 1650s. In his *Ephemerides* of 1655, Hartlib noted yet another new method of saltpeter production created by George Starkey—the Bermudan-born, Harvard-educated, American alchemist who had immigrated to England in November 1650—which Robert Boyle had recommended to him.[101] First referred to as "a young Physitian from New England" and a "most rare and incomparable Vniversal Witt," Starkey became acquainted with Hartlib on 11 December, shortly after the former's arrival in London at just twenty-

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[99] Benjamin Worsley to unknown recipient, 18/28 June 1654, HP 31/1/15A. Given that this letter directly discusses a number of issues Hartlib had written about the previous month, it seems likely that Hartlib was its recipient.

[100] Leng, *Benjamin Worsley*, 118 and 187-90.

[101] Hartlib, *Ephemerides* 1655, Part 1 (January – February), HP 29/5/6A-6B. For the most significant biographical details of George Starkey, see William R. Newman, *Gehennical Fire: The Lives of George Starkey, an American Alchemist in the Scientific Revolution* (Cambridge: Harvard University Press, 1994).

two years of age.[102] Hartlib delighted in Starkey's alchemical exploits—which, reputedly, included the transmutation of lead into gold—throughout the pages of his Ephemerides during the 1650s.[103]

Boyle and Hartlib's son-in-law Clodius, who had been working together in London in early 1655, attempted Starkey's method themselves. The principal ingredients were exceptionally simple: "a stratum of good fat earth" and a small amount of saltpeter to seed the mixture.[104] After emptying "all the Vrine of the House" from time to time upon it and letting the mixture sit undisturbed for four months, the saltpeter would increase fourfold.[105] Neither Hartlib, Boyle, nor Clodius reported on its efficacy, but Boyle noted several separate experiments attempted by Clodius around the same time, including trials to manufacture saltpeter out of seawater, aqua fortis, spirit of niter, and "seed of niter," and wrote several weeks later that Clodius believed he had achieved success with one of them, though he did not say which.[106]

Starkey immediately had two effects on the chemical philosophy of the reformers associated with the Hartlib Circle. First, he flatly rejected the *sal nitrum* theory originating with Sendivogius, De Nuysement, and De Vigenère, and heavily promoted by Worsley, calling those who sought the essence of life in saltpeter "grosse sots."[107] Secondly, he very

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[102] Hartlib, *Ephemerides* 1650 Part 2 (February – May), HP 28/1/57A.
[103] For reference to this transmutation, see Hartlib, *Ephemerides* 1653, Part 3 (May – 2 September), HP 28/2/68A-69B. Hartlib typically referred to Starkey, who published under the pseudonym "Eirenaeus Philalethes," as "Mr Stirk" or "Mr Stirke."
[104] Hartlib, *Ephemerides* 1655, Part 1 (January – February), HP 29/5/6A. This recipe is a near-verbatim description of Boyle's, found in Robert Boyle, "A Philosophical Diary. Begun this first of January, 1654/5 [Workdiary 12]," Royal Society MSS, Boyle Papers, Vol. 8, ff. 142*r-v.*
[105] Ibid., 6A-6B.
[106] Boyle, "A Philosophical Diary," Royal Society MSS, Boyle Papers, Vol. 8, ff. 147*r*. For the context of these experiments, see also Frank, *Harvey and the Oxford Physiologists*, 122.
[107] George Starkey, *Marrow of Alchemy* (London, 1654/55), Part 1, 58-59. For Starkey's ridiculing, see Hartlib, *Ephemerides* 1651, HP 28/2/7B. For more context of these passages, see Newman and Principe, *Alchemy Tried in the Fire*, 215 n.26.

quickly supplanted Worsley as the prime scientific influence on Boyle, and their working relationship transformed Boyle's understanding of the chymistry of salts (among other things).[108] Though he repudiated the *sal nitrum* school in favor of the Geberian mercurial tradition, Starkey and Boyle remained interested in vitalist alchemy, and the influence of Van Helmont and Helmontian chymistry endured within their work.[109]

One major interest for both was the alkahest—the putative universal solvent originally hypothesized by Van Helmont and later the principal desideratum of Glauber—and the possibility that it was composed of salts. Starkey claimed in an unaddressed letter, probably to Robert Boyle, on 26 January 1652, that he had discovered the recipe, which included salt, sulfur, and an unnamed alkaline substance.[110] Boyle eagerly anticipated a breakthrough on the creation of the alkahest, but he disagreed with Starkey's conclusions, which purportedly came to him in a dream sent directly by God.[111] Nevertheless, Boyle continued to believe that the alkahest was possible and that even if Starkey had reached his conclusions in an unorthodox way, there was something to the recipe and something to Starkey's claim that a "saline spirit" was a principal ingredient. Other new interests in salts and "saline spirits" included Boyle's search for a vital spirit in blood and his conviction that the properties of saltpeter would bolster the evidence for his corpuscular philosophy, a

[108] For Starkey's influence on Boyle, see Michael Hunter, *Boyle: Between God and Science* (New Haven: Yale University Press, 2009), 75-79. Hunter calls the years between 1649 and 1652 "the turning point" in Boyle's career. For the transition in Boyle's thinking about salts and saltpeter, see Frank, *Harvey and the Oxford Physiologists,* 121-128.

[109] See Neman, "From Alchemy to 'Chymistry,'" 514. Newman notes that followers of the *sal nitrum* school universally rejected attempts to create the philosopher's stone from common quicksilver.

[110] George Starkey, Royal Society MSS, Boyle Letter 5, ff. 133*r*-133*v.* Boyle also later claimed that an associate had used this recipe fruitfully. See Robert Boyle, *The Usefulnesse*, in *The Works of the Honorable Robert Boyle*, Vol. 2, 97. Starkey later elaborated upon this recipe in his *Secret of the Liquor Alkahest*, written under the pseudonym Eirenaeus Philalethes, where he called it a "noble circulated salt…yet…not a corporal salt made liquid by a bare solution, but is a saline spirit which heat cannot coagulate by evaporation of the moisture, but is of a spiritual uniform substance." See Eirenaeus Philalethes, *The Secret of the Immortal Liquor Called Alkahest or Ignis-Aqua*, in *Collectanea chymica* (London: William Cooper, 1683), 11-12.

[111] Clericuzio, "From Van Helmont to Boyle," 316.

mechanistic worldview envisioning all matter as composed of infinitesimally small, though not indivisible, particles.[112] While Hartlib professed interest in these investigations, they had little impact on the practical projects that had earlier preoccupied him. Their work continued to have a distinct intellectual impact on the chymistry of salts but this shift by Boyle and Starkey away from practical saltpeter projects marked a clear decline in their involvement with the artificial saltpeter projects of the Hartlib Circle.

Hartlib's correspondences and notes on saltpeter projects in the final half-decade of his life were characterized by two developments. The first was the continuation of an attempt to isolate the crucial ingredient for artificial saltpeter through the addition of new, previously untried substances or the subtraction of specific, traditional ones. The second was his growing interest in the possibility of creating saltpeter out of seawater, which was a project that operated concomitantly with others designed to desalinate seawater, sometimes called "sweetening" or "freshening," which themselves had developed new techniques in light of other projects designed to drain fens in southeastern England and reclaim coastal territory and convert it to arable land.[113] Unlike the later saltpeter projects,

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[112] For Boyle's interest in the vital spirit of blood and its possible saline nature, see Robert Boyle, *Memoirs for the Natural History of Humane Blood, Especially The Spirit of that Liquor* (London, 1684). These investigations are discussed in Clericuzio, "From Van Helmont to Boyle," 332; Allen G. Debus, "Chemistry and the Quest for a Material Spirit of Life in the Seventeenth Century', in M. L. Bianchi and Marta Fattori, eds*., Spiritus. Atti del IV Convegno Internazionale del Lessico Intellettuale Europeo* (Rome, 1984), 254-26; Frank, *Harvey and the Oxford Physiologists*, 186. For Boyle's corpuscularian philosophy and their possible saline or seminal nature, see Robert Boyle, *The Origine of Formes and Qualities According to the Corpuscular Philosophy* (London, 1666). For more on Boyle's corpuscularianism, see Clericuzio, *Elements, Principles, and Corpuscles*, 125-7; Peter Anstey, "Boyle on Seminal Principles," *Studies in the History and Philosophy of Biology and Biomedical Sciences*, 33 (2002): 597-630; William Newman, "The Corpuscular Theory of J.B. van Helmont and Its Medieval Sources," *Vivarium*, Vol. 31, No.1 (1993): 161-191; Frank, *Harvey and Oxford Physiologists,* 122-28; and Hunter, *Boyle: Between God and Science*, 3, 104, 117-120, and 213*.*

[113] Hunter, *Boyle: Between God and Science*, 217-18. On the draining of the fens, see in particular, Eric H. Ash, *The Draining of the Fens: Projectors, Popular Politics, and State Building in Early Modern England* (Baltimore, MD: Johns Hopkins Press, 2017), esp. chapters 7 and 8.

the desalination attempts held the attention of Boyle, as it did many English natural philosophers and projectors during the second half of the seventeenth century.

This first development led to some interesting, if ultimately unproductive, insights into the role of soil and sunlight in saltpeter growth. Throughout 1657 and 1658, a number of Hartlib's correspondents, including Cheney Culpeper and Henry Jenney, wrote that lime or calk, often mixed with chalk or a chalky soil, was the essential ingredient.[114] Culpeper claimed, following his replication of an experiment by one John Bate, that he had produced evidence "plainly & vndeniably…that the riches w*hi*ch the Lyme gives to the earthe is saltepeeter" and the consequences of this discovery were "too many & greate for [his] wearied hand to discourse now vpon."[115] Hartlib simultaneously carried on multiple correspondences with John Beale and Henry Oldenburg advocating—contrary to the practices of traditional saltpetermen, as well as Moriaen's earlier effort to simplify the recipe—that sunlight *was* necessary, and that new procedures for "condensing sunbeams" or "drawing the liquor from the beams of sun" were required. In the margins of Jenney's letter on the topic, Hartlib wrote, in no uncertain terms, "the explanation of this miracle is the point of the world."[116] Hartlib later received word from Worsley that Moriaen had actually produced a design for "an instrument of catching and condensing…sun-beams,"

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114 See Cheney Culpeper to Samuel Hartlib, 20 September 1657, HP 42/15/13A; Henry Jenney to Samuel Hartlib, 28 September 1657, HP 53/35/3A; and Samuel Hartlib, *Ephemerides* 1658, HP 29/7/10B. This, in fact, contributed the calcium carbonate necessary to create a reaction between potassium in wood ash and nitrates in decomposing organic matter.
115 Culpeper to Hartlib, 20 September 1657, HP 42/15/13A. See John Bate, *The Mysteries of Art and Nature* (London: Ralph Mab, 1634).
116 Ibid. *"…in Explic miraculi Mundi punct."* See also, Henry Oldenburg to Samuel Hartlib, 23 September 1658, HP 39/3/16A. While in Mainz, Oldenburg had met Johan Joachim Becher, who, among other things, had described a perpetual motion machine and an indestructible submarine ("*Nova inventio Argonautica*") he had invented, and vouchsafed to Oldenburg a recipe for artificial saltpeter. For more on their meeting, see Smith, *The Business of Alchemy*, 59-63.

presumably meaning a lens of some sort.[117] Though not explicitly devised for saltpeter projects, Hartlib seemed extremely interested in its implications for them. One week later, Hartlib wrote to Boyle that Henry Oldenburg, then in Mainz, relayed to him a similar process formulated by Johan Joachim Becher. The process went as follows:

> You must put a couple of pounds of good mercury into an alembic, luting the head thereof as well as is possible, to the end that nothing exhale, and expose the said alembic into the sun against a wall of reverberation in the hottest time of the year; upon which he said the mercury would after some time draw the ce[le]stial spirit, and coagulate it into a yellowish liquor, that would be a considerable dissolvent. So much he spoke in gross, which I pray communicate with Mr. *Boyle*. At the first I would not have it go farther than to Mr. *Boyle*, and according as he shall judge of it, we may proceed farther.[118]

Hartlib simply deferred to Boyle's expertise on the subject. Sunlight remained a conundrum in these projects. As we have seen, some recipes required it and others eschewed it, while still others made no comment one way or the other. Among those that prescribed sunlight, some argued that the heat was necessary, some the light, and some proffered more metaphysical causes.

Almost all of Hartlib's references to saltpeter projects in the final three years of his life involved conjectures about the possibility of using seawater or other saltwater as a base for creating saltpeter. These projects were likely an outgrowth of similar speculation about removing the salt from seawater to make it potable, which had obvious ramifications for the livelihood of long-distance sailors and naval provisioning. This also remained the sole saltpeter topic about which Robert Boyle corresponded with Hartlib during this time.

The concept of desalination had a deep history, even if technologically driven projects to accomplish it did not begin in earnest until the seventeenth century. Numerous

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[117] Samuel Hartlib to Robert Boyle, 5 April 1659, in *Works of the Honourable Robert Boyle,* Vol. 6, 116-7.
[118] Samuel Hartlib to Robert Boyle, 12 April 1659, in *Works of the Honourable Robert Boyle,* Vol. 6, 118.

ancient references to the distillation of seawater can be found in Thales of Miletus, Hippocrates, Aristotle, and Pliny the Elder, among others, and by the Middle Ages, copious similar techniques, including filtration through dense soil or wax, distillation using an alembic, and evaporation into fine, porous cloths like wool fleece and linen existed.[119] By Hartlib's lifetime, mariners, projectors, alchemists, and naval officials were pursuing these and a slew of other ways to desalinate seawater.

In Madrid in the early 1590s, an Italian Jewish spy in service of Phillip II of Spain named Simone Vitale Sacredote presented a secret plan for desalination, while the English privateer Sir Richard Hawkins later recorded that his sailors had some success with distillation techniques during their 1593-94 expedition around Cape Horn.[120] Spanish seaman Pedro Fernadez de Quierós noted the same thing on a voyage to the South Pacific the following year. Around the turn of the seventeenth century, administrators for the

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[119] Hippocrates, *Airs, Water, and Places*, 8; Aristotle, *Meteorologica*, 3.358.16-18 and 359.1-5; and Pliny the Elder, *Historia Naturalis*, 31.70. For a brief rundown of ancient references to desalination, see Giorgio Nebbia and Gabriella Nebbia-Menozzi, "Early Experiments on Water Desalination by Freezing," *Desalination* Vol. 5, No. 1 (1968): 49-54; idem, "A Short History of Desalination," *Acque Dolce dal Mare, II Inchiesta Internazionale*, *Proceedings of the International Symposium*, Milan, (April 1966), 129-172; and Joseph Needham, Ho Ping Yü, Le Gwei Djen, and Nathan Sivin, *Science and Civilisation in China,* Vol. 5, Part 4 (Cambridge: Cambridge University Press, 1980), 60-62. Other ancient writers who wrote about desalination include Plato (in the *Timaeus* and *Laws*), Theophrastus, Dioscorides, Plutarch, Olympiodoros, Alexander of Aphrodisias (in a commentary on Aristotle's *Meteorologica*), Basil of Caesarea (in the *Hexameron* 4.7), and Johannes Philopanus. In the Middle Ages, commentaries and discussions of these techniques were especially common in the Islamic world, such as those by Arab surgeon Abū al-Qāsim al-Zahrāwī and Persian physician Abu Mansur al-Harawi. There were, reputedly, similar trials attempted by seamen in Zheng-he's treasure fleet. In the Latin West, all three techniques were recorded in the fourteenth-century text by John of Gaddesen, *Rosa Anglica*, or *Rosa Medicinæ* (c. 1305-7). The last method was illustrated in the 1559 version of Conrad Gessner, *Thesaurus euonymous philiatri* (London, 1559), 17. The original edition was published in Zurich in 1552. He claimed his information came from al-Zahrāwī. Other Muslim and Medieval Latin commentators include al-Hirani, al-Niruni, Nikepherous Blemmides, Gilbertus Angelicus, Leon Battista Alberti, and Giambattista della Porta. For this and other basic information, see Anthony A. Delyannis and Eurydike A. Delyannis, *Sauerstoff: Anhangband Wasser-Entsalzung* (Berlin and Heidelberg: Springer-Verlag, 1974), 5-6.

[120] For Vitale Sacredote, see Andrea Gaberini, ed., *A Companion to Late Medieval and Early Modern Milan: The Distinctive Features of an Italian State* (Brill: Leiden and Boston, 2015), 398; and Flora Cassen, "Philip II of Spain and His Italian Jewish Spy," *Journal of Early Modern History*, Vol. 21, No. 4 (2017): 318-342, quoted in Flora Cassen, *Making the Jews in Renaissance Italy: Politics, Religion, and the Power of Symbols* (Cambridge: Cambridge University Press, 2017), 90 n.27. For Hawkins, see James D. Birkett, "Desalination Activities in England during the Late Seventeenth Century," *IDA Journal of Desalination and Water Reuse,* Vol. 3, No 4 (2001): 14-20; and Sir Richard Hawkins, *Voiages to the South Seas* (London, 1622).

Dutch East India Company (VOC) began investing in schemes to create stills for use on long, transoceanic voyages. In 1624, Amsterdam physician and scientific supervisor to the Amsterdam Chamber of the VOC, Aegidius Snoek, developed a portable still for shipboard use, which allegedly worked well but was prohibitively expensive. His Dutch compatriot, the inventor and engineer Cornelius Drebbel, later improved upon the device by making it smaller and more efficient.[121] Commercial competition with the Dutch in the seventeenth century impelled the English to invest in their own desalination plans, both private and state-funded. Hartlib would have been aware of many of these examples and Boyle clearly was.

Hartlib's interest in these projects dated back to 1654, when he repeatedly enquired about a former major from the Royalist army named Saunderson, whom he later discovered had been acquainted with another of his frequent correspondents, Sir Kenelm Digby, a keen student of alchemy.[122] Digby informed Hartlib that Saunderson "is full of all manner of Inventions and vndertakes great matters for making of saltpeter" and had begun a program of converting simple seawater into saltpeter through fermentation on land he had bought for £300 in Ireland, although he had kept the precise recipe a secret.[123] Hartlib's son-in-law Clodius vouched for both Saunderson and the process. "Hee [Saunderson] does it by a way of Leven or ferment (w*hi*ch my son Clod*ius* hit vpon before hee told it him)," Hartlib wrote, "and therefore requires some lenght [*sic*] of time. An

[121] R.E.W. Maddison, "Studies in the life of Robert Boyle, FRS, Part 2: Saltwater Freshened," *Notes and Records of the Royal Society*, 9 (1952): 196–216; and Mathieu Torck, *Avoiding the Dire Straits: An Inquiry into Food Provisions and Scurvy in the Maritime and Military History of China and Wider East Asia* (Weisbaden: Hasserowitz-Verlag, 2009), 214.
[122] Samuel Hartlib, *Ephimerides of 1654* (January – April), HP 29/4/9A.
[123] Ibid. This is the first mention of Saunderson in Hartlib's own writings. I have been unable to find Digby's letter to Hartlib in which they first discussed him. Hartlib mentioned him again in his next *Ephemeris of 1654* (April – August), HP 29/4/15A, though there is no new information in this entry.

extraor*dinary* com*m*odity for Irel*and* that it may bee furnished sufficiently."[124] Hartlib wrote excitedly to Robert Boyle about the potential of this project. Boyle wrote Hartlib back in May with affirmation that it could work, though he granted only lukewarm approval of the idea. However, Worsley disagreed. Shortly after Boyle's letter, he informed Hartlib that he could not "bee so modest as to thinke Major Saundersons Proposition of making Saltpeter out of Sea or Salt Water to bee any thing."[125] Hartlib continued to express hope in this scheme in future letters with Boyle, though Worsley's interest in the technical aspects of saltpeter production had by this point reached its nadir and he never wrote on the topic again.[126]

By April 1659, Hartlib "endeavor[ed] to inform himself" the best he could "concerning the way of making saltpeter out of sea-salt."[127] He wrote to the Dutch historian and professor at the University of Leyden, Georg Horn, in late April, plying him with "some considerable presents…of books and manuscripts" to persuade him to divulge information about an experiment there to turn seawater into freshwater, but he either received no reply or the response has been lost.[128] Shortly thereafter, Henry Oldenburg left Mainz, where he had been meeting with Becher, and traveled to France, where he made inquiries through an unnamed contact about whether "there were no French philosofer [that] hath

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[124] Samuel Hartlib, *Ephimerides of 1654* (25 April – August), HP 29/4/15A.
[125] Benjamin Worsley to unknown recipient, 18/28 June 1654, HP 31/1/15A.
[126] According to Thomas Leng, in the final two decades of his life, Worsley's interests became much less worldly, and much more spiritual. Even the millennarian, universal reformative projects that had occupied his early professional life had been internalized as a spiritual reform later in his life. See Leng, *Benjamin Worsley*, 187-95.
[127] Hartlib to Boyle, 9 April 1659, in *The Works of the Honourable Robert Boyle,* Vol. 6, 116-7.
[128] Hartlib to Boyle, 12 April 1659, and Hartlib to Boyle, 17 May 1659, in *The Works of the Honourable Robert Boyle,* Vol. 6, 118 and 125. Hartlib mentioned that he was awaiting a return letter from Horn in several other correspondences over the next several months, but I have found no evidence that one ever came. I have found only one letter from Horn to Hartlib and it is undated (HP 16/1/1A-1B). Though it has the epigram "*Chymica et Phylosophica*," there is little in it about chymistry or natural philosophy, let alone the desalination of seawater.

the way of making saltpeter out of seasalt," but he too never reported back regarding these requests.[129] Hartlib died in 1662 without any of these plans coming to fruition.

Oldenburg's contact may have been Balthasar de Monconys, on whose works he later reported to the Royal Society. De Monconys had visited England in 1663 and examined the still that had been produced by Cornelius Drebell, then in the hands of his daughter Catherina Kuffler and his son-in-law Johannes Sibertus Kuffler.[130] De Monconys reported in his autobiography the *Journal des voyages de Monsieur de Monconys* that he had met with Oldenburg around this time to compare notes on measurements they had both taken on properties of seawater, on a cylinder for testing its pressure, density, and salinity at different depths, and on an aerometer for establishing the specific gravity of seawater.[131] These experiments clearly possessed scientific value and merited mention in the first volume of *Philosophical Transactions of the Royal Society* in 1665. Therein, an anonymous observer also reported on experimental trials to replicate the wax filtration jar first described by Aristotle.[132]

Robert Boyle's involvement in these activities endured another two decades, as he became embroiled in a patent controversy over a desalination device developed by his nephew Robert Fitzgerald in 1683 and a man named William Walcot, who had patented a similar device eight years earlier. He penned three works concerning the chymical properties of saltwater during this time, including "Observations and Experiments on the Saltiness of the Sea" (1673), *Short Memoirs for the Natural and Experimental History of*

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[129] Oldenburg to Hartlib, 30 April 1659, HP 39/3/22B.
[130] Nebbia and Nebbia-Mezzoni, "A Short History of Desalination," 145.
[131] Balthasar de Monconys, *Journal des voyages de Monsieur de Monconys* (Lyons, 1666), 27 and 57.
[132] *Philosophical Transactions, Royal Society of London* (hereafter *Phil. Trans.*), Vol. 1, No. 7, (4 December 1665), 127-128.

Mineral Waters (1685), and the pamphlet in explicit defense of his nephew's claims, *Saltwater Sweetned* (1683).[133] The prospect of transforming seawater into saltpeter appeared in none of these projects, correspondences, patents, or published works.

Ultimately, all of these various new attempts, so far as we know, failed to produce saltpeter in the cornucopian quantities Hartlib and his associates assumed were possible. The traditional methods of mining or creating it through the unpalatable process of saltpeter beds or plants filled with animal waste still managed to produce it more simply and in greater quantities, even as Hartlib, Worsley, and others desired to supplant these unpleasant methods. Neither of these would ultimately be as important, however, as international trade.

In England, the East India Company overtook foreign imports, domestic mining, and domestic manufacturing plants in the amount of saltpeter it was able to obtain beginning in the late 1630s and early 1640s, first turning a profit in 1643 and attaining enough Indian refineries to manufacture high-quality saltpeter by 1644. Beginning in the 1620s, EIC ships, imitating the Dutch, began using saltpeter instead of rocks for ballast. Its preservative and insect repellant properties also helped to extend the life of ship hulls and protected perishable cargo like tea, pepper, indigo, and various spices. As early as 1639, the company had to regulate the amount of saltpeter they shipped to England for fear of flooding the market and crashing the price.[134]

[133] For Boyle's experiments and writings on saltwater, see Hunter, *Boyle: Between God and Science*, 215-221. For his involvement in the patent dispute between Fitzgerald and Walcot, see Adrian Johns, *Piracy: The Intellectual Property Wars from Gutenberg to Gates* (Chicago: University of Chicago Press, 2009), 73-78.
[134] On these details, see "The History of Saltpeter," Parts I-XIX, February 26 – June 6, 2016, *Firearms History, Development, and Technology* (blog), http://firearmshistory.blogspot.com/.

It was during the early Restoration, though, that the domestic production of saltpeter became largely superfluous due to the massive, relatively inexpensive influx of it from India.[135] By the late 1660s, the EIC had ensured massive amounts of naturally mined and refined saltpeter made its way to the shores of England.[136] In the 1620s, the English imported just twenty to thirty tons of saltpeter per year—an amount that could be burned through in mere days during major cannon sieges. This increased to 280 tons in the 1630s. By 1670, Charles II's government could count on nearly 1000 tons—most of it mined in Bengal and refined in Surat and Ahmedabad—to flow to the Ordnance Office.[137] At this point, the EIC had amassed a virtual monopoly on the product. Once consistent trade had safeguarded the supply, the domestic production of saltpeter ceased to be a necessity, at least for national security.

In agriculture and husbandry, other reforms in like new techniques for crop rotation and fallowing, the introduction of new fodder grasses, and new plowing technologies, among other innovations, held much greater sway amongst agricultural improvers, farmers, and plantations owners, who focused on less eccentric and risky endeavors. The desire for a stable, consistent, and potent artificial fertilizer remained, though, and further searches for such a substance owed a great deal to vitalist matter theory and this vitalist version of alchemy.

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[135] Cressy, *Saltpeter*, 133-5.
[136]Ibid. On the role of the English East India Company in the global saltpeter trade, see also, Chaudhuri, *The Trading World of Asia and the English East India Company 1660-1760*; Frey, "The Indian Saltpeter Trade, the Military Revolution, and the Rise of Britain as a Global Superpower," 507-554; and Buchanan, "Saltpetre: A Commodity of Empire," 77.
[137] Ibid., 139.

Conclusions

Understanding how alchemy and chemical philosophy influenced the life sciences is imperative if we are to gain a greater understanding of the reciprocal relationship between practical and theoretical sciences in the early modern era. Most members of the Hartlib Circle who were interested in understanding the ultimate *spiritus vitalis* thought to inhere in all matter were also interested in how to harness that spirit for practical gain, whether supplying gunpowder to the nation or chemical fertilizers for agricultural reform. The study of saltpeter as a potential incubator for the spark of life and as the material lynchpin for vastly more productive agriculture is a case study in these issues.

Worsley's interpretation of salts in general and saltpeter in particular was a relatively common one among mid-seventeenth-century alchemists and matter theorists, and he sought the eventual application of these theoretical processes in the service of practical goals, such as the ability to create better fertilizers and realize a more abundant supply of one of the chief ingredients of gunpowder, in addition to discovering the vital, life-giving principle underlying all matter. Samuel Hartlib, and many members of the circle surrounding him, saw the discovery of these underlying principles not just as a matter of national security, as the Elizabethan Jacobean governments did, nor as a promising way to make money, as the saltpetermen of these eras did. Neither was it regarded simply as a means to contribute practical solutions to agricultural scarcity. This endeavor was part of a long-term, overarching plan to recreate the conditions of Eden on earth and use the newfound powers of human science to manipulate and eventually change the natural conditions of life on earth.

This attitude motivated and sustained numerous alchemists, matter theorists, and agriculturists throughout the seventeenth century, and this reformative spirit is at the heart of *sal nitrum* school and the saltpeter projects of the Hartlib Circle. There seems to have been a genuine reciprocal nature to this process, even as many saltpetermen and projectors had little knowledge of alchemical laboratory techniques. Their fieldwork, or "rusticall chymistry" as Peter Smith designated it, clearly relied on a chemical worldview little different from those who toiled in the laboratory, even if the latter required a different technical expertise.

The technology, material substances, textual sources, and problem-solving techniques varied as conditions warranted, but this difference in venue does not imply a body of knowledge devoid of natural philosophical erudition. The fact that those figures more associated with laboratory work (Glauber, Moriaen, Clodius, Starkey, Boyle) overlapped heavily in their theoretical commitments and material interests with those more associated with fieldwork (Worsley, Beale, Smith, Dymock, Hartlib) substantiates this. Many of them, like Worsley, Moriaen, and Clodius, were at home in both, even if they possessed skills more suited to one setting or the other. The chemical philosophy based in part on Helmontian chymistry, Sendivogian matter theory, and the *sal nitrum* school of interpreting salts undergirded the worldview of most members of the Hartlib Circle interested in saltpeter projects. Discovering the vital seat of life in matter would lead to more potent fertilizers just as readily as trial-and-error attempts to create such fertilizers would lead them to a deeper understanding of how life arose from nonliving matter.

Given the proper technological, experimental, practical, and—most importantly—*manipulative* science, coupled with a belief that agricultural improvement was also a form of spiritual improvement, members of the Hartlib Circle genuinely believed they could ameliorate the human condition precipitated by the Fall. Yet, many of the vitalist alchemists I have examined oscillated between dreams of cornucopian abundance and fears of scarcity. After all, many of these projects to artificially create saltpeter and improve husbandry would not be necessary if scarcity did not lie heavy on their hearts. But without the belief in the *capacity* of nature to provide all material needs through human ingenuity and resourcefulness, cornucopianism would not be thought possible. These concomitant anxieties and aspirations characterized their alchemical and agricultural pursuits throughout the seventeenth century.

CHAPTER 3

A LABORATORY IN THE FIELD(S): THE ALCHEMY AND CHYMISTRY OF SEED STEEPS AND FRUCTIFYING WATERS

"O heaven! O water! O Mercury! O and our salt-nitre, abiding in the sea of the world! O vegetable! O sulfur fixed and volatile! O *caput mortuum*, or deadhead, or feces of our sea! O water that wets not our hands, without which no mortal can live, and without which nothing grows, or is generated in the whole world!"

--Michael Sendivogius, *Novem lumen chemicum*, 44.

Introduction

While saltpeter eventually became one of the most promising avenues for Hartlib Circle members seeking the vital spirit inherent in matter, many other material substances were available. Sometimes these were deceptively simple, like water. In one of the most celebrated and cited trials on plant growth from the early seventeenth century, Paracelsian chymist and physician Johan Baptista van Helmont conducted an experiment to investigate the relationship between living and non-living matter and the ways that plants used water, soil, air, and other substances to sustain themselves. He placed a willow tree sapling into a container of soil, both of which he had meticulously weighed. For five years, he kept the tree sheltered from the elements, ensuring that he was the only one who added water to the soil. At the conclusion of his experiment, he reweighed both the soil and tree. The five-pound sapling had grown into a 169-pound tree while the soil had reduced in weight by mere ounces. As Van Helmont wrote, "one-hundred and sixty-four pounds of wood, bark, and roots have come up from water alone."[1]

According to this experiment, a willow, and by extension other trees, were properly understood as transmuted water, created by an inner activating agent of the willow tree. This vital principle had reorganized the inert matter of the water into all of the living parts of the tree. For Van Helmont, the vital principle of life was to be found in the tree but galvanized by the water, which, along with air, constituted one of the two "primogenital" or fundamental elements. Based on his reading of Genesis, water was nobler than earth, as the heavens had contained the waters from which the earth was made—he simply extrapolated their material relationship on earth and the priority of their importance from this exegesis.[2] For Van Helmont, and for many who studied him, the potential liquefaction of solid material on earth, from stones, sand, and clay to plant and animal bodies, which often became or produced crystalline salts upon heating, boosted his theory that water was the primeval element and that a universal solvent, or alkahest, was possible. Much of the debate among alchemists, agricultural reformers, and projectors who subscribed to vitalist theses revolved around what element contained these principles of life and what elements activated them.

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[1] Johan Baptista van Helmont, *Oriatrike or Physick Refined,* trans. John Chandler (London: Lodowick Loyd, 1662), 109, quoted in Allen G. Debus, *The Chemical Philosophy: Paracelsian Science and Medicine in the Sixteenth and Seventeenth Centuries*, Vol. 2 (New York: Science History Publications, 1977), 319. *Oriatrike* was an English translation of his *Ortus medicinae, vel opera et opuscula Omnia* (Amsterdam: Lodevijk Elsevir, 1648), sometimes shortened as *Ortus* or *Opuscula*. The section from which this experiment is derived is titled "Complexionum atque mistionum elementalium figentum." It should be noted that it is likely Van Helmont did not devise the experiment himself, even if the details were his alone. Nicholas Cusanus described a similar experiment in *De Staticus Experimentis* of 1450, and he in turn had replicated it based on an anonymous Gnostic theological tract from ca. 200-400 C.E. called *Recognitions*. See Walter Pagel, *Joan Baptista Van Helmont: Reformer of Science and Medicine* (Cambridge: Cambridge University Press, 1982), 53-56; and H.M. Howe, "The Root of van Helmont's Tree," *Isis* 56 (1965): 408-419.

[2] See Genesis 1:2-9 and 1:20.

This experiment had a long afterlife and many other natural philsophers cited it throughout the seventeenth century, in part for its ingenious methodology, but just as often for its specific results, which suggested the great importance of investigating aquaculture for clues to plant growth. Remarking that some plants like duckweed and water-mint grew in water without soil, John French cited Van Helmont's experiment as evidence that "vegetables are produced out of water."[3] Samuel Hartlib had listed the experiment in a short document containing notes and methods for growing fruit trees and again in his 1656 *Ephemeris*, where he called it Van Helmont's "experiment of fructifying of Trees by means of water…inferring thence that water hath a marvelous fructifying nature in itself."[4] Though he noted that it might simply dissolve other "alimentary" necessities and transport them to the roots, Robert Boyle claimed that it demonstrated "the easy Transmutableness of water" and seemed to agree generally with Van Helmont upon replication of the experiment.[5] Thomas Browne mentioned it in passing when writing on the preservation of the "generative and medicinall virtues of plants" among those grown hydroponically in glasss containers, while Robert Sharrock, a pupil of Boyle's, based an entire regime of water experiments around this example.[6] More than any specific reference, Van Helmont's willow

[3] John French, *The Art of Distillation…* (London, 1653), 108-9.

[4] Samuel Hartlib, "Notes on Fruit Trees," undated, HP 55/14/25A; Samuel Hartlib, *Ephemerides 1656*, Part 3, June 1656 – September 1656, HP 29/5/90B.

[5] Robert Boyle, *The Origin of Formes and Qualities* (London, 1666), 121-22. On the experiment's replication, see also Robert Boyle, *The Sceptical Chymist* (London, 1661), 68.

[6] Thomas Browne, *Hydriotaphia, urn-burial, or, A discours of the sepulchral urns lately found in Norfolk together with the Garden of Cyrus, or, The quincuncial lozenge, or network of plantations of the ancients, artificially, naturally, mystically considered: with sundry observations* (London, 1669), 63; and Robert Sharrock, *The history of the propagation & improvement of vegetables by the concurrence of art and nature:: shewing the several ways for the propagation of plants usually cultivated in England, as they are increased by seed, off-sets, suckers, truncheons, cuttings, slips, laying, circumposition, the several ways of graftings and inoculations; as likewise the methods for improvement and best culture of field, orchard, and garden plants, the means used for remedy of annoyances incident to them; with the effect of nature, and her manner of working upon the several endeavors and operations of the artist. Written according to observations made from experience and practice* (London, 1660), esp. 53-55 and 107-9.

tree experiment, in part, helped catalyze a generation of water-culture, seed-steeping, and "fructifying" ventures and incentivized agriculturists and naturalists to seek the sources of plant nutrition and the wellspring of fertility in everyday organic materials that could be dissolved into water.[7] In spite of Van Helmont's example, however, water alone was almost never sufficient for these experimental trials and an array of chymical combinations added to water became increasingly common throughout the seventeenth century.

In this chapter, I detail some of these ventures and in particular the ways that alchemical knowledge of various chymical substances and the processes of altering and recombining them led to novel, if often ineffectual, liquid concoctions designed to produce more potent seeds. Various individuals, from ordinary farmers to large landholders to elite alchemists, applied chymical substances to seeds and saplings, with the goals of hastening germination, increasing the quality and quantity of crop yields, guarding against fungal diseases and other maladies, and repelling insects and rodents. In the process, they also garnered input from works on husbandry reform, iatrochemical medicine, and vitalist alchemical theory and added to the growing body of knowledge about the function of seed germination, the lifecycle of plants, and the relationships between plants and soil, water, air, and fertilizers. They also suggested ways that these substances could be manipulated and exploited for agricultural and economic benefit.

Though the early modern era was not the first to see the use of chymical substances in agriculture and horticulture—in the West, they dated back at least to pre-classical Greece, if not to earlier oral traditions—it seems to have been the earliest to produce an

[7] Webster, *The Great Instauration*, 331. See also, idem., "Water as the Ultimate Principle of Nature: The Background to Boyle's *Skeptical Chymist*," *Ambix* 13 (1966): 96-107; and J.R. Partington, *A History of Chemistry*, Vol. 2 (New York: St. Martin's Press, 1962), ii and 223-4.

explicitly alchemical context for their production and use. A number of other practical, agricultural problem-solving techniques incorporated chymical substances normally associated with alchemical laboratories and apothecaries. Many agricultural writers, beginning especially in the mid to late sixteenth century and accelerating in the seventeenth, regularly discussed alum, quicklime, natron, distilled water, blue vitriol, potash, vitriolic acid, verdigris, copperas, all manner of salts including saltpeter, and mixtures of numerous, sometimes secret substances often called "fructifying waters," among many other things, as liquid solutions to steep seeds or use as pest control for crops.[8] Many agricultural reformers made every effort either to procure these substances or to create them artificially for these purposes. Like artificial saltpeter projects, their goals were manifold: they sought to improve agriculture and reform the methods of husbandry, to increase the quantity of viable seeds and alleviate the risks of poor harvests, and to develop marketable and sometimes patentable recipes for profit. And they sought to answer two of the knottiest questions in botany—what caused seed germination and could this be controlled?

Husbandry Manuals, Salts, and Seed Steeps from the Late Sixteenth through Seventeenth Centuries

In seventeenth-century England the sources of fertility and the causes of germination had yet to be explained. Many attempts—particularly among elites who had

[8] For a fairly comprehensive list of various chemical substances used in pre-Industrial agriculture in Europe from the ancient world to the mid-nineteenth century (though an incomprehensive list of historical sources), see Allen E. Smith and Diane M. Secoy, "A Compendium of Inorganic Substances Used in European Pest Control before 1850," *Agricultural and Food Chemistry*, Vol. 24, No. 6 (1976): 1180-1191; and idem., "Early Chemical Control of Weeds in Europe," *Weed Science*, Vol. 24, No. 6 (1976): 594-597. For more information specifically about salts, see idem., "Salt as a Pesticide, Manure, and Seed Steep," *Agricultural History*, Vol. 50, No. 3 (1976): 506-516.

some experience with both husbandry and alchemy—hinged on interpreting Paracelsian matter theory and its offshoots, Aristotelian cosmology, and classical farming traditions, and synthesizing or reconciling these to create a comprehensive vegetable philosophy. Yet, skilled laborers, farmhands, and grain merchants also contributed a great deal to seventeenth-century knowledge of seeds. While chemical agriculture has become an important subfield of the history of science, much of the historiography of agriculture itself has taken a macroscopic view, focusing on issues such as land management, longitudinal quantitative analyses of crop yields and population growth, and the long-term effects of changing agricultural practices.[9] However, understanding plant growth, as seventeenth-century agricultural reformers well knew, began with understanding seeds. The use of various words for "seeds"—*semina, sperma, archeus*—to describe the generative properties of matter in the theories of Paracelsus, Sennert, Severinus, Sendivogius, and various subscribers to the *sal nitrum* school was no mere metaphor.[10] Adherents of these modes of thought understood the generative power in nature as the unfolding of some seminal

[9] On some important deviations from this trend that fruitfully combines agricultural history and the history of the science of seeds and seed steeping, see Secoy and Smith, "A Compendium of Inorganic Substances Used in European Pest Control before 1850," 1180-91; idem., "Salt as a Pesticide, Manure, and Seed Steep," 506-16; Joan Thirsk, *Agricultural Change: Policy and Practice, 1500-1750*, Vol. 3: *Chapters from the Agrarian History of England and Wales* (Cambirdge: University of Cambridge, 1990); G.E. Fussell, "Crop Nutrition in Tudor and Stuart England," *British Agricultural History Society*, Vol. 3 (1955): 95-106; idem., *Crop Nutrition: Sceince and Practice before Liebig* (Lawrence, KS: Coronado Press, 1971), esp. 53-74; F.A. Buttress and R.W.G. Dennis, "The Early History of Cereal Seed Treatment in England," *Agricultural History Review*, Vol. 21, No. 2 (1947): 93-103; and somewhat more recently, Malcolm Thick, "Garden Seeds in England before the Late Eighteenth Century, Part I: Seed Growing," *Agricultural History Review* Vol. 38, No. 1 (1990): 58-71; Mauro Ambrosoli, *The Wild and the Sown: Botany and Agriculture in Western Europe, 1350-1850* (Cambridge: Cambridge University Press, 1997); and Elizabeth Scott, *The Secret Nature of Seeds: Science and Seed Improvement, c. 1520-1700* (PhD Dissertation, University of East Anglia, 2016).

[10] See Christoph Lüthy, "Seeds Sprouting Everywhere," *Annals of Science* 64 (2007): 411-420; and Jole Shackleford, "Seeds with a Mechanical Purpose: Severinus's *Semina* and Seventeenth-Century Matter Theory," in *Reading the Book of Nature: The Other Side of the Scientific Revolution*, ed. Allen G. Debus and Michael T. Walton (Kirksville, MO: Truman State University Press, 1998), 15-44. On the origins of these terms in the context of seed metaphors, see Peter Severinus, *Idea medicinæ philosophicæ* (Basel, 1571); Michael Sendivogius, *Novem lumen chemicum* (Frankfrut and Prague, 1604); and Paracelsus, *Labyrinthus medicorum errantium*, in *Sämtliche Werke*, Vol. 11, 183.

principle in matter, just as the growth of a plant was the unfolding of some virtue, quality, or design housed in its seed. Even as larger schemes of transforming husbandry from enclosure to new methods of field rotation to the wholesale adoption of alternative crops occupied a great deal of the time and imagination of reformers, a considerable amount of energy was spent attempting to understand how water, soil, air, and chymical substances affected seeds.

In some cases, water by itself was held to have enriching properties beyond its basic necessity for plant sustenance. In his 1569 *Booke of the Art and Maner*, *Howe to Plante and Graffe, all sortes of trees…*, an uncredited, mostly plagiarized translation of the French Benedictine Davy Brossard's *L'Art et Manièr de Semer…*, Leonard Mascall wrote that when flowers blossomed on certain trees in the spring, water or lightly salted water should be sprinkled on the buds and petals to discourage caterpillars.[11] Gabriel Plattes suggested a similar remedy for hop plants when they gathered mildew.[12] John Worlidge noted that during droughts or prolonged periods without ample rainfall, small amounts of water brushed onto the leaves of "Sweet-bryar and Gooseberry, which are only Lowsie in dry times," would protect them from lice.[13]

Some of the oldest and simplest recipes for steeping seeds involved water mixed with salts. As we saw in the previous two chapters, saltpeter's effectiveness as a fertilizer had become apparent over the course of the later Middle Ages and through the sixteenth

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[11] Leonard Mascall, *A Booke of the Arte and maner howe to plant and graffe all sortes of trees, howe to set stones, and sowe Pepines to make wylde trees to graffe on…With divers other new practise, by one of the Abbey of Saint Vincent in Fraunce…With an addition…of certaine Dutch practises, set forth and Englished by L. Mascall* (London, 1569); and Davy Brossard, *L'Art et manière de semer, et faire pepinieres des sauvageaux* (Lyon: Olivier Arnoullet, ?1543). Mascall also pulled from other German and Dutch works. On this remedy in particular, both cited Theophrastus's *Historia plantarum* and Pliny the Elder's *Historia naturalis.* See Secoy and Smith, "Compendium of Inorganic Substance Used in Pest Control," 1188.
[12] Gabriel Plattes, *Practical Husbandry Improved* (London, 1656), 62.
[13] John Worlidge, *Systema Agriculturæ* (London, 1669), 198 and 216.

century, at least in part due to the observation that plants flourished in niter beds and because of the already fertile raw materials sourced for its production. Saltpeter fabricated at these artificial plants for use in agriculture could be baked into clods of soil and then crumbled over land or dissolved into water intended to soak seeds or be sprayed over fields. Other salts also saw a great deal of use in seed-steeps and brining liquids, either as germination aids or pest control. These were regularly combined with unslaked lime, in addition to well-known fertile materials such as animal dungs and urine, marl, clay, or pond muck.[14]

Like those who made similar comments made about saltpeter, many early modern agricultural writers remarked upon common salt's generative and destructive powers. In large quantities or in oversaturated mixtures it readily killed weeds and pests, but its existence as detected in calcinated or distilled plant matter, as well as in the blood of animals, indicated it was also necessary to sustain life. Its damaging effects on vegetation and soil are mentioned in the Biblical book of Judges and in Greco-Roman agricultural writers including Xenophon, Virgil, Pliny, and Palladius.[15] Numerous husbandry manuals in the sixteenth and seventeenth centuries mentioned salting in between rows of crops and on gravel pathways to eliminate weeds.[16]

Notably, in some of these texts, authors observed that an unexpected side effect of this type of earth salting was that its immediate result was to eradicate unwanted plant life

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[14] Joan Thirsk, *Agricultural Change: Policy and Practice, 1500-1750*, Vol. 3, 20-21.

[15] Smith and Secoy, "Salt as a Pesticide, Manure, and Seed Steep," 506 and 506 n.1. On these references, see Judges 9:45; Xenophon, *Oeconomicus* 20.12; Virgil, *Georgics* 2.226; Pliny, *Historia Naturalis* 31.7; and Palladius, *On Husbandy* 1.9 (derived from a unique manuscript of ca. 1420).

[16] Smith and Secoy, "Compendium of Inorganic Substances Used in Pest Control," 1187. See Hugh Plat, *The Jewel House of Art and Nature* (London, 1594), 43; Gervase Markham, *A Farewell to Husbandry* (London, 1620), 11 and 22; John Evelyn, *A Philosophical Discourse of Earth* (London, 1676), 103; and John Worlidge, *Systema Horticulturæ* (London, 1676), 43.

but that in later years the areas that received the most salt also saw a concomitant rise in plant growth.[17] In his 1620 agricultural book *A Farewell to Husbandry*, Gervase Markham recommended that any farm within a reasonable cart ride from the sea coast or "any Creeke or River where [there was] salt water," should fetch a

> great store of the salt Sand, and with it couer your ground which hath beene formerly plowed and hackt, allowing to euery Acre of ground, three score or, fourescore full bushels of Sand, which is a very good and competent proportion; and this Sand thus layed, shall be very well spread and mixed amongst the other hackt and broken earth. And heerein is to be noted, that not any other sand but the salt...is good or auaileable for this purpose, because it is the brine and saltnesse of the same which breedeth this fertillitie and fruitfulnesse in the earth, choaking the growth of all weedes and bad things which would sprout from the Earth, and giuing strength, vigour, and comfort to all kinde of Graine or Pulse, or any fruit of better nature.[18]

Similarly, in his 1676 book *A Philosophical Discourse of Earth*, John Evelyn wrote that excessive salt "burn[ed] the earth for a time," but "once the rains have well diluted it, [plants] spring up more wantonly than ever." He compared salt to marl and animal manures, which made the ground "unprofitable, as if it were barren for a time" if not used in the proper proportions, but greatly intensified fertility when it was.[19]

That same year, Moses Cook wrote in his *Manner of Raising, Ordering, and Improving Forest-Trees* that as a child he had observed the sea flooding his father's Lincolnshire farm. This killed all of the grasses that grew in the submerged areas. The following year very

[17] It should be noted that saltwater does not, in fact, confer fertility upon plants, which, like animals, cannot absorb saltwater via osmosis and eventually dehydrate. Presumably, once the salt had eradicated various species of weeds and rainwater or groundwater had washed enough of the salt away, the planted crops competed with fewer other plants for nutrient resources in the soil. There is some evidence to suggest that in very small quantities sodium chloride may draw water to a plant and naturally increase water intake at the root, but it also activates stress hormones in most plants, thus negating any positive effect. Other nutrient salts confer this advantage as well, making any addition of sodium chloride detrimental. Saltpeter, which contains nitrogen and potassium, as well as sulfate, phosphate, iron, trioxide, and other nitrate salts, on the other hand, can contribute to plant growth once dissolved in the soil. See "Breakthrough: How Salts Stop Plant Growth," 23 January 2013, last accessed 6 August 2018, https://carnegiescience.edu/news/breakthrough-how-salt-stops-plant-growth.

[18] Markham, *Farewell to Husbandry*, 11-12.

[19] Evelyn, *A Philosophical Discourse of Earth*, 107.

little grew there and what did came late in the growing season. However, the next several years following that produced a bumper crop of fodder grasses, grains, and pulses, which Cook later deduced was due to the seasalt eliminating the weedier grasses, but allowing the more useful ones to flourish.[20] Other similar observations had been made in the previous century and seem to have endured as a rationale for using various salts in lieu of animal manures or as fertility aids in moderation.

For the purposes of steeping, common salt seemed best suited to prevent mildew, smut diseases, fungal infections, and other ailments that threatened to rot seeds, rather than as an agent to boost a seed's fertility. Saltpeter, along with a handful of other salts, were better suited to that purpose, though they too tended to be mentioned in husbandry manuals for their resistance to disease, vermin, and insects. One of the more vigorous promotions of saltpeter as a fertilizer in seed steeps came from agricultural reformer and practicing alchemist Robert Child. In his "Large Letter concerning the Defects and Remedies of English Husbandry," published in Hartlib's *Legacy of Husbandry*, a compilation of his and others' writings on agriculture, Child noted the historical uses of salts in seed steeping:

> The *Ancients* used to steep *Beans* in salt-water: and in *Kent* it's usuall to steep *Barley,* when they sow late, that it may grow the faster; and also to take away the soil: for wild *Oats, Cockle,* and all save *Drake* will swim: as also much of the light Corn, which to take away is very good. If you put *Pigeons-dung* into the water, and let it steep all night, it may be as it were half a dunging: take heed of steeping *Pease* too long; for I have seen them sprout in three or four hours.[21]

Importantly for Child, saltpeter replicated the properties of manure because the crucial procreant ingredients in manure were various salts. He called saltpeter "a special cause of

[20] Moses Cook, *The Manner of Raising, Ordering, and Improving Forest-Trees* (London, 1676), 18.
[21] Robert Child, "A Large Letter concerning the Defects and Remedies of English Husbandry, written to Samuel Hartlib," in Samuel Hartlib*, His Legacy of Husbandry…*, 37. Emphases in original.

fruitfulness," and argued that "the salt of ashes, &c. seemeth...to have as much, if not more affinity to common salt as to *Niter,* as appears by its Cubick form; yet they do much fertilize both Corn and Pasture."[22]

Another letter published in Hartlib's *Legacy of Husbandry* from an unnamed sender in "the Low Countries" described a "secret experiment" from Paris—which the author claimed to have learned from a physician named "Hartmannus," but which had also appeared in Gervase Markham's *Farewell to Husbandry*—in which boiling hot water was mixed with quicklime or unslacked lime until "an Egge may swim in it."[23] Quoting Gabriel Plattes, the anonymous author directed farmers to steep seeds in this mixture for twenty-four hours, sometimes mixed with rainwater or cow dung, and afterwards to sow on wet or sandy ground. At this point, one could sprinkle either saltpeter or sheep's dung over the top, either of which, the author opined, would fertilize the mixture in equal measure.[24]

Experimental trials featured prominently in Hartlib's *Legacy of Husbandry*. Attempts at fertilizing farm fields—which Hartlib credited, in part, to the knowledge of unnamed saltpetermen—prompted Gabriel Plattes, for example, to devise an experiment "wherein is showed how a rich compost may be made in the form of Earth...which may be converted

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[22] Robert Child, "An Answer to the Animadversor on the Letter to Mr. *Samuel Hartlib* of Husbandry," in Samuel Hartlib, *His Legacy of Husbandry…,* 149. By "Cubick form," Child may have been referring to its appearance under a microscope.

[23] Samuel Hartlib, *His Legacy of Husbandry…*, 110. On Markham, see *Farewell to Husbandry*, 21, though he described this as the way to test the appropriate amount of bay salt rather than quicklime. These instructions were repeated in letters from the 1660s between John Beale and William Oak. See William Oak to John Beale, 13 October 1664, *The Correspondence of Henry Oldenburg*, 13 Vols., ed. A. Rupert Hall and Marie Boas Hall (Madison: University of Wisconsin Press, 1965-73 and Cambridge: Cambridge University Press, 1975-1986), Vol. 2, 256-7. By Hartmannus, the author of the letter might have meant the late fifteenth-century Nuremberg humanist physician, historian, and cartographer Hartmannus Schedel, though there are no other references to him in this work against which to check this.

[24] Ibid., 110-11.

into saltpeter."[25] He cited the saltpetermen's report of saltpeter as the source of "the best Liquors...to be got" for fertilization. Their work led him to conclude that saltpeter was the best salt that could be used specifically as a fertilizer dissolved in water, though he suggested that other salts related to saltpeter might do as well. In any case, these experiments suggested to Hartlib, Child, Plattes, and the anonymous author from the Low Countries that fertilizing directly with saltpeter on the field or dissolved in water to steep seeds had a similar effect.

Perhaps an even more spirited defense of saltpeter as the most essential ingredient in seed steeps came around two decades later in John Worlidge's *Systema Agriculturæ* of 1669. In this work, Worlidge touted the uses of "steeping *Corn* in Dung-water," as supported through the experience of many farmers; yet he warned that the agricultural reformer with alchemical knowledge was likely to have grander expectations than the country farmer and might be disappointed with the yields. Instead, Worlidge promised that his way, reinforced by contemporary chymistry, was more "excellent," "grounded on more rational Principles," and "more effectual" than any other. He wrote, "that which containeth in it most of the *Universal Subject* or *Matter* of *Vegetables*…is the fittest for this purpose; of all which, *Nitre* or *Sal terrae* is esteemed the best, wherewith *Virgil* adviseth to infuse or besprinkle the seed."[26] Worlidge cited the experimental work of Glauber to bolster his

[25] Gabriel Plattes, "A Treatise…containing certain Notes, Observations, Experiences and Improvements of Husbandry, with the judgement upon them of an experiences Husbandman, who hath also brought the Invention of Setting Corn to greater perfection," in Samuel Hartlib, *His Legacy of Husbandry…,* 192. This section is part of a larger section of "annotations" on the *Legacy of Husbandry*, penned by Arnold Boate.

[26] Worlidge, *Systema Agriculturæ*, 56. He quoted Virgil as saying, "*Semina vidi equidem multos medicare serentes et nitro prius—profundere—*," which comes from Virgil, *Georgics* 1.193-95. The full text reads: "*Semina vidi equidem multos medicare serentis et nitro prius et nigra perfundere amurca, grandior ut fetus siliquis fallacibus esset."* ["I myself have seen many sowers steep their pulse seeds, soaking them with niter and black oil-lees, so that the fruit may swell within the deceitful pods."]. Translation adapted from Henry

assertions and claimed that the "menstruum" both ripened grains quicker and improved the chances of each individual grain bearing a healthy plant. The same mixture supposedly worked when applied directly to the roots or through simple irrigation to a young plant. However, according to Worlidge, the niter that was best suited for this task was not the niter found already efflorescing in caves or mined from dry salt flats. Again quoting Glauber, Worlidge alleged that

> Common Nitre [was] not fit for that purpose. The *Nitre* or *Sal terrae* intended by these and other Learned Authors as apt for this work, is the fixed Salt extracted out of any *Vegetable, Animal,* or *Mineral* throughly calcined, as after the burning of Land in the common way of *burn-baiting,* that which causeth so great Fertility is as well the fixed *Salt* or *Alcali* that's left in the *Ashes,* as the waste or expence of the sterile acid Spirit which before kept that vegetating Salt from acting. What is it that is fertile in Lime, Ashes, Soap-ashes, *&c.* but this *Nitre,* or *Sal terrae,* this *Universal Subject* left therein, and most easily separable after calcination?[27]

Calcination had long been a well-known alchemical procedure in which a mineral or metallic substance was roasted over a very hot flame until much of the original material had burned away. This remnant was known generally as calx or calcinate, though there were also recipes for the production of specific calcinated materials like lime and calx of mercury. In modern chemical terms, it consisted of oxidized metals.[28] However, calcination

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Rushton Fairclough, trans. and ed., *Virgil: Georgics: Aeneid I-VI: Eclogues* (Cambridge: Harvard University Press, 1978), 94-5. By "niter," Virgil likely referred to sodium carbonate rather than potassium nitrate.

[27] Ibid.

[28] On the meaning of these terms, see Newman, "Alchemical Glossary," http://webapp1.dlib.indiana.edu/newton/reference/glossary.do; and Carmen Giunta and Gleb Butuzov, "Alchemical and Archaic Chemistry Terms," http://www.alchemywebsite.com/al_term1.html, sourced from Julius Grant, *Chemical Dictionary*, 3rd ed. (Philadelphia: Blakiston Press, 1944); James Bryant Conant, ed., *Harvard Case Histories in Experimental Science*, Vol. 1 (Cambridge: Harvard University Press, 1957); and W. E. Flood, *The Dictionary of Chemical Names* (New York: Philosophical Library, 1963). Both accessed 10 July 2018. Calx was sometimes used to refer generally to lime (calcium oxide, or CaO), though it could also refer to specific limes, like carbonate of lime (calcium carbonate, or $CaCO_3$) or slaked lime, sometimes known as caustic calcareous earth (calcium hydroxide, $Ca(OH)_2$). Due to the general terminology for a number of substances, it is difficult to tell what Worlidge meant by "alcali." Alkali referred to several basic materials, and in the context of calcination, could produce a number of oxide, hydroxide, and carbonate compounds. A "vegetable alkali" usually meant potassium carbonate (K_2CO_3), which was found in wood ash and was the last chemical product before nitrates replaced carbonates in the artificial formation of saltpeter.

became a common practice in plant chymistry in the sixteenth and seventeenth centuries, especially among *sal nitrum* theorists, since various salts and alkaline materials often remained in the residue of fully charred vegetable matter. In Worlidge's text, the "fixed salt" likely referred to the solid, caustic salt, or one of two versions of "niter," produced upon the burning of naturally occurring saltpeter.[29] Here, Worlidge, like many from the previous generation of *sal nitrum* theorists, simply noted that the salts found in plant or animal matter demonstrated that they had already been essential to sustain life and thus reintegrating them into the soil or water used to steep or nourish newly planted seeds was akin to manuring a field with animal dung. By extracting it from plant matter and infusing it directly back into the seed, farmers simply skipped a step and sped up this natural process.

Brining, liming, and steeping seeds in chymical mixtures made up primarily of water and various salts continued throughout the late seventeenth century and into the eighteenth century. However, in contrast to the sixteenth century through the mid-seventeenth century, later recipes almost universally extolled salt for its pesticidal properties rather than its fertilizing potential. In the 1650s, Walter Blith and Adolphus Speed both recommended steeping wheat with common saltwater to prevent smut diseases.[30] In the first decade of the eighteenth century, John Mortimer advocated mixing salt with sheeps' dung, alum, and urine as a preventative for the same diseases.[31] The celebrated mid-eighteenth-century agriculturist Jethro Tull simply argued that brining seeds after treating them with quicklime had a similar effect on seeds as it did on meat and

[29] If this referred to the same "fixed salt" of Glauber, it was "vegetable alkali," or potassium carbonate. See Ahonen, "Johann Rudolf Glauber," 107 n.59, and page 102 above.
[30] Blith, *The English Improver Improved*, 127; and Adolphus Speed, *Adam out of Eden* (London, 1659), 105.
[31] John Mortimer, *The Whole Art of Husbandry* (Dublin, 1721), 40, 41, 84, and 194.

could be a potent preservative to guard against decay.[32] Later, in the eighteenth century, the ingredients multiplied, again. Thomas Hale argued for the addition of copperas to defend roots against burrowing worm attacks.[33] A recipe from 1771 contained lime, saltpeter, alum, verdigris, vitriol, plant ash, and common salt as well.[34] These practices seem to have died out between the late eighteenth and early nineteenth centuries as a result of French research into the fungal maladies of wheat seeds, which showed lime to be instrumental in warding off infection and brines to be of little or no use. At a purely practical level, even stripped of the alchemical or agricultural reasoning for steeping, soaking seeds in saltwater caused sterile seeds, weed seeds, and seeds hollowed out by worms and insects to float, and farmers could skim them from the surface and discard them, ensuring minimal waste of valuable field space.[35]

As for saltpeter, it too evolved from fertilizer to treatment primarily as a pesticide, first against fungal diseases and then increasingly against soft-bodied invertebrates like slugs and snails. In his 1675 *Planters Manual*, Charles Cotton mentioned it specifically for this purpose, particularly on branches and leaves.[36] Worlidge, Mortimer, and Hale all mentioned using it for similar reasons in their works as well.[37] Its return as a fertilizer would have to wait until potassium and nitrogen were chemically isolated and emerged as

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[32] Jethro Tull, *The Horse-Hoing Husbandry*, 2nd ed. (London, 1743), 66.

[33] Thomas Hale, *A Compleat Body of Husbandry* (London, 1756), 353. Copperas was the term for the crystallized form of green vitriol, or ferrous sulfate ($FeSO_4$). This was also called *sal martis.*

[34] See Matthew Peters, *Winter Riches, or a Miscellany of Rudeminets, Directions and Observations, Necessary for the laborious Farmer, on a New Vegetable System of Agriculture…* (London: W. Flexney, 1771), 133.

[35] Buttress and Dennis, "The Early History of Cereal Seed Treatment in England," 93-103.

[36] Charles Cotton, *The Planters Manual* (London, 1675), 88.

[37] Worlidge, *Systema Agriculturæ*, 56; Mortimer, *Whole Art of Husbandry*, 41; and Hale, *Compleat Body of* Husbandry, 373. For these and examples from the above paragraph, see Smith and Secoy, "Salt as a Pesticide, Manure, and Seed Steep," 513-16; and idem., "Compendium of inorganic Substances Used in European Pest Control before 1850," 1184 and 1186.

macronutrients in industrial chemical agriculture from the mid-nineteenth through early twentieth centuries.

The Alchemy of Seed Steeps: Fermentation, Germination, Transmutation

The potential importance of salts as fertilizers, and later as fungicides and pesticides, received some of the first chymical and alchemical validation within the context of English agricultural improvement with Hugh Plat's works in the 1590s and 1600s.[38] Though they became more analytical over the course of the seventeenth century, husbandry manuals tended to be observational and descriptive, and in Plat's time, most proffered little in the way of theories of germination or growth. Likewise, herbals, which made up a large fraction of botanical texts in the sixteenth century, tended to portray seeds as inactive, lifeless bodies, usually illustrated in their dried forms. The mystery of seeds' inner nature had led to all manner of narratives regarding the astrological and cosmological influence on plant growth from pre-classical Greece to the early modern era. This contrasts with dynamic descriptions of the interior of seeds to be found in seventeenth-century works, which alchemical theory helped to explain.[39]

Like Moses Cook nearly a century later, Plat had made his own coincidental observations on the accidental fertilizing properties of salts. In his *Jewel House of Art and Nature*, Plat wrote that he had witnessed a poor rural farmer drop a bag of seed corn into a

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[38] On Plat in general, see especially, Harkness, *Jewel House*, esp. 211-53; and Malcolm Thick, *Sir Hugh Plat: The Search for Useful Knowledge in Early Modern London* (Totnes, UK: Prospect Books, 2010).

[39] On this "astrological botany" prevalent in herbals, see Agnes Arber, *Herbals: Their Origins and Evolution, 1470-1670* (Cambridge: University of Cambridge Press, 1912), 247-63; and Scott, *The Secret Nature of Seeds*, 125. On the distinction between "cosmic vitalism," which presumed that the vital nature of matter came externally from the macrocosm, and "immanent vitalism," which presumed that it came from within matter, see Chang, "Alchemy as Studies of Life and Matter," 324 and 327.

shallow bay, which became fully submerged under saltwater such that he was not able to recover it until low tide. As this was his only bag, he had no choice but to sow the seed. Much to his surprise, his crop provided superior yields than his neighbors', even though he had sown it on inferior land.[40] Plat went on to describe inland salt pits at Nantwich visited by farmers in Cheshire who gathered salt for steeping and fertilizing. Eventually, he provided proper proportions of salt, water, and grain, recommending one part salt to two parts grain for fertilizing upon the ground and a ratio in steeping liquids of one part salt to eighteen or twenty parts water, which "in diverse ground procure a good increase."[41] In this, he simply relayed the best contemporary estimate of the ratio of salt to water as found naturally in seawater.[42] Though both Cook's and Plat's examples read much like Just-So stories, the eyewitness observations of multiple agricultural reformers helped solidify the connections between this particular husbandry practice and alchemical theory.

Plat's notions of the alchemy of seed and soil fertility were very much of his time. He was an avid collector of domestic and exotic plants and seeds, and both his house and garden, which he referred to as his "laboratory," were typically brimming with new specimens.[43] As in his previous works and many other horticultural and gardening texts of his era, Plat moved seamlessly back and forth between practical advice for gardeners and esoteric explanations of botanical knowledge. As Mauro Ambrosoli has argued, text and practice were closely interwined in agricultural and botanical matters, and he has tracked a close relationship between the movement of new seeds and plants and the movement of

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[40] Hugh Plat, "Diverse New Sorts of Soyle not yet brought into any publique use," in *The Jewel House of Art and Nature* (London, 1594), 41.

[41] Ibid.; and Hugh Plat, *A New and Admirable Arte of Setting of Corne* (London, 1600), sig. D*r-v.* See also, Smith and Secoy, "Salt as a Pesticide, Manure, and Seed Steep," 511-12.

[42] The actual ratio of salt to water for most seawater is between 1:27 and 1:28.5 (or 3.5% – 3.7% salinity), most of which is sodium chloride, though there are other salts as well.

[43] Scott, *Secret Nature of Seeds*, 76.

texts describing their uses.[44] Plat clearly supports this reading. In a short span of text from his 1608 *Floraes Paradise*, in which he recounted a recipe for an artificial fertilizer, Plat cited, among others, Heinrich Cornelius Agrippa, Giambattista della Porta, Francisco Velles, and Bernard Palissy.[45] After mixing vegetable matter with various herbs and allowing it to sit undisturbed for several days, Plat commented that the "Heauenly Earth so manured with the Starres" would bring forth the most robust plants, making them "prosper in the highest degree."[46] This well-composted vegetable matter contained "elemental" Saturn and Mercury, equated to philosophical lead and quicksilver respectively, which absorbed the stellar seminal virtue that Plat called *aqua coelestis*, the combination of which produced fermentation in seeds. This fermentation released a *quintessence*, which caused transmutation in the seed producing a plant.[47] He called the seminal virtue "a vegetable salt," which nature transmuted from common salts and contributed a crucial source of fertility to support plant life as part of a neverending circulation of vital spirits throughout the cosmos.[48] For Plat, the alchemical process of fermentation explained the physical process of germination in seeds.[49]

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[44] See Ambrosoli, *The Wild and the Sown*, 257-9.
[45] On these, see Peter R. Antsey, "Boyle on 'Seminal Principles,'" *Studies in the History of Biology and Biomedical Science* 33 (2002): 597–630; Kevin Killeen, "Duckweed and the Word of God: Seminal Principles and Creation in Thomas Browne," in *The Word and the World: Biblical Exegesis and Early Modern Science*, eds. Kevin Killeen and Peter Forshaw (Basingstoke: Palgrave, 2007); and Hiro Hirai, "Les Logoi Spermatikoi et le Concept de Semence dans la Mineralogie et la Cosmogonie de Paracelse," *Revue d'histoire des sciences* 61 (2008): 245–64.
[46] Hugh Plat, *Floraes Paradise*, 6-7.
[47] Hugh Plat, *The Garden of Eden* (London, 1653), 168. *Garden of Eden* was a posthumously published, re-edited version of Plat's *Floraes Paridise*. See also, Scott, *Secret Nature of Seeds*, 126-7.
[48] Ayesha Mukherjee, "'Manured with the Starres': Recovering an Early Modern Discourse of Sustainability," *Literature Compass*, Vol. 11, No. 9 (2014): 607. In this, Plat disagreed with Palissy. See Plat, "Diverse New Sorts of Soyle not yet brought into any publique use," 40-43.
[49] On these relationships, see Scott, *Secret Nature of Seeds*, 150; and Moran, *Distilling Knowledge*, 67-98. This sequence of events was highly redolent, at least in terms of the terminology used, of alchemical instructions for "the vegetable work for fructification only, or for physick, wrought without any plant at all only by aqua coelestis and mercury," found in BL, MS Sloane 2246 ff. 11*b*-20.

Plat received this specific concept of a vegetable salt from Paracelsus, via Palissy, whom he quoted in the opening passage of his "Diverse New Sorts of Soyle" as an authority on "all sorts and kinds of marl, or soyle whatsoever, either known or used already for the manuring or bettering of all hungry and barren grounds...[which] draw their fructifying vertue from that vegetative salt."[50] Though imbued with a certain poetic and metaphorical quality, Plat, unlike many sixteenth-century alchemists, seems to have thought of this vegetative salt as a literal, physical object, and even if the seminal virtue that circulated throughout the cosmos eternally was immaterial, it manifested itself materially in salts that could be used in seed steeps. This vegetative salt, he wrote, "may become pregnant from the heavens, and draw abundantly that celestiall and generatiue vertue into the Matrix of the earth," which would no doubt prove that the practitioner was "the true and philosophicall Husbandman."[51]

Discovering this vegetative salt required careful study of soil, putrefied plant matter, animal manures, and the thick, silt- and lime-rich sedimentary marl that could be found throughout the British Isles, all of which contained salts. Using language similar to Paracelsus and Palissy that would shortly be echoed by Sendivogius, it was Plat's evaluation that the vegetative salt caused heat, which activated an inner virtue within a seed that instigated its germination.[52] "There is not any kind of vegetable whatsoever, that coulde grow or flourishe," Plat wrote, "without the action of salt, which lieth hidde in euerie seed."[53] Found in animal manures, the amount and quality depended a great deal on salts

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[50] Plat, *The Jewel House of Art and Nature,* 91.
[51] Plat, *Floraes Paradise*, 9. For more on this concept of fertilizers, see Mukherjee, "'Manured with the Starres,'" 604-5.
[52] Plat, "Diverse New Sorts of Soyle not yet brought into any publique use," 23.
[53] Ibid., 10.

found in the grasses and other fodder plants they consumed. Plat concluded that it was the salts held within animal dung that explained its fertility in the first place. "All excrements as well of man and beast, serve to fatten and enrich the earth," he wrote,

> but if any man will plow and sow his ground yearly without dunging the same, the hungry seed in time will drink up all the salt of the earth, whereby the Earth being robbed of her salt, can bring forth no more fruit, until it be dunged again, or suffer to lie fallow a certain time, to the end that it may gather a new saltnesse from the clouds, and rain that falleth up on it.[54]

Here, Plat had discerned the problem of soil exhaustion and intuited that possibilities other than fallowing existed. With keen insight into the movement of nutrition through the food chain, Plat endeavored to record salt content through each step in the process: he took note of salt in putrefied plant matter, salt in the dung of animals that had fed on similar plants, salt levels in the soil, and salt levels in seeds to be planted on farms.[55] Should a seed contain too little natural salt, then brining, liming, or steeping might be necessary.

These types of investigation into seed steep recipes became quite common in the early seventeenth century. Francis Bacon further explained the scientific justification for the use of on-field fertilizers and seed steeps and attempted to provide both a natural history and an experimental foundation for their chymical attributes and practical uses. Bacon did not explicitly hold fully to the *sal nitrum* theory of alchemy and in fact argued that it was a mistake to seek the vital principle of matter in any one specific substance. Nevertheless, he recommended the use of salts as manures and in seed steeps on vitalistic grounds, averring that land "obtained a special vertue by the salt: for salt is the first

[54] Plat, *Jewel House of Art and Nature*, 103. For more context of these passages, particularly in relation to Plat's debt to Palissy, see Debus, *The Chemical Philosphy*, 411-19.
[55] For Plat's understanding of the nutrient transfer of salt to seed, see Scott, *Secret Nature of Seeds*, 199-200.

rudiment of life."[56] He further remarked that sea-sand was the second-best nutrient for rich soil, on account of its saltiness. It was surpassed only by marl, which possessed "the most fatnesse."[57] Again, saltpeter in particular exhibited the qualities of an exemplary salt for these purposes. Bacon wrote that if one were to mix saltpeter with water until it reached the viscosity of honey and brush this on the buds of flowering plants, they would open faster, due to the "Spirit of the *Nitre;* For *Nitre*" was "the Life of *Vegetables.*"[58] Like Plat, Bacon believed that fertilizing through steeping was an alchemical process that manipulated the matter within the seed.[59] His experiments were meant to demonstrate this.

In one series of experiments recorded in his posthumously published *Sylva sylvarum*, Bacon steeped numerous seeds from different grain, pulse, and vegetable species in all manner of steeping liquids, some containing salts and some not. In the first mention, at the opening of his "Natvrall Historie" section, Century 5, he wrote of sowing a bed of turnip, radish, and cucumber seeds along with wheat and peas. "There was taken Horse-dung, old, and well rotted," he wrote, which was

> laid vpon a Banke, halfe a foot high, and supported round about with Planks; And vpon the Top was cast Sifted Earth, some two Fingers deepe; And then the *Seed* Sprinkled vpon it, hauing beene steeped all night in *Water* Mixed with *Cow dung.* The *Turnip-Seed,* and the *Wheat* came vp halfe an Inch aboue Ground, within two dayes after, without any Watring. The Rest the third day. The *Experiment* was made in *October;* And (it may be) in the *Spring,* the *Accelerating* would haue beene the speedier. This is a Noble *Experiment;* For without this helpe, they would haue beene foure times as long in comming vp.[60]

[56] Francis Bacon, *Sylva sylvarum, or a Natural History in Ten Centuries…* (London: W. Leee, 1627), 149-50.
[57] Ibid.
[58] Ibid., 117.
[59] On this comparison, see Scott, *Secret Nature of Seeds*, 185-7.
[60] Bacon, *Sylva sylvarum*, 109-10.

While the experimental results appeared to confirm the use of water and dung, he cautioned that there was no economic benefit in having these crops harvested mere days early, with the possible exception of peas, which commanded higher prices earlier in the growing season, along with strawberries, cherries, and other sweet fruits, which he claimed were also improved by this manner of steeping.

More important for Bacon was a comparative analysis of steeped seeds and unsteeped seeds. Unlike the previous experiment in which the steep remained the same while multiple types of seeds were tested, Bacon conducted another experiment with wheat grains as his prototypical seed and steeped them in a number of different concoctions to determine which led to the quickest germination, the healthiest plants, and the highest yields. He steeped wheat in water mixed with cow dung, horse dung, pigeon dung, human urine, powdered chalk, soot, ashes, bay-salt, claret wine (a red, Bourdeaux wine), malmsey (a sweet, fortified Madeira wine), and spirit of wine, or aqua vitae.[61] The proportion was one part each ingredient to three parts water, except the bay-salt, which was one part salt to seven parts water.[62] He did not dilute the urine, claret, or spirit of wine with water. Bacon steeped the seeds for twelve hours before planting, and, as a control, also planted unsteeped wheat that he watered twice a day with warm water, and unsteeped wheat that he did not water at all. The result was

> That those that were in the Mixture of *Dung,* and *Vrine,* and *Soot, Chalke, Ashes,* and *Salt,* came vp within six dayes: And those that afterwards proued the Highest, Thickest, and most Lustie, were; First the *Vrine;* And then the *Dungs,* Next the *Chalke;* Next the *Soot;* Next the *Ashes;* Next the *Salt;* Next the *Wheat Simple* of it selfe,

[61] In modern terms, spirit of wine, also called aqua vitae and *spiritus vini*, typically referred to concentrated, aqueous ethanol (C_2H_5OH), called spirit of wine as it was usually distilled from wine. It was typically 50% – 70% ethanol by volume. See Newman, "Alchemical Glossary," http://webapp1.dlib.indiana.edu/newton/reference/glossary.do; and Carmen Giunta and Gleb Butuzov, "Alchemical and Archaic Chemistry Terms," http://www.alchemywebsite.com/al_term1.html. Both accessed 10 July 2018.
[62] Notably, this was a much saltier mixture than Plat's steeping brine.

> vnsteeped, and vnwatered; Next the *Watered twice a day* with warme water; Next the *Claret Wine.* So that these three last were slower than the ordinary *Wheat* of it selfe; And this Culture did rather retard, than aduance. As for those that were steeped in *Malmsey,* and *Spirit* of *Wine,* they came not vp at all.[63]

Although the bay salt proved to be less effective than the urine, dung, soot, chalk, and ashes in producing lush plants, it did initiate germination just as quickly, and did better than both the unsteeped seeds and those steeped in claret, malmsey, and spirit of wine. Importantly for Bacon, and for agricultural reformers, the most effective ingredients were cheap and easy to procure.[64]

Alchemical explanations for fermentation and transmutation within the matter of the seed and its ultimate germination followed a particular logic that depended largely on an alchemically-based theory of growth and a teleological understanding of seeds. Between the 1620s and the 1660s, writers of husbandry manuals, gardening pamphlets, herbals, and botanical textbooks increasingly came to view seeds as vessels containing the design of a plant within them.[65] It required an external, activating agent for germination. Those influenced by a vitalist alchemical worldview imagined seeds as minuscule alchemical furnaces. For Plat, just as base metals could be subjected to extremely high heat, melted, and reconstituted as new metals, including gold, so too was the interior of a seed a location of extreme heat, which caused fermentation, literally absorbing and transmuting the soil, water, and nutrients around the seed into a plant based on its internal design.[66] Agricultural writers had long connected manure with the quality of heat. Saltpeter's

[63] Bacon, *Sylva sylvarum*, 109-10.
[64] Smith and Secoy, "Salt as a Pesticide, Manure, and Seed Steep," 512-13.
[65] Scott, *Secret Nature of Seeds*, 150-51.
[66] Ibid., 151.

association with gunpowder indicated an explosive or fiery quality that might catalyze ignition at the microscopic level.

Diverse seventeenth-century theorists from Hugh Plat to Robert Boyle to Moses Cook to Nehemiah Grew attempted to explain germination in this way. In an attempt to explain the "multiplication of vegetables," Boyle undertook a chymical analysis of plants in an effort to test the validity of Van Helmont's theory that water was the primogenital element. Unlike Van Helmont, in his "Reflexions…," Boyle did not deny the importance of the seeds themselves as Van Helmont had.[67] He also, at this point, clearly maintained a semi-vitalistic, "spermatic" interpretation of the sources of fertility and as the catalyst of germination. On this point, Boyle deliberately chose spring water rather than rainwater because "the latter is more discernibly a kind of panspermia, containing in it (besideth the celestial influences or streams of the heavenly bodies, which are supposed to impregnate it) a considerable and fertilizing Earth and salt."[68] That is, to determine whether water alone possessed such a vital principle, he eliminated supposedly known sources that might interfere with his experiment. Even as he claimed to confirm Van Helmont's results that the bulk of the weight and volume of trees derived from water, Boyle nevertheless upheld the importance of soil and salts as the suppliers of key nutrients.

If anything, this further established how microscopic these nutrients were. In his appraisal of the replication of Van Helmont's experiment, Boyle stressed the importance of a seminal impregnating or activating agent. "I must admire the strange power of the

[67] The full title is "Reflexions on the experiments vulgarly alleged to evince the 4 peripatetique elements, or ye 3 chymical prinples of mixt bodies," found in Henry Oldenburg's commonplace books, and first published by Marie Boas in 1954. See Marie Boas, "An Early Version of Boyle's *Sceptical Chymist*," *Isis* Vol. 45, No. 2 (1954): 153-68; Antonio Clericuzio, "Carneades and the Chemists: A Study of *The Sceptical Chymist* and its Impact on Seventeenth Century Chemistry," in *Robert Boyle Reconsidered*, Michael Hunter, ed. (Cambridge: Cambridge University Press, 1994), 79-90; and idem., "From Van Helmont to Boyle," 303-334.
[68] Boyle, "Reflexions," quoted in Clericuzio, "From Van Helmont to Boyle," 318.

formative power of the seeds of things," he wrote, "which do not only fashion the obsequious matter according to the exigency of their own natures, and the parts they are to act; but do also dispose and change the matter, they subdue, as to give it a consistency, which it seemed incapable of admitting."[69] That is to say, even if plants were composed mostly of water, water acted simply as the inert material substance to be transformed—the blueprint was to be found in the seeds, which were activated by an external seminal virtue that changed the water with the aid of soil and salts.[70] For the agricultural reformer, the important takeaway from any of these interpretations was that the inner matter of the seed was alchemically manipulable: with the right fertilizing agent or steeping liquid, one could control germination and increase the ultimate potency of a seed.

Alchemy in the Field(s):
The Hartlib Circle and Experiments with "Fructifying Waters"

In the seventeenth century, several projectors established an interest in developing, standardizing, and profiting from seed steeps and fructifying waters. As Joan Thirsk and G.E. Fussell have noted, there is evidence that various projectors performed a great deal of experiments in steeping seeds around the turn of the century.[71] At least three applied for patents. In June of 1613, a grant was issued to Adam Newton, John South Coke, and John Wood to "use the art of steeping seed to be sown, for the furtherance of tillage in England and Wales, for 11 years."[72] Their process involved steeping wheat seed in rapeseed oil.

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[69] Ibid.
[70] For Boyle's recreation of this experiment, see Boas, "An Early Version of Boyle's *Sceptical Chymist*," 167; and Clericuzio, "From Van Helmont to Boyle," 318.
[71] Thirsk, *Agricultural Change: Policy and Practice 1500-1750*, 20-21; G.E. Fussell, *Crop Nutrition: Science and Practice before Liebig*, 60.
[72] "James 1 - volume 74: June 1613," in *CSPD: James I, 1611-18*, ed. Mary Anne Everett Green (London: Her Majesty's Stationery Office, 1858), 186-189, last accessed 1 August 2018, *British History Online*, http://www.

Once steeped, the mixture was sprinkled with a powder comprised of crushed, malted beans, pulverized rapeseed, one quart of lime, and urine. According to the recipe, the powder could be sprinkled directly on the land just as one would spread manure, though whether one needed to steep the seeds in liquid beforehand was not mentioned. The three projectors listed alternative substances to use if any of the ingredients could not be obtained.[73] Although they specified wheat seed, the proclamation mentioned that it was "a liquor for steeping all kinds of grains for sowing" and the patentees proclaimed their "willingness to give information, Etc upon it."[74]

Though there is scant other evidence of attempts to patent these liquids, there is a great deal of evidence of experimental trials, to replicate earlier methods found in both the alchemical recipes and natural histories of people like Plat and Bacon and the earlier husbandry manuals of writers like Mascall and Markham. By the late 1630s, many members of the Hartlib Circle became especially keen on pushing these experiments even further, testing various organic and inorganic chymical ingredients, seeking inexpensive solutions to fertilizing land and seeds, and uncovering dormant productive virtues in waters, from seawater to pond water to water carefully distilled in an alembic.

One such example comes from the work of Gabriel Plattes and his readers. Plattes wrote a number of books very quickly in the half decade before his death in 1644, one of which was *The Discovery of Infinite Treasure*. The titular "treasure"—shared in the title to one of his other prominent works, *The Discovery of Subterraneall Treasure*—referred to the

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british-history.ac.uk/cal-state-papers/domestic/jas1/1611-18/pp186-189. For the details of the patent, see TNA, SP 14/187/22A.

[73] For the rest of the information not contained in the *CSPD*, see Anon., *A direction to the husbandman in a new cheap and easy way of fertilizing and enriching arable ground* (London, 1634).

[74] *CSPD, James I, 1611-18*, 186.

renewable and sustainable soil and mineral wealth that, with proper technical knowledge, one could maintain in perpetuity. In the former, Plattes purported to explain how to "putrefy" rainwater without the addition of any external organic materials. He claimed that he had

> tried to putrifie water by it selfe, and also with helps, and doe finde that it may be done even as milke by helpe of rennet is curded into cheese; a thing that no man would beleeve, but that experience shewes it to be true; but as yet I have not brought the experiment to full perfection, and therefore as yet I will respit the publishing thereof: some experience hereof may be seene in the Moats and standing Pooles which yeeld great store of good Manure, and I wish that they were more made use of.[75]

In this context, the use of the term "putrefy" may have had a double meaning, with both agricultural and alchemical connotations. Outside of alchemy, putrefaction simply referred to the decaying of organic matter; but in this case, Plattes indicated that water itself had some spontaneously generative property. This possibility, as we have seen, was in no way problematic and aligned with what he and most other early moderns expected from nonliving matter. Alchemical literature dating back to the Middle Ages had detailed the genesis of small animal life from decaying plants and animals. Dead bulls reputedly birthed bees. Other rotting animal carcasses produced flies, while worms and crawling insects emerged from putrefied mud, pond scum, or decomposing plant matter.[76] This was highly similar to the alchemical meaning of putrefaction. Citing these instances of spontaneous generation, Paracelsus had written that new life began with putrefaction, and many alchemical texts discussed putrefaction, or *nigredo* ("blackness"), as one of the first phases

[75] Gabriel Plattes, *The Discovery of Infinite Treasure* (London, 1639), 36.
[76] Principe, *Secrets of Alchemy,* 132.

to making the philosopher's stone.[77] Well-known alchemists George Ripley, Basil Valentine, Guido of Montanor, and the anonymous author of *Mutus Liber* all mentioned putrefaction as one of the twelve principal alchemical operations, alternatively described as "gates," "keys," or "steps" to the philosopher's stone.[78] Plattes's discussion of the process typified the interlacing of alchemy and agriculture in their works. Just as the alchemist in the lab could use putrefaction as a starting point for generation and transmutation, so too could the farmer synthesize a propagative liquid and apply it to the growth of plants. Later in the same chapter of *The Discovery of Infinite Treasure*, Plattes claimed that he had accomplished the feat of creating fructifying water from putrefied rainwater, but "not in such exquisite manner for expedition in great quantitie."[79]

Less than a year after the publication of Plattes's *Discovery of Infinite Treasure* in 1639, Johann Moriaen wrote in a letter to an unknown recipient (likely Hartlib) that he had performed several experiments from Plattes's work, including the rainwater putrefaction, and had, in fact, devised similar trials independently. Sometime before then, Moriaen and his wife Odilia had come into possession of some farmland outside of Cologne, either as part of Odilia's dowry or as an inheritance, possibly from her brother Adam von Zeuel, who

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[77] [Pseudo-?] Paracelsus, *De rerum natura*, in *Sämtliche Werke*, Vol. 11, 312-17 and 348-49, quoted in Principe, *Secrets of Alchemy*, 132, and William R. Newman, *Promethean Ambitions: Alchemy and the Quest to Perfect Nature* (Chicago: University of Chicago Press, 2004), 200.
[78] See George Ripley, *Compound of Alchymie, or the Twelve Gates leading to the Discovery of the Philosopher's Stone* [1471], in *Theatrum Chemicum Brittanicum*, ed. Elias Ashmole (London: J. Grismond, 1652), 107-93; Basil Valentine, *Ein kurtz summarischer Tractat, von dem grossen Stein der Uralten…* (Eiselben, 1599) (the second section is titled "The Twelve Keys"); and Anonymous, *Mutus Liber* (La Rochelle, 1677). On these works in relation to the twelve operations, see Principe, *Secrets of Alchemy*, 144. On Ripley and Guido of Montanor, see Jennifer Rampling, "Establishing the Canon: George Ripley and His Alchemical Sources," *Ambix* Vol. 55, No. 3 (2008): 189-208; idem., "Transmission and Transmutation: George Ripley and the Place of English Alchemy in Early Modern Europe," *Early Science and Medicine* 17 (2012): 477-99; and page 160 below.
[79] Plattes, *Discovery of Infinite Treasure*, 42.

had died in 1635.[80] According to Moriaen, these lands had been badly damaged in the ongoing Thirty Years War, their yields had plummeted, and they required serious improvement, yet he seemed optimistic about their prospects. Mentioning in July 1639 that he had not yet finished Plattes's work, having made it only to chapter nine, Moriaen stated that he would reserve judgment on this possibility for when he had.[81] In this letter and another the next year to Hartlib, Moriaen described using a drilling device for planting seeds that had supposedly been invented by Plattes and working to successfully cultivate sandy soil by mixing it with marl. He also described Plattes's aforementioned ability to "putrefy" rainwater and create a fructifying liquid.[82] Despite never reporting back on the efficacy of cultivating sandy soil or putrefying rainwater, he later spoke highly of the drilling device and requested that Hartlib convince fellow German expatriate Theodore Haak to begin translating Plattes's works into their native language, though there is no evidence that Haak ever undertook any such translations.[83]

Among members of the Hartlib Circle, seed steeps and fructifying waters consumed a great deal of intellectual energy in the 1650s. In Cressy Dymock's pamphlet "A Discoverie For Division or Setting out of Land," he included "an experiment for the multiplying of corn, practiced neer Paris in France," a recipe that would be much discussed over the next decade. The recipe went as follows:

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[80] Johann Moriaen to ?, 21 July 1639, HP 37/35A. For more on Moriaen's land acquisition and interest in Plattes's agricultural experiments, see Young, *Faith, Medical Alchemy, and Natural Philosophy*, 25.
[81] Johann Moriaen to ?, 21 July 1639, HP 37/35A. "*Plattes buch of Infinit Threasure habe ich bis aufs 9. Capitel gelesen vnd gefallet mir nicht vbel desto mehr weil mir theils davon nicht allein bekand sondern auch durch erfahrung probiret ist*."
[82] Ibid., and Johann Moriaen to Samuel Hartlib, 2 August 1640, HP 37/66B.
[83] Johann Moriaen to Samuel Hartlib, 7 November 1641, HP 37/93A. It should be noted that it is unlikely that Plattes ever constructed a drilling device and it is unknown what Moriaen used as his own model. See Young, *Faith, Medical Alchemy, and Natural Philosophy*, 199-200.

> IN to two French pintes of rain-water, they did put a certain quantity of Cow-dung well-rotted, and as much Sheeps-dung and pigeons dung. This water they boiled, till but half a pinte was left, then they strained it through a linnen cloth, and in it dissolved 3 small handfuls of common salt, and as much Salt Peter. This brine they set in some vessel upon hot ashes, and in it they steeped their Seed-corn; which being so ordered, and at the usuall seed-time, being put into barren ground. produced unusuall increase, I my selfe have seen one hundred and fourteen eares upon one root, which, they told me, came from one single corn so prepared.[84]

Here, fructification was linked to multiplication. He compared this to another recipe "found in an old manuscript" that had similar ingredients but included the step of letting the mixture sit for eight days in the sun, presumably to allow it to putrefy, though in this, too, boiling the mixture while constantly stirring could quicken the process, assuming one could stand the fetid stench. This recipe promised a similar multiplication of yields at one hundred ears per individual seed corn.

In "another Secret worthy to be tryed by all" who labored for the advancement of husbandry, Dymock elaborated on the alchemical meaning of both of these recipes. "In the production of plants," Dymock wrote

> the earth is considered as a female, whose sterility may be much helped by the extraordinary melioration of the seed; As if you take water, which hath bin made fat with horsdung wel rotted, and afterwards dissolve in it as many pounds of Sal terræ as you intend to sowe acres. In this water steep the aforesaid weighty seed for 24 hours. So shall you have a better crop, then usuall, though you sowe but halfe the usuall quantity of seed, and though your ground be not so often ploughed, nor be at all dunged; nay though it were barren of it selfe. Your harvest will be ripe sooner by a month, and by reason of the Salt-peter, this corn will be fitter for store-houses; for there it will lie ten years uncorrupted.[85]

The female Earth acted as a womb for the male seed, which might need enhancement. Not only did these ameliorated seeds steeped in horse dung and sal terræ generate higher-

[84] Cressy Dymock, Printed Pamphlet, "A Discoverie For Division Or Setting Out Of Land," Cressy Dymock et. al. Part 2 (n.p., 1653), 13, last accessed 1 March 2018, https://www.dhi.ac.uk/hartlib/view?docset=pamphlets &docname=pam_47&term0=transtext_dymock&term1=transtext_cressy#highlight.
[85] Ibid., 14.

quality seeds, but they also produced a higher-quality corn ready for harvest up to a month early, which could also be stockpiled for a decade.

Experiments with various dungs and salts became increasingly common, as did alchemical eplanations for their efficacy. In the fall of 1656, Cheney Culpeper and Samuel Hartlib exchanged several letters discussing when to steep corn and how "moshing" dung the same way brewers malted grains was the best way to activate its fertility. From there he proceeded to "the imbibing of Corne," presumably meaning the soaking of grain in the dung mixture, "in such a contracted qvintessence…[that] will serve, till the art of fermentation, shall have opened a wider door to the stupendious multiplication of all things."[86] Though we do not have Hartlib's response, he must have informed Culpeper of a German recipe for fructifying water, as Culpeper mentioned it in a return letter in October. He claimed he had no experience in fashioning these and hesitated to commit himself to following one recipe. Culpeper did not give the full recipe, though the mixture must have contained saltpeter and lime, for he compared it to John Bate's *Book of the Mysteries of Art and Nature* and the same French recipe related by Dymock that Hartlib had included in his own *Legacy of Husbandry*, which produced saltpeter for fertilizing "by the mosshing of qvick lime with warme water, then vapouring away the water by the Sunne."[87] What the German recipe, Bate's recipe, and the anonymous recipe from Harlib's *Legacy of Husbandry* all had in common was the creation of saltpeter by leaching lime and crystallizing the remnant, which would then be used to brine seeds. As we have seen, this was a rather

[86] Culpeper to Hartlib, Fall (?) 1656, HP 70/3/1A-2.
[87] Culpeper to Hartlib, 13 October 1656, HP 70/3/2A-2B. This is a partial copy of a longer letter in HP 42/15/1A-2B. See also, John Bate, *The Mysteries of Art and Nature* (London: Ralph Mab, 1634), 261; and Hartlib, *His Legacy of Husbandry*, 110. This was the "secret experiment" from Paris, which came from a letter sent by an unnamed person in the "Low Countries." See page 113 above.

common method of artificially producing saltpeter in the sixteenth century and had become a common starting point for seed steeping by the middle of the seventeenth.

Though often used interchangeably with "seed steeps" by members of Hartlib's circle, the phrase "fructifying waters" sometimes possessed certain subtle meanings that differentiated it. The purpose of seed steeps, again, was threefold: to accelerate the germination process, to infuse seeds with fertilizer, and to coat seeds with protectants against disease, insects, and vermin. However, "fructifying water" acquired another meaning, connecting it more directly to concepts of alchemical change and demonstrating an affinity with liquors, menstrua, mild solvents and other liquids commonly used by laboratory alchemists. When used in this context, agricultural reformers experimenting with fructifying waters expected that the seeds soaked in them would also "multiply"—multiplication, like putrefaction, being one of the "keys" to the philosopher's stone—with recipes sometimes promising exorbitant yields that certainly never materialized.[88]

One such recipe came from Henry Jenney, an occasional correspondent with Harltib and regular experimenter in matters of husbandry. He had mentioned that after having read works about "multiplieing corn 200 fold" by Heinrich Cornelius Agrippa and Giambattista della Porta and about the "fructifying experiments" of Hugh Plat and Johan Rudolf Glauber, he had concluded that "steeping seed in water impregnated with nitrum purified from its acid salt and calcining it in a crucible" was essential for improving yields.

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[88] On the "keys" or "operations," see again, Principe, *Secrets of Alchemy*, 144. Some versions had more than twelve. The English alchemist Samuel Norton counted fourteen and split multiplication into two: "multiplication in virtue" and "multiplication in quantity," reflecting both the idea that only an adept pure of spirit could attain the philsopher's stone as well as the assumption of alchemists in both the Geberian/mercurial school and the *sal nitrum* school that there was a philosophical version and a physical version of each elemental substance. See, Samuel Norton, *Mercurius redivivus*, in *Ramorum Arboris Philosophicalis Libri tres* (Frankfurt, 1630). Earlier versions of this work, along with a number of other short pamphlets, can be found in BL, MS Sloane 3667, ff. 31-88; and Bodl., MS Ashmole 1448, ff. 42-104*v.*

He added that he had failed thus far to replicate this, but he blamed himself rather than the process.[89] Jenney referred to Hugh Plat's recent, posthumously published work *The Garden of Eden*, an abridged and re-edited version of his *Floraes Paradise*, wherein Plat made reference to Agrippa's *De occulta philosophia libri tres* and della Porta's supposed commentary on it.[90] Jenney wrote Hartlib requesting more information on these writings:

> S*i*r Hugh Plat to his Garden of Eden hath annexed a short Philosophicall Garden, it is indeed a meere Sphinx not to bee vnderstood without an oedipus. If you could procure a Com*m*ent vpon it, that wee might know what the Philosophers Aq: vitæ there meaneth with the rest of the ænigmatica therein contained you should do a famous worke. Hee saith also in his Epistle there, that hee hath made an Abstract of Corn. Agrip: his occulta philosophia, & hath discovered Baptista Porta his secret of multiplieing Corne 200 fold, if these [books] bee to bee had, I beseech you s*i*r let me know where.[91]

Significantly, Jenney mentioned that he had read husbandry manuals by Hartlib and Richard Weston before testing this, suggesting that Jenney deemed these chymical experiments as an important aspect of agricultural reform and evincing the intellectual content of his fieldwork.

Members of the Hartlib Circle seeking a cohesive vegetable philosophy regularly cited the works of della Porta and Agrippa, especially when natural magical explanations seemed to elucidate commonly observed but poorly understood physical processes. The concept of "multiplication" was well represented in the pages of their major works. These works emphasized the economic importance of husbandry, the wholesale creation of new types of plants and animals though experimentation, and the confluence of empirical study and natural magical techniques to understand "the riches and delights of the natural

[89] Jenney to Hartlib, 28 September 1657, HP 53/35/3A.
[90] See Plat, *The Garden of Eden*; idem., *Floraes Paradise*; and Heinrich Cornelius Agrippa, *De occulta philosophia libri tres* (Paris, 1531; Cologne, 1533). It is unclear to what Giambattista della Porta text he refers, though it is likely a passage from his *Naturalis magiæ*.
[91] Jenney to Hartlib, 28 September 1657, HP 53/35/3A.

sciences."[92] Within the section on the production of new plants, della Porta indicated that it was possible, among other things, that "one and the same Vine-branch may bring forth a black and a white grape together."[93] He suggested how "Lettice should grow, having in it Parsley, and Rocket, and Basil," how to produce an "Almond peach, which is outwardly a Peach, but within hath an Almond kernel," and how to grow a "Citron that hath a Limon in the inner parts."[94] Slightly less outlandish prospects included instructions on "hastening the fruits" of cucumbers, melons, figs, and quinces; how to ripen cherries, rape root, colewort, parsley, peas, and vetches "before their time;" how to grow roses in the month of January; and how to enlarge apples, pears, apricots, mulberries, onions, garlic, citrus fruits of all kinds, and so on.[95] Similar lists could be found in Hartlib and Cressy Dymock's *Cornu Copia* and Adolphus Speed's "General Accommodations" from the early 1650s.

John Beale, about whom there is much more in Chapter 5, became one of the most vocal supporters of all manner of experiments to test the value of fructifying waters. He and Hartlib exchanged a long series of missives in 1656 and 1657 discussing the most effective ingredients of fructifying waters, the operative principles at work, and on which seeds they functioned best. In the first letter, dated 23 February 1656, Beale thanked Hartlib for "the 6 bottles of Fructifying water" he had sent him and noted that he planned to "trye it upon all kinds of Lentgraine, as wee call barly, oates, fitches, pease, beans, kidney, Lupines, and garden seedes."[96] He then went on to describe a wheat-steeping experiment, different substances he had used in the steeping liquid, including "bloud of a tub of beefe in it, &

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[92] Giambattista della Porta, *Natural Magick* (London: Printed by Thomas Young and Samuel Speed, 1658), "Preface to the Reader," [unpaginated].
[93] Ibid., 67-8.
[94] Ibid., 70-2.
[95] Ibid., 75-8 and 82-6.
[96] Beale to Hartlib, 23 February 1656, HP 62/22/1A.

urine draind through salt peter earth, & a rich fold water of sheepe dung, horse dung, & cowe dung, & pigeons dung," and the poor weather that had hindered his progress "for 8 or 10 dayes."[97] He steeped, or "swild," half in the "fold water" while another third he "rolled in lime" to keep from clumping. The result was the seed, "which was not swild from *th*e salt, came up a weeke sooner than the other; & both seeme nowe much better than other corne."[98] This suggested to Beale that lime imparted something perhaps more important than salt.

The use of lime had begun to appear regularly in husbandry manuals beginning in the late 1500s, particularly as a chemical for killing insects, slugs, snails, and other common garden pests.[99] Usually, these instructed farmers to sprinkle lime around the plant rather than steep seeds in a liquid containing it. In some cases, it was mixed with sulfur, ashes, soot, soap, tobacco, and other irritants to magnify its potency. It had been an integral component in artificial saltpeter manufacture, intimating possible chymical affinities related to their fertilizing properties. In continental Europe, where salt was much more expensive than in England, farmers regularly used lime in lieu of salts and, if reports were to be believed, suffered no reduction in yields.[100] Beale later noted that the enriching power of natural streams that ran over limestone seemed to corroborate this.[101] In this letter, he

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[97] Ibid.
[98] Ibid., 1B.
[99] Smith and Secoy, "Compendium of inorganic Substances Used in European Pest Control before 1850," 1183. On the use of lime—which, in these recipes, usually refer to slaked lime (calcium hydroxide), though unslaked lime (calcium oxide) was also used—in the sixteenth and seventeenth centuries, see, Mascall, *A Booke of the Arte and maner howe to plant and graffe all sortes of trees*, 65; Gervase Markham, *A Way to Get Wealth* (London, 1631), 88; Hartlib, *His Legacy of Husbandry*, 16; Speed, *Adam out of Eden*, 98; Nicolas de Bonnefons, *The French Gardiner*, trans. by John Evelyn (London, 1669), 101; and Worlidge, *Systema Agriculturæ*, 197.
[100] Henri Louis Duhamel du Monceau, *A Practical Treatise of Husbandry* (London, 1762,), 94. On this, see Smith and Secoy, "Salt as a Pesticide, Manure, and Seed Steep," 513. Some alchemists had noted similar chymical proprties between lime and certain salts and one was often mentioned in recipes for producing the other. On "sal nitre" and "lyme," see, for instance, BL, MS Sloane 1094 ff. 18*b*-19*b.*
[101] Beale to Oldenburg, c. early July 1675, *The Correspondence of Henry Oldenburg*, Vol. 8, 381-89; also

continued onto other topics without much analysis and included this perhaps to shore up his *bona fides* with Hartlib as a serious reformer engaged in contemporary agricultural experiments.

In the next letter, dated less than a week after the previous one, Beale reported his assessment of Hartlib's fructifying water:

> One bottle I have opened, I find the water cleare, of a light yellowish color, of an odious smell, and (as it were) of putrid fish. I have steepd in it seedes of gellyflowers of divers sorts, kernells of apples, lupins, smaller kidney-beanes, & Roman beanes. but w*i*th some iealousy, That all thiese are unfit; for heretofore I haue found them hurte by swelling in fat water. My people are nowe sowing fitches oates, beanes, & pease; And till I have further directions, I dare not adve*n*ture on the*m*.[102]

Beale looked forward to the results of the experiment but politely doubted that Hartlib's mixture would do much to improve his crops because in Herefordshire, his native county, they already had "the richest Corn" that he had ever seen in England. Nevertheless, he promised to withhold judgment until the harvest came in.

Unlike others who had presumably embellished their success with various steeping liquids or outright lied about the results, Beale appeared to be honest to Hartlib about his failures. Multiple attempts to replicate the fructifying waters of Hartlib, Plattes, and others either disappointed in their enrichment or prevented the seeds from sprouting altogether. We have a few specific inquiries Beale made of Hartlib and indications that Beale would attempt some of the more idiosyncratic suggestions from Plattes's *Discovery of Infinite Treasure.* "First," he wrote that he intended to inquire "whether any man hath yet attained the art of putrifying water Mentioned by G Plats pag. 36, & againe pag. 42 See it there I

published in *Phil. Trans.* No. 116 (1675): 357-67.

[102] Beale to Hartlib, 23 February 1656, HP 62/22/3B. Underlining in the original, though it is not known whether Beale or Hartlib did this.

pray y*o*u."[103] Here, Beale referred to Plattes's claim that water could putrefy—that is, come to possess decomposing organic material—without any external addition. This was a request for information on the same process that Johann Moriaen had also attempted after having read Plattes.[104] As we have seen, later on in the same chapter, Plattes claimed that he had accomplished this feat, but that the process was far from perfect and that it did not produce a yield quantity to his satisfaction. Beale hoped either to recreate the experiment himself to boost the amount of fructified water or acquire information through Hartlib on someone who had, though it does not appear that Hartlib ever informed him of Moriaen's earlier efforts.[105]

Beale also hoped to determine "Howe the seede-corne may bee soe composted, as to make a very considerable improvem*en*t upo*n* weak land," in the same manner as the unnamed Parisian experimenter mentioned in the works of Dymock and Hartlib, though the effectiveness of the method had been called into question by Hugh Plat, whom Beale and Hartlib considered an early authority on agricultural chymistry.[106] Beale referred to "honest Gabriel," who had written about the method and denied its efficacy.[107] However, Beale was not so sure that it had no merit. The improvement consisted of steeping seed-corn in a clay-bottomed container filled with putrefied water in the sun until the seeds had almost absorbed all of the liquid, at which point lime was sprinkled on them and the seeds were planted. "You will save ten times as much labour in carriage of your dung," Plattes reported, "so farre as this labour cometh too, and as for your crop, though you shall not

[103] Beale to [?]Hartlib, 13 March [?]1657, HP 62/16/2B.
[104] See above, page 156.
[105] See Plattes, *Discovery of Infinite Treasure*, 42.
[106] Beale to [?]Samuel Hartlib, 13 March [?]1657, HP 62/16/3A.
[107] Ibid.

have so much increase as some have Mountebanklike reported of it…you shall have good material increase for one crop."[108] Though he remained skeptical of Plattes's statements about putrefaction, his own experiences with liming seeds actually suggested that these steps were well worth taking.

In September of 1658, Beale once again wrote to Hartlib about his fructifying water, claiming it rendered the seeds incapable of germination. Describing it as a "Menstrum Philosophicum," Beale wrote that he was "desirous to knowe w*ha*t others observd of the Fructifying water w*hi*ch y*o*u sent mee. For though mine fayld in all things, & mortified most kinds of seedes, Yet I do impute that to some kind of mistake, eyther in drawing the water, or of ordering the directions."[109] Like Henry Jenney before him, Beale modestly assumed that he, rather than the process, was amiss, "especially finding probability in the Materialls."[110] Citing Paracelsus, he noted that there had to be some as yet undiscovered, underlying force causing life to emerge—either in the soil, the fertilizer, or the seeds themselves—because he was "certaine there is a peculiar vigor in beane holme tow*ar*ds fructificatio*n*, as well appeares in that the grounds that are used for beanes doe never neede composte."[111] The mortified seeds were not entirely unusable, according to Beale. Following their failure to sprout, one could burn them, combine their ash with "fat molde & true marle," and then add water, "w*h*ich is impregnated fro*m* heaven, & then draynd through it," to produce saltpeter.[112] His nephew Peter Smith had reported saltpeter as a by-

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[108] Plattes, *A Discovery of the Infinite Treasure,* 36-7.
[109] Beale to Hartlib, 23 September 1658, HP 52/13A.
[110] Ibid., 13B.
[111] Ibid., 13A.
[112] Ibid., 13B. Beale had translated the Latin term "*argilla*," used by Paracelsus, as "marle," though this is usually translated as "clay."

product of this type of agricultural work nearly a decade earlier, and Beale seems to have confirmed this in the interim.

Seeds, bean hulls, ash, and marl were all regular components of artificial saltpeter recipes by this point and could be included in seed steeps requiring saltpeter as well. Beale's allusion to impregnation from heaven probably referred to the Paracelsian concept of astral emanation or the circulation of Sendivogius's *sperma*, which bestowed the fructifying power of the vital nitrous spirit on earth. This had been one of Glauber's working hypotheses about the origin of the vital power of saltpeter. According to some theorists, these astral seeds traveled to earth via sunbeams, though there is no indication that Beale necessarily accepted this interpretation as true at this time.[113] These references imply that Beale readily cross-referenced the practical experimentation of agricultural improvement with the much more speculative Paracelsian and Sendivogian chemical philosophy, again, also commonplace by this time, which connotes the increasingly reciprocal relationship between these forms of knowledge. Like Jenney's concurrent work, it also indicates that attempts to isolate the life-giving component of matter remained as idiosyncratic as they were elusive.

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113 Beale eventually acquiesced to the significance of sunlight in plant growth in letters to Henry Oldenburg. See Beale to Oldenburg, c. early July 1675, *Correspondence of Henry Oldenburg*, Vol. 8, 383; and page 260 below. On the importance of sunlight either as the source or the conveyer of a necessary vital principle of life, see [Jean d'Espagnet], *Enchyridion physicae restitutae; or, the Summary of Physicks Recovered…* (London, 1651), 19. This book first appeared in Latin without an author around 1623 and had one more edition before 1651, when it was translated into both English and French. See also, Michael Sendivogius, *A New Light of Alchemy*, trans. John French (London: A. Clark for Thomas Williams, 1674), 44-45; Johan Rudolf Glauber, *On the Nature of Salts* (London, 1689), 248 (an English translation of the German original published in 1658); idem, *Continuatio miraculi mundi*, 163-5; and Edward Jorden, *A Discourse of Naturall Bathes, and Minerall Waters*, 57. For more context on vitalism and sunlight in the context of mid-seventeenth-century chymistry, see Allen G. Debus, *The Chemical Philosophy*, 88, 224, 230-235, 259-260, and 432. For more specifically on d'Espagnet work, see Betty Jo Teeter-Dobbs, *The Foundations of Newton's Alchemy, or 'The Hunting of the Greene Lyon'* (Cambridge: Cambridge University Press, 1975), 37-39.

Beale's last letter to Hartlib on the topic of fructifying waters deferred to the judgment of Robert Boyle, who had remarked that seed steeps and fructifying waters appeared to be promising avenues of fertilization, though he thought that they were not a panacea for general improvement and likely only worked for certain crops. Most recipes found in husbandry manuals were for use on grains and pulses, but Beale and Boyle both thought they might be most useful for fruit trees and plants that produced pitted fruits. After exchanging some recent news about diplomatic relations with the French and Portuguese, Beale wrote that he concurred with

> much of Mr Boyles iudgem*en*t concerning fructifying Waters: but their proper use is for delicate fruite, in the very time, when the seede or kernell does first putrify tow*ar*ds [generation; for then it] acquires a speciall kind. For the delicacy of apples, peares, & some other fruite, is like a diversion fro*m* the strength & vigor of nature, & is therefore of weaker woode & lesse lasting, than the crabstoc or wilde fruite.[114]

The less hardy the plant, the argument went, the more it was in need of fructification.

This assessment matched other descriptions from husbandry writers who had compared the utility of seed steeps and fructifying water for different types of seeds and plants and for different parts of the plant, including not only seeds, but also roots, stems, leaves, and buds after the plant had begun to grow. An undated letter from Cressy Dymock to Hartlib on the "precious fructifying liquor" of an otherwise unknown individual named "Dr Robinson" or "Dr Robertson" (the manuscript is unclear) stipulated different steeping durations and separate locations of application depending on the type of plant.[115] Although the contents of the liquid remained unspecified in the letter, the instructions for steeping included: mixing barley with dry, crumbled, fertile earth and soaking for twenty-four hours before planting; soaking the roots only of fruit tree saplings for ten to twelve days, but for

[114] Beale to Hartlib (?), 3 November 1657, HP 52/14A.
[115] Dymock to Hartlib, Dr [Robinsons/Robertsons?] Method of Fructifying Corn, undated, HP 65/16A.

older trees, soaking a wool cloth and wrapping the roots to keep them moist for two weeks; and steeping the roots of flowers and small plants for twenty-four hours but observing each closely, as some individual plants needed slightly less or slightly more time depending on their absorption rate.[116] Even though some of these seed steeps and fructifying waters likely did little to aid in germination time or plant growth, many of them did, and by the mid seventeenth century, agricultural improvers and manual writers could give nuanced instructions about the ratio of ingredients, the time intervals for steeping, and site of implementation.

Conclusions

The creation of seed steeps and fructifying waters can be viewed as a subset of a broader category of aquaculture experiments throughout the seventeenth century typified by trials like Van Helmont's famous willow tree experiment. Water, of course, had been known as an instrumental aspect of agriculture for thousands of years, but precisely what it conveyed to plant matter to induce growth remained a mystery. Whether designed and conducted by traditional alchemists in their laboratories, by botanists in their gardens, or by farmers in their fields, only experiments would provide the answers to these questions. Depending on the interpretation, these experimenters inferred that water was the principal necessity for life, the activating agent of some other vital principle, the matrix or menstruum in which alchemical operations transpired, or the primogenital element of the cosmos.

[116] Ibid., 16A-B.

Seed steeps and fructifying waters were the province of farmers at all social levels. Though we have the best evidence of their composition from elite gentlemen farmers like Jenney, Beale, and others, their profusion in husbandry manuals, everyday pamphlets, and other instructional booklets strongly suggests that European farmers commonly steeped seeds before planting. Historians of agriculture have noted this for a very long time. Less noted but no less important, however, are the similarities that seed steeps and fructifying waters had with recipes for alchemical liquors, menstrua, and solvents that contained organic matter as part of their composition. Furthermore, the botanical and agricultural investigation of the constituents of plant matter increasingly began to rely upon operational techniques derived from alchemy. Calcining and distilling, long staples of laboratory practice, became agricultural tools when applied to plant matter. Alchemical notions like putrefaction, fermentation, and multiplication found direct analogs in the botanical world. For the agricultural reformer, it was the manipulable nature of seeds, plants, manures, salts, and the steeping liquids that could be made from them that suggested that control was possible for improvement. This was necessary because, just as the production of gunpowder was a matter of national security, so too was the production of food. And, according to many agricultural reformers, seventeenth-century husbandry was in crisis.

CHAPTER 4

"TURNING PLOW-MEN INTO PHILOSOPHERS": GABRIEL PLATTES, THE ALCHEMY OF SOIL FERTILITY, AND AGRICULTURAL IMPROVEMENT

Ruricolae pingui mandant sua femina terrae,
Cum fuerit rastris haec foliata suis.
Philosophi niveos aurum docuere per agros
Spargere, wui folii se levis instar habent:
Hoc ut agas, illus bene respice, namque quod aurum
Germinet, ex tritico videris, ut speculo.

"The farmers entrust their seed to the fat earth,
After having foliated it with their mattocks.
The Philosopher has taught that gold must be scattered over white fields,
Which reacts like a light leaf.
When you undertake this, pay good attention to it,
For from the wheat you see, as in a mirror, that gold germinates."

--Michael Maier, *Atalanta Fugiens*, Sixth Epigram (1617) (Figure 4.1)

Introduction: Husbandry in Crisis

According to agricultural reformers in mid-seventeenth-century England, husbandry was in crisis. The terrifying political, religious, and social upheavals of the first half of that century had upended more than political institutions, interfaith relations, and class distinctions. Destructive events from the continent-wide Thirty Years War (1618-1648) to the Civil Wars that racked the British Isles (1642-1646, 1648-1649, and 1649-1651) elicited strife not only because of their armed atrocities but also through the deprivation brought on by food dearths. Though the possibility of famine had been ever-present throughout much of recorded history, the frequency and severity of widespread malnutrition and food deprivation increased across Europe in the 1550s and culminated with mass starvations in the 1590s.[1]

Figure 4.1, A farmer sprinkles gold on cropland. The metaphor worked both ways: surplus crops were a form of convertible wealth, while the adept alchemist could effectively "grow" gold. From Michael Maier, *Atalanta Fugiens*, Emblem 6 (Source: Wikimedia commons).

This was but prelude to the food shortages of the early seventeenth century, during which few places escaped the scourge. Compared to continental Europe, along with northern England, Scotland, and Ireland, most of southern England was spared the worst of these famines, although it too experienced significant food shortages in 1622-23, 1629-31,

[1] Guido Alfani and Cormac Ó Gráda, eds., *Famine in European History* (Cambridge: Cambridge University Press, 2017), 8-11; and Cormac Ó Gráda, *Famine: A Short History* (Princeton: Princeton University Press, 2009), esp. 1-7 and 25-38.

and in specific locales in the late 1640s.[2] For mid-seventeenth-century agricultural reformers, the key to remedying these ills and creating a sustainable, agricultural system lay in developing a sophisticated understanding of soil fertility, the causes of plant growth, the physiology of plant care, and the wholesale improvement of the land itself. The reformers of the Hartlib Circle—the sprawling correspondence network of natural philosophers and social reformers who shared results of various scientific investigations—became focused squarely on the scientific management of agriculture around mid-century and sought, as one of its foremost advocates, Gabriel Plattes, wrote, "to turne Plow-men into Philosophers" for the improvement of the nation.[3]

Indicative of this concern with the deficiencies of husbandry was the sudden explosion of husbandry manuals and agricultural improvement tracts, which proliferated in England especially between the late 1630s and early 1660s, peaking around the year 1650. Among these we might mention all of the notable works of Gabriel Plattes, Walter Blith's *The English Improver Improved,* which underwent three editions between 1649 and 1653, Richard Weston's *Discourse on Husbandrie* (1650), Samuel Hartlib's compilation of many short agricultural writings in his *Legacy of Husbandry* (1655), and four short pamphlets by Cressy Dymock, including his popular *Reformed Husbandman* (1651). All shared common themes concerning the paucity of sufficient knowledge about botanical

[2] Alfani and Ó Gráda, eds., *Famine in European History*, 9-10, Table 1.1. Recent climatological research has demonstrated that the peak of the so-called "Little Ice Age" of ca. 1300-1850 occurred during the seventeenth century—a period of decreased solar activity known as the Maunder Minimum—from roughly 1645 to 1715, which contributed to the increased frequency of bad harvests and famine. See Brian Fagan, *The Little Ice Age: How Climate Made History, 1300-1850* (New York: Basic Books, 2000), 121-122; and Geoffrey Parker, *Global Crisis: War, Climate Change, and Catastrophe in the Seventeenth Century* (New Haven: Yale University Press, 2013), xix-xxvii and 3-24.

[3] Gabriel Plattes, *A Discovery of Infinite Treasure* (London, 1639), [9]. Note: the front matter, dedication, preface, table of contents, and introduction to the first edition of this work are unpaginated, totaling 35 pages. I have used bracketed Arabic numerals to refer to these pages starting with the first blank page.

growth, the necessity of reliable, productive agriculture for a strong nation, and the importance of systematically restructuring husbandry to accompany a broader spiritual, social, and political reform. Many emphasized empirical and experimental methodologies and the importance of a chemical and alchemical understanding of the natural substances involved in agriculture, particularly soil and plant matter.

Epitomizing these and other concerns, for example, we may quote Richard Weston at length, who wrote in his *Observations and animadversions upon the foregoing secrets or experiments: Written by the author of the large letter in the legacy of husbandry* that

> It is a main deficiencie in Husbandry, that…we are very ignorant of the true causes of Fertility, and know not what Chalk, Ashes, Dung, Marle, Water, Air, Earth Sun &c. do contribute: whether something Essential, or Accidental; Material or Immaterial; Corporal or Spiritual; Principal or Instrumental, Visible or Invisible; whether Saline, Sulphureous or Mercurial; or Watery, Earthly, Fiery, Aereal: or whether all things are nourished by Vapours, Fumes, Atoms, Effluvia: or by Salt, as Urine, Embrionate or non-specificate? or by Ferments, Odours, Acidities? or from Chaos, or inconfused, indigested, and unspecificated lump? or from Spermatick, dampish vapour which ascendeth from the Centre of the Earth? Or from the influence of Heaven? or from Water onely impregnated, corrupted or fermented? or whether the Earth, by reason of the Divine Benediction hath an Infinite, multiplicative Vertue, as Fire, and the Seeds of all things have? or whether the multiplicity of Opinions of learned Philosophers (as Aristotle, Rupesc, Sendivog, Norton, Helmont, Des Cartes, Digby, White, Plat, Glauber) concerning this Subject sheweth the great difficulty of this question, which they at leasure may persue. I for my part dare not venture on this vast Ocean in my small bark, lest I be swallowed up; yet if an opportunity presents, shall venture to give some hints, that some more able Pen may engage in this difficult Question which strikes at the Root of Nature, and may unlock some of her choicest treasure. The Lord Bacon hath gathered stuble (as he ingenuously and truly affirms) for the bricks of this foundation; but as yet I have not seen so much as a solid foundation plainly laid by any, on which an ingenious Man might venture to raise a noble Fabrick: I acknowledge the burthen too heavy for my shoulders.[4]

[4] Richard Weston, *Observations and animadversions upon the foregoing secrets or experiments: Written by the author of the large letter in the legacy of husbandry*, in Samuel Hartlib, *A discoverie for division of setting out of land....* (London: Printed for Richard Wodenothe, 1653), 16. The authorship of this piece is questionable, and Hartlib may have penned it himself.

This telling passage demonstrates the sheer philosophical and practical diversity reformers applied to the deficiencies of husbandry and the acknowledgement of just how little was yet known. It opens with references to material substances commonly used in husbandry that were known to contribute to fertility even if their causes remained unknown. It contains allusions to Aristotelian qualities, the three material principles of Paracelsus, and the four traditional elements of Empedocles. It enters into the contemporary discussion surrounding contested matter theories, such as the possibility of spirits, *effluvia*, and atoms; the notion that salts might contain the vital principle of life; and whether fertility is geologically, hydrologically, atmospherically, or cosmically derived. It openly ponders the alchemical possibilities of the "Infinite, multiplicative Vertue" of the soil. It generously appeals to authorities from ancient Greece and Rome, Renaissance Italy, and contemporary England and Continental Europe concerning the chymical qualities of soil. Drawing on these sources, the debates over which theories best explained fertility and which material substances and immaterial forces should be experimentally investigated characterized the Hartlib Circle's approach toward husbandry. They revolved around developing a systematized basis for more productive husbandry by resolving the debates about the constituents of matter and physical processes of growth.

While these disputes thrived, there were two things on which almost all Hartlibian writers on husbandry agreed: agricultural yields could be drastically improved upon given the proper scientific management of farmland and natural resources, and the bounds of human ingenuity—not nature—marked the threshold of cornucopian possibilities.[5]

[5] On the idea of potential infinity in nature and its possible applications in economics, see Andrea Lynne Finkelstein, *Harmony and Balance: An Intellectual History of Seventeenth-Century English Economic Thought* (Ann Arbor: University of Michigan Press, 2000), 213-14; and Wennerlind, *Casualties of Credit*, 59-60. Both of

Although contemporary agricultural development perhaps did not yet warrant such unbridled optimism, for many reformers, the promise of these gains fueled their ambition and justified their unconventional methodology. Just as the chemical philosophy of and alchemical experiments on saltpeter suggested that it could be a most potent fertilizer, so too did they suggest that a more profound comprehension of the qualities of soil would transform English agriculture. At least, it would significantly improve yields. At best, it would conquer famine forever.

Toward a "Vegetable Philosophy"

There were a number of scientific influences that led to the particular agricultural and managerial philosophies adopted by the Hartlib Circle and their associates. Mid-seventeenth-century experimental husbandry was fixated on "improvement" and employed a mélange of overlapping approaches toward natural history, agriculture, horticulture, and botany from multiple traditions. The writings and experiments of these reformers, projectors, and alchemists demonstrated a familiarity with numerous traditional and contemporary sources concerning these topics. Among other things, they drew on the classical tradition of Roman agricultural writings, sometimes known collectively as the *rei rusticae scriptores,*[6] classical natural histories, medieval and early modern herbals, Renaissance humanist cataloguers and compilers of natural wonders,

these draw, to some degree, from Arthur O. Lovejoy, *The Great Chain of Being: A Study of the History of an Idea* (Cambridge: Harvard University Press, 1934).

[6] Literally, "on rural (or rustic) matters." Also known as the *res rustica, rei rusticae auctores*, or *de re rustica* tradition, so-called because, beginning in the early-to-mid sixteenth century, many of the works falling into this category were published together in one volume: see Marcus Pocius Cato, et al., *Libri de re rustica* (Venice, 1533); idem., *De re rustica. M. Catonis lib. I, M. Teretij Varronis liv. Iii, Palladij lib. Xiiii* (Lyon, 1537); and Lucius Junius Moderatus Columella, *De re rustica,* in *Rei rusticate auctores Latini veteres, M. Cato, M. Varro, L. Columella, Palladius* (Heidelberg, 1595).

particularly those who also dabbled in natural magic or who purported to have gained access to *prisca sapientia*, the more recent Baconian tradition of practical experimentation, and alchemy. For many, alchemy represented the most promising, operative method to achieve the cornucopian potentials of agricultural improvement. This combination of sources, sciences, and techniques focused on understanding "growth" sometimes went under the category of "vegetable philosophy."[7]

The classical Roman agricultural writings included the Latin works of Palladius, Columella, Cato, Varro, and most especially Virgil, which were themselves derived, in part, from the Greek *œconomia* tradition.[8] These writers merited mention in dozens of published works and scores of letters and manuscripts among mid-seventeenth-century agricultural reformers regarding various aspects of farming and botany, as well as other more niche or speciality topics ranging from bee-keeping and the astrological significance of agricultural

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[7] This is a topic about which much remains to be written. For some recent attempts, see Oana Matei, "Husbandry Tradition," 35-52; Peter R. Antsey, "Experimental versus Speculative Philosophy," in *The Science of Nature in the Seventeenth Century: Patterns of Change in Early Modern Natural Philosophy*, ed. Peter R. Antsey and John A. Schuster (Dordrecht: Springer, 2005), 215-42 (though Antsey does not discuss vegetable philosophy by name); Ayesha Mukherjee, "The Secrets of Hugh Plat," in *Secrets and Knowledge in Science and Medicine, 1500-1800*, ed. Elaine Leong and Alisha Rankin (Burlington, VT: Ashgate Publishing, 2011), 69-86; and Fabrizio Baldassarri, "Manipulating Flora. Gardens as Laboratories in Renaissance and Early Modern Europe," *Rivisita de Storia della Filosofia,* Vol. 72, No. 1 (2017): 175-78. For an older interpretation of vegetable philosophy as a part of the "poetry of nature," see Charlotte F. Otten, *Environ'd with Eternity: God, Poems, and Plants in Sixteenth and Seventeenth Century England* (Lawrence, KS: Coronado Press, 1985).

[8] Joan Thirsk, "Making a Fresh Start: Sixteenth-Century Agriculture and the Classical Inspiration," in *Culture and Cultivation*, Leslie and Raylor, eds. (Leicester: Leicester University Press, 1992), 18. Much of the work of G.E. Fussell has also explored the influence of ancient agricultural traditions on medieval and early modern agriculture in Europe, and his work has been an important resource on the topic for nearly half a century. See, especially, G.E. Fussell, *The Classical Tradition in West European Farming* (Teaneck, NJ: Farleigh Dickinson University Press, 1972), and several of his earlier articles containing research contributing to this book, including G.E. Fussell and André Kenney, "L'équipment d'une ferme romaine," *Annates*, Vol. 21, No. 2 (1966): 306-323;; G.E. Fussell, "Farming Systems of the Classical Era," *Technology & Culture*, No. 1 (1967): 16-44; idem., 'The Classical Tradition in West European Farming: The Fourteenth and Fifteenth Centuries," *Agricultural History Review* (1969): 1-8; and idem., "The Classical Tradition in West European Farming: The Sixteenth Century," *Economic History Review* Vol. 22, No. 3 (1969): 538-551.

events to natural theories of witchcraft and the medical analysis of urine.[9] Many members of the Hartlib Circle cited them in their discussions of viniculture, arboriculture, and gardening: Palladius was known as an expert on grafting grape vines, Cato on the economic management of farmland, and Columella on garden care, the proper reading of calendars, when fruits ripened, and the cross-breeding of various plants and animals.[10]

As a complement to these, ancient natural history (*historia naturalis*) also contributed botanical and biological knowledge to the conversation on agricultural reform. Major works like Aristotle's *De generatione animalium, De partibus animalium, Historia animalium,* and the spuriously attributed *De plantis* received numerous references.[11] Aristotle's immediate successor, Theophrastus, composed two essential works—*Historia plantarum* and *De causis plantarum*—which provided a theoretical foundation for understanding growth and the physical and biological properties of plants. As Brian Ogilvie has demonstrated, these works, along with Pliny the Elder's *Historia naturalis* (*Natural History*), provided Italian humanists from the late fifteenth to early seventeenth centuries with the rudiments of botanical knowledge, although they also revealed the limitations of ancient natural history.[12] While they used these texts to imbue their herbaria,

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[9] On bees and bee-keeping, see, e.g., Samuel Hartlib, *Notes on Bees*, undated, HP 26/29/30B, and Samuel Hartlib, *The Reformed Commonwealth of Bees* (London, 1655); on aspects of astrology in relation to the timing of agricultural activities, see, e.g., Samuel Hartlib," Dr Brown's Miscellanies on Husbandry," undated, HP 70/4/1B; on witchcraft and urine analysis, see John Beale, "Discourse on Pearl-Bearing Shellfish," ?10 January 1659, HP 25/17/1A-16B.

[10] See, for example, Samuel Hartlib, *Ephemerides of 1650*, February – May, 1650, HP 28/1/58B; John Beale, "Treatise on Withies, Sallies, Willows, and Osiers," undated, HP 52/162A-165B; John Beale to ?Samuel Hartlib, 23 March, 1658, HP 52/5A-6B; John Beale to Samuel Hartlib, 15 November 1659, HP 62/25/1A-4B; Peter Smith to ?John Beale, 11 April 1650 – 7 April 1656, HP 67/23/8B (the date of the mention of Cato is 18 September 1655).

[11] *De plantis* is now believed to have been written by Nicholas of Damascus in the first century B.C.E.

[12] Brian Ogilvie, *The Science of Describing: Natural History in Renaissance Europe* (Chicago: University of Chicago Press, 2006), esp. 1-24. Ogilvie identified the era from approximately 1490 to 1630 as integral to this process—1490 to 1530 set up natural history as a standalone discipline while the next century constituted the development of Ogilvie's "science of describing," in which humanist naturalists corrected the errors of

pharmacopeia, and taxonomic catalogues with authority, they also expended a great deal of intellectual energy correcting these classical sources in light of recent botanical discoveries from the Americas, Africa, and Asia, so they could be practically deployed to identify exotic plants, bolster proprietary knowledge of expensive herbs or spices for trade, and enhance herbal or spagyrical medicine.[13]

Much like the humanist revival of interest in the *rei rusticae* and *historia naturalis* traditions, scholars from the late fifteenth through sixteenth centuries resuscitated long dormant ideas from late antiquity regarding the hidden mysteries of nature, sometimes referred to as the *prisca sapientia* ("ancient" or "pristine wisdom"), which, through careful study, could be revealed.[14] Important writers from this tradition included Giambatista della Porta, whose *Magia naturalis* and *Villæ* provided speculation on topics as diverse as geology, medicine, cooking, and metallurgy, among other things, and Heinrich Cornelius Agrippa von Nettesheim, whose *De occulta philosophia libri tres* contributed, as we have

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their classical forebears. Unlike encyclopedists, such as Juan Luis Vives, Giorgio Valla, and Polydore Vergil, these naturalists conferred a philosophical status on natural history that marked it not just as a rhetorical form or mode of writing about nature, but also as a scientific discipline in its own right.

[13] Ibid. See also, Anthony Grafton, *New Worlds, Ancient Texts: The Power of Tradition and the Shock of Discovery* (Cambridge: Harvard University Press, 1992), esp. 159-194. On spagyrical medicine, see Principe, *Secrets of Alchemy*, 129. Probably coined by Paracelsus, the term derives from the Greek words *span* ("to draw out") and *ageirein* ("to bring together").

[14] For a classic take on these ideas, see Frances A. Yates, *Giordano Bruno and the Hermetic Tradition* (Chicago: University of Chicago Press, 1964), though her study is somewhat narrowly focused on Hermetic philosophy at the expense of other equally important esoteric traditions. Similarly, the very phrase "*prisca sapientia*" is sometimes used as a catchall term for many humanistic interpretations of ancient knowledge that also included *prisca theologia* ("ancient theology") and *philosophia perrenis* ("perennial philosophy"). For a recent reassessment of these traditions, see Brian P. Copenhaver, *Magic in Western Culture: From Antiquity to the Enlightenment* (Cambridge: Cambridge University Press, 2015). For the influence of this "ancient wisdom"—recovered from a distant past by Renaissance humanists—on seventeenth-century natural philosophy, see various essays in Brian Vickers, ed., *Occult and Scientific Mentalities in the Renaissance* (Cambridge: Cambridge University Press, 1984); Martin Mulsow, trans. Janita Hamalainen, "Ambiguities of *Prisca Sapientia* in Late Renaissance Humanism," *Journal of the History of Ideas*, Vol. 65, No. 1 (2004): 1-13; K. Theodore Hoppen, "The Nature of the Early Royal Society: Part I," *British Journal for the History of Science*, Vol. 9, No. 1 (1976): 1-24; G. McDonald Ross, "Occultism and Science in the Seventeenth Century," in *Philosophy, Its History and Historiography*, ed. A.J. Holland (New York: Springer, 1985), 95-115; and Sarah Hutton, "Aristotle and the Cambridge Platonists: The Case of Cudworth," in *Philosophy in the Sixteenth and Seventeenth Centuries: Conversations with Aristotle*, ed. Constance Blackwell and Sachiko Kusukawa (London: Routledge, 1999), 337-49, esp. 338-41.

seen, to the Hartlib Circle's understanding of alchemy and the "multiplication" of natural objects.[15] The former included books on topics such as "the generation of animals, showing how living creatures of diverse kinds, may be mingled and coupled together, and that from them new and yet profitable kinds of living creatures may be produced" and the "production of new plants, which delivers certain precepts of Husbandry, and shows how to intermingle sundry kinds of Plants and to produce new kinds."[16]

Taken together, all these traditions informed the "vegetable philosophy" of early modern English agricultural reformers, those who developed projects for agricultural improvement, and those who wrote manuals, pamphlets, public letters, and *vade mecums* on the topic. Though difficult to categorize in isolation, when viewed as part of these broader traditions, Baconian and Hartlibian writings on agriculture appeared as a genre all their own. Like Aristotelian and Plinian natural histories, they delved into the physical attributes, geographical provenance, and medicinal properties of plants, but they were largely uninterested in taxonomy. Like the *rei rusticae scriptores*, they provided a compendium of agricultural practices, but unlike their ancient counterparts, they attempted to deliver an experimental justification for their theories. Like della Portan and Agrippan natural magic, they interpreted nature as a territory to be manipulated and refashioned, but unlike their Renaissance predecessors, who often sought to alter species

[15] Oana Matei, "*Macaria,* the Hartlib Circle, and Husbanding Creation," *Society and Politics,* Vol. 7, No. 2 (2013): 10. For della Porta's contributions, see Laura Orsi, "Giovan Battista della Porta's Villa (1592): Between Tradition, Reality, Fiction," *Anali di Storia Moderna e Contemporanea* 11 (2005): 11-66. For his major work touching on the topic of agriculture other than the *Magiæ naturalis*, see Giambattista della Porta, *Villæ J. B. Portæ, Neapolitani, libri XII…* (Frankfurt, 1592). On Agrippa, see, in general, Christopher I. Lehrich, *The Language of Demons and Angels: Cornelius Agrippa's Occult Philosophy* (Leiden: Brill, 2003). Both writers' works saw English translations in the 1650s: Giambattista della Porta, *Natural Magick* (London: Printed by Thomas Young and Samual Speed, 1658); and Heinrich Cornelius Agrippa, *Three books of occult philosophy, written by Henry Cornelius Agrippa, of Nettesheim…*, trans. John French (London: Printed by R.W. for Gregory Moule, 1651). French dedicated his translation to notable Hartlib associate Robert Child, whose primary interests were agriculture and alchemy.
[16] Giambattista della Porta, *Natural Magick*, "Preface to the Reader," [unpaginated].

or transform them for the sake of creating new and marvelous things, they pursued transformation, transmutation, and multiplication to amerliorate existing matter. Like all of these previous traditions, they accentuated the moral and spiritual dimension of their enterprise, but through the influence of radical, eschatological, Protestant interpretations of nature, they viewed natural knowledge as potentially unlimited.[17]

Vegetable philosophy—like chemical philosophy or mechanical philophy—purported to provide an explanatory framework for understanding the inner workings of nature and the cosmos. To be sure, neither the concept nor the term "vegetable philophy" originated in the seventeenth century, and though its meanings morphed, it endured into the eighteenth and even nineteenth centuries. In an early usage, Hugh Plat endorsed openness and unadorned language in the dissemination of the sciences in the preface to his 1608 *Floraes Paradise* by writing of della Porta's "vegetable Philosophy," which he obscured as "a Sphinx & roll'd it up in the most cloudy and darksome speech that he could possibly have devised."[18] Here, Plat referred to della Porta's operative magic, which promoted the creation and growth of natural objects. From the late seventeenth through early nineteenth centuries, when "vegetable philosophy" received far more attention from naturalists, it shed its non-botanical connotations and came to be applied to discussions of

[17] For a comparison of these traditions and Hartlibian works on husbandry, see Matei, "*Macaria,* the Hartlib Circle, and Husbanding Creation," 10; and idem., "Husbandry Tradition," 37-8. For the natural magic tradition, see Giambattista della Porta, *Natural Magick*, 3 and 58-64. For a prime example of an incorporation of this variety of traditions, see Ralph Austen, *A Treatise of Fruit-Trees shewing the manner of grafting, setting, pruning, and ordering of them in all respects… with the alimentall, and physical use of fruits. Togeather with the spirituall use of an orchard: held forth in divers similitudes, etc.* (Oxford, 1653). For the eschatological dimension, see Daniel 12:4; Francis Bacon, *Novum Organum*, frontispiece and Book 1, Chapter 93; John Henry, "The Scientific Revolution in England," in *The Scientific Revolution in National Context*, eds. Roy Porter and Mikuláš Teich (Cambridge: Cambridge University Press, 1992), 178-209; Edward B. Davis and Michael P. Winship, "Early Modern Protestantism," in *Science and Religion: An Historical Introduction*, ed. Gary B. Ferngren (Baltimore: Johns Hopkins University Press, 2002), 117-129, and more generally, Charles Webster, *The Great Instauration.*

[18] Hugh Plat, *Floraes Paradise* (London, 1608), sig. A5*r*. This also appears in the "Epistle to the Reader," in Hugh Plat, *The Garden of Eden*, 15.

the physiology and morphology of plants, including in some foundational texts on that topic such as Nehemiah Grew's *Anatomy of Plants* (1682) and Stephen Hales's *Vegetable Staticks* (1723). It also applied to the emergence of fields like phytochemistry, phenology, and agrobiology *avant la lettre*, and after Linnaeus, described the sexual features and taxonomy of plants as well.[19]

Among Hartlib's intelligencers, vegetable philosophy found its most notable expression in the opening passage of Ralph Austen's epistle to the reader in his *Observations upon some part of Sr F. Bacon's Naturall history, as it concernes fruit-trees, fruits, and flowers*, dedicated to Robert Boyle. In it, Austen commended Bacon for bequeathing to his generation the "Rules…of all kinds to learning" and especially his validation of

> Vegetable Philosophy, which was as it were, his darling delight, having left unto us much upon Record in his Naturall History; some part whereof referring to Fruit-trees, Fruits, and Flowers, I have, (by encouragement from himself) endeavoured to improve unto publique profit, according to what understanding, and experience I have therein….[20]

Experimentally grounded, informed by natural history, and directed toward public improvement, this Baconian variant of vegetable philosophy characterized the coalescence of these sources of botanical and agricultural tradition in the mid-seventeenth century.

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[19] See Nehemiah Grew, *The Anatomy of Plants* (London: W. Rawlins, 1682); and Stephen Hales, *Vegetable Staticks* (London: W. and J. Innys, 1723). For its continued usage in this context in the eighteenth and nineteenth centuries, see John Hill, *The Vegetable System…*, 26 vols. (London: R. Baldwin, 1759-1775); idem, *Exotic Botany, illustrated in thirty-five figures of curious and elegant plants, explaining the sexual system, and tending to give some new light into the Vegetable Philosophy* (London, 1759); Charles-François Brisseau de Mirbel, *Traité d'anatomie et de physiologie de végétales* (Paris, 1802); Benjamin Smith Barton, *Elements of Botany, or Outlines of the Natural History of Vegetables* (London: J. Johnson, 1804); and Mary Jackson Henry, *Sketches of the Physiology of Vegetable Life* (London: John Hatchard, 1811).

[20] Ralph Austen, *Observations upon some part of Sr F. Bacon's Naturall history, as it concernes fruit-trees, fruits, and flowers* (Oxford: Henry Hall for Thomoas Robinson, 1658), [unpaginated], Dedicatory Epistle.

At risk of oversimplifying, for English agricultural reformers of this time, husbandry had become the practical, experimental complement to the more abstract ancient and Renaissance botanical traditions. These reformers merged the intellectual content of *historia naturalis* and *rei rusticae*, the chymical worldview of Renaissance natural magic, the experimentalism of Bacon, and the operationalism of alchemy, all embedded within the broader context of economic, political, and spiritual improvement.[21] This desire to understand the physical and chymical nature of growth created a potent admixture of new and newly synthetic agricultural ideas designed to produce cornucopian yields.

Alchemy, Cornucopianism, and the Improvement of Soil

Although cornucopianism had deep roots in Western thought, with allegorical imagery dating back to Greco-Roman mythology, its early modern representations tended to depict bounties of food and material wealth. As a practical scientific and economic worldview, it maintained a distinctly alchemical and agricultural ethos.[22] The attention contemporary historians have paid to early modern cornucopianism stems, in part, from the increasingly notable parallels between seventeenth-century economic development

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[21] These, of course, were often *already* overlapping categories. For a comparative analysis of the botanical experiments of Giambatista della Porta and Francis Bacon, see Doina Cristina Rusu, *From Natural History to Natural Magic: Francis Bacon's* Sylva sylvarum (PhD dissertation, Nijmegen: Radbound University, 2014), esp. chap. 4. For the relationship between Paracelsian chymistry and Baconian natural history, see Graham Rees, "Francis Bacon's Semi-Paracelsian Cosmology, " *Ambix* Vol. 22, No. 2 (1975): 81-101; and idem., "Francis Bacon's Semi-Paracelsian Cosmology and the *Great Instauration*," *Ambix* Vol. 22, No. 3 (1975): 161-173. For the Renaissance attempt to synthesize the works of Aristotle, Pliny, Virgil, Palladius, Columella, and Varro under a della Portan philosophical umbrella, see Laura Orsi, "Giovan Battista della Porta's *Villa* (1592): Between Tradition, Reality, Fiction," *Anali di Storia Moderna e Contemporanea* 11 (2005).

[22] "Cornucopia" derived from the Late Latin "*cornucopia*," itself derived from the Latin "*cornu copiæ*," meaning "horn of plenty," after the mythical horn of the goat Amalthea, from which the infant god Zeus nursed. See David Lemming, *The Oxford Companion to World Mythology* (Oxford: Oxford University Press, 2005), 13. For a thorough introduction to the historical origins and trajectory of cornucopian thinking from the early seventeenth century to the present, see Fredrik Albritton Jonsson, "The Origins of Cornucopianism: A Preliminary Genealogy," *Critical Historical Studies,* Vol. 1, No. 1 (2014): 151-168, esp. 154-160.

and modern critiques of the idea of a post-scarcity economy.[23] Just as the modern global economic system is predicated on the possibility of perpetual economic growth through continuous investment in the always-increasing production of goods and services, many agricultural reformers assumed that certain versions of alchemy and intensive agricultural improvement provided the technical key to doing the same.

Cornucopianism was more than just the possibility of economic bounty, though. As attested to in early modern works touting its potentials, cornucopian thinkers considered the possible plenitude of natural capital as well.[24] Samuel Hartlib's *Cornu Copia* and Francis Bacon's *New Atlantis* both suggested that agriculture, when buttressed by contemporary applied sciences and innovative technological developments, could become an inexhaustible source of wealth.[25] Alchemy has an uneasy relationship with these ethics and

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[23] For critiques of the idea of a post-scarcity economy, particularly within the ambit of steady-state economic theory, see, for example, Herman E. Daly and Joshua Farley, *Ecological Economics: Principles and Applications* (Washington, D.C. Island Books, 2011); Tim Jackson, *Prosperity without Growth: Economics for a Finite Planet* (London: Earthscan, 2009); Rob Dietz and Dan O'Neill, *Enough Is Enough: Building a Sustainable Economy in a Finite World* (London: Routledge, 2013); Paul Gilding, *The Great Disruption* (London: Bloomsbury Press, 2011); and Naomi Klein, *This Changes Everything: Capitalism versus the Climate* (New York: Simon and Schuster, 2014), among many others.

[24] It should be noted that during the seventeenth and eighteenth centuries, political economy and the natural world were conceptually intertwined in a way that is not so prevalent or obvious today. See, for instance, Margaret Schabas, *The Natural Origins of Economics* (Chicago: University of Chicago Press, 2005), esp. 1-41; and more generally, Margaret C. Jacob, *Scientific Culture and the Making of the Industrial West* (Oxford: Oxford University Press, 1997), esp. 99-115.

[25] Albritton Jonsson has traced the origins of the English word "cornucopia" with its current meaning to the late Elizabethan or early Jacobean eras. See Albritton Jonsson, "The Origins of Cornucopianism," 155-6; and "Cornucopia," *OED*, a. The *Oxford English Dictionary* attests to an earlier usage than either Bacon's 1606 letter or the King James Bible of 1611, in the 1592 long poem by Robert Greene, entitled "A Maiden's Dream," in Stanza 31, Line 216, though its meaning appears to be something closer to "extreme hospitality" as opposed to "limitless material bounty." Thomas Johnson's *Cornucopiae, Or divers Secrets: Wherein is contained the rare Secrets in Man, Beasts, Foules, Fishes, Trees, Plantes, Stones and such like, most pleasant and profitable, and not before committed to be printed in English* (London: William Parley, 1595) is the earliest reference I have found with an unambiguous meaning referring to natural history, agricultural, and political economy. I have found even earlier uses, particularly in poetry, though the meaning is highly varied in these works. For perhaps the first printed usage in English, see John Skelton, *A ryghte delectable treatyse upon a goodly garlande or a chaplete of laurel…* (?London: Richard Faulkes, 1523), "Skelton Poeta," unpaginated. A keyword search at Early English Books Online (EEBO) [https: //eebo.chadwyck.com/home] returns over 300 mentions of "cornucopia" in 202 texts between 1523 and 1700, though nearly all of these prior to the 1610s are in poetic and religious, rather than agricultural, economic, or alchemical contexts.

economics. Some earlier descriptions negatively juxtaposed alchemy with more acceptable forms of cornucopia, such as the preface to the 1611 edition of the King James Bible, which implied that contemporary alchemists made promises they could not keep concerning the possible infinitude of both gold and foodstuffs instead of focusing on the never ending spiritual gifts of the Christian religion. Others, including Bacon's own 1606 letter to King James I entitled "Certain Considerations Touching on the Plantations in Ireland…," advised that artisanal workshops, commercial farms, and tightknit communities with robust local trade networks were preferable to haphazard settlement "where every man must have a cornucopia in himself for all things he must use; which cannot but breed much difficulty and no less waste," indicating that cornucopias grew out of needs rather than wants.[26]

Yet, during the seventeenth century, cornucopias ceased to be regarded either as pale imitations of Christian spiritual treasures or as necessities born out of a lack of economic opportunity and came to encompass notions of all manner of positive improvements to material conditions. For example, in his dedication of Richard Weston's 1650 pamphlet *A Discourse of Husbandrie*, Hartlib wrote,

> if concerning…the advancement of Agriculture (as being the main Interest of the State)…[there] were thought upon to set forward the Judicial, and regulate the Practical waie of Husbandrie, such overtures could bee made in that kinde, as would sensibly (even to the meanest capacitie) demonstrate a very Cornu Copia and fulness to bee atteined of the choicest temporal blessings to supplie all men's wants.[27]

[26] Francis Bacon, "Certain Considerations Touching the Plantation in Ireland, Presented to His Majesty, 1606," in James Spedding, ed., *The Works of Francis Bacon* (London: Longmans, Green, Reader, and Dyer, 1868), Vol. IV, 124, transcribed from the original, BL, MS Harley 6797, f. 122. See also, Albritton Jonsson, "The Origins of Cornucopianism," 155.
[27] Samuel Hartlib, "Dedication," in Richard Weston, *A Discourse of Husbandrie* (London, 1650), sig. A4*r*-*v*.

According to Hartlib, cornucopianism neither usurped God's spiritual gifts nor emerged as a condition of individual isolation but rather entailed worldly fulfillment of material needs through initiative and resourcefulness.

Around two years later in his *Cornu Copia*, Hartlib recounted his "luciferous and most fructiferous Experiments, Observations, and Discoveries," which included descriptions of how to improve barren land by sowing fodder grass seeds, how to quicken the growth of trees for timber, how to provision horses without hay or grain, how to make charcoal burn longer, and how to keep root vegetables alive throughout the winter, among other things.[28] Similarly, Gabriel Plattes's *Description of the Famous Kingdome of Macaria* proposed a number of economic and social reforms, using similar language to describe projects designed to maximize domestic output of both natural and manufactured goods, and he spoke in glowing terms of the technological and entrepreneurial impulse, especially emphasizing agriculture, animal husbandry, alchemy, metallurgy, and mining as areas ripe for cornucopian enhancement.[29] In this work, and in Plattes's thought more generally, this new intertwining of alchemy, natural history, and political economy were clearly on display. As Carl Wennerlind has argued, the Hartlib Circle exhibited early signs of cornucopian thinking "by shifting to a worldview in which the only constant was continuous change, growth and improvement," the challenge of which "was to find a way to

[28] Samuel Hartlib, *Cornu Copia, A Miscellanium* (?London, ?1652). It is possible that Hartlib's associate, Cressy Dymock, composed this list, which is also repeated in Adolphus Speede, "General Accommodations," undated, HP 57/3/8/1A-8B.

[29] Plattes, *A Description of the Famous Kingdome of Macaria* (London, 1651), *passim.* This was originally published anonymously and scholars long considered Samuel Hartlib to have authored it. See Charles Webster, "The Authorship and Significance of *Macaria*," *Past and Present* 56 (1972): 34-48; idem., *Utopian Planning and the Puritan Revolution: Gabriel Plattes, Samuel Hartlib, and "Macaria"* (Oxford: Oxford University Press, 1979), 25-32; and below.

expand the money stock so that it could keep pace with the ever growing world of goods."[30] Before that was possible, though, it was preferable to find ways to enlarge the range and number of those goods themselves. Trade, financial investment in new industries, and imperial expansion all played a role, but for agricultural improvers, especially from roughly the Civil Wars through the 1660s, the improvement of domestic, non-subsistence farming became foundational. Agriculturally speaking, increased wealth came from increasingly productive farmland, which, according to reformers, was best achieved through improvement projects.

What was meant by "improvement"? English agricultural manuals from at least the 1520s onward frequently alluded to this shifting idea of improvement, usually employing either the term "improve" or "approve." Etymologically, improve and approve were related concepts, derived from Old and Middle French words, and they were used almost interchangeably before the early sixteenth century, though they became increasingly distinct over the next hundred years. According to the *OED*, "approve" had originally meant "to make profit to oneself (of land), by increasing the value of rent esp. said of the Lord of a Manor and closing or appropriating to his own advantage common land."[31] Over the course of the sixteenth century, this part of its meaning merged with that of improvement, which in its earliest recorded usage in the field of agriculture meant "to turn land to profit; to enclose and cultivate wasteland; hence to make land more valuable or better by such

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[30] Carl Wennerlind, "The Alchemical Roots of the Financial Revolution," *Berfrois: Literature, Ideas, Tea* (blog), March 14, 2012, http://www.berfrois.com/2012/03/carl-wennerlind-credit-alchemy/. For his extended analysis of these topics, see Wennerlind, *Casualties of Credit,* esp. 1-18 and 61-83; and idem., "Credit-Money as the Philosophers Stone: Alchemy and the Coinage Problem in Seventeenth-Century England," *History of Political Economy* Vol. 35 (2003): 236.

[31] "Approve," *OED*, v2. The first attested use with this meaning was in 1483. This comes from the Statute of Merton (20 Hen. III.c.iv.). Its phrase "*faciant commodum suum*" translates the Old French word "*aproent*," and is rendered in the Statute of Westminster as "*appruare se possint de*." Other Latinized adaptations from the French included "*approare*," "*approvare*," and by the seventeenth century, "*approbare."*

means."[32] Those engaged in major land reforms such as enclosure, fen draining, and new methods of crop rotation often interpreted their work through the lens of improvement.

In the seventeenth century, these definitions accumulated further nuances beyond the agricultural and economic and came to encompass the moral, religious, legal, and political improvement emphasized by Bacon and Baconians, whose goals were adopted by Hartlib and his associates beginning in the 1630s.[33] For example, Hartlib's associate Robert Child, who wrote widely on intensive agriculture, alchemy, and the political economy, suggested that personal gardens offered a sort of microcosmic living laboratory for the improvement of the earth. He envisioned gardeners as masters of their own small dominions, whose sensible tilling of their plots would create both personal abundance and self-sufficiency, which would lead to a less exploitative attitude toward the natural world at the macroscopic level. Had gardening been more widespread before the seventeenth century, he wrote, "*Gardiners* might have saved the lives of many poor people."[34] Their contemporary proliferation led to "new and laudable ingenuities."[35]

Many other associates clearly held similar views. In notes on social reform, the agricultural theorist Cressy Dymock advocated for Hartlib to petition Parliament for the creation of a "Steward General of Husbandry for the Nation."[36] Gabriel Plattes had suggested special bodies of Parliament devoted to these issues, including a "Councell of Husbandry" and a "Councell on New Plantations," which would instruct "that the twentieth

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[32] "Improve," *OED,* v2.2b. First attested use in 1473.
[33] McRae, "Husbandry Manuals and the Language of Agrarian Improvement," 36.
[34] Child, "A Large Letter concerning the Defects and Remedies of English Husbandry, written to Samuel Hartlib," in Samuel Hartlib*, His Legacie of Husbandrie…*, 26. See also, Walter W. Woodward, *Prospero's America: John Winthrop, Jr., Alchemy, and the Creation of New England Culture, 1606-1676* (Chapel Hill: University of North Carolina Press, 2010), 90.
[35] Ibid., 38.
[36] Samuel Hartlib, *Ephemerides of 1650*, HP 28/1/45A.

part of every mans goods that dieth shall be employed about the improving of lands…by which meanes the whole Kingdome is become like to a fruitfull Garden," in essence making inheritance taxes on land contribute to a national agricultural fund.[37] These policy proposals never materialized, but found some later conceptual resonances in the creation of the Georgical Committee on agricultural affairs within the Royal Society in 1664, though this, too, never led to any serious policy changes.[38]

In spite of his admiration for Bacon, Hartlib used his rhetoric about "torturing nature to give up her secrets" as an example of how *not* to conduct experiments on the natural world, lest "learning [be] reduced to certain emptie & barren Generalities, being but the very Huskes & Shales of Sciences, all the Kernel being forced out, & expulsed with the torture & presse of their vntimely Methods."[39] Others within Hartlib's orbit held similar opinions. The prominent early Royal Society member John Evelyn wrote in his *Sylva* and *Fumifugium* what amount to some of the earliest tracts in English on natural resource sustainability and rectifying the problem of air pollution, both of which advocated for improvement without domination. The former called for extensive planting and conservation of trees to provide fruit, ensure timber for shipbuilding, and decontaminate the air. In the latter, he wrote that "money has blinded people to the thing which keeps them alive and which can, for their own sake, be improved so easily...it seems absurd that men, who owe their lives to air, are not able to breathe freely, but instead are allowed to live in misery."[40]

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[37] Plattes, *Macaria*, 3-4.
[38] Joan Thirsk, ed., *The Agrarian History of England and Wales,* Vol. 2, 1640-1750, Part I, *Agrarian Change* (Cambridge: Cambridge University Press, 1985), 372, 444, and 562-565.
[39] Samuel Hartlib to John Dury, 13 September 1630, HP 7/12/3A.
[40] John Evelyn, *Fumifugium, or, The inconveniencie of the aer and smoak of London dissipated together with some remedies humbly proposed* (London, 1661), 2. For more on the importance of this work, see William M.

Endorsing what Carolyn Merchant called a "managerial ecology," Evelyn, along with other promoters of agricultural management like Gabriel Plattes, John Beale, and William Petty, sought to increase crop yields, maximize profits, expand the power of the state for public good, and resuscitate a fallen nature all in one fell swoop.[41] Even in the face of the massive influence of the Baconian sciences, the aspiration to produce cornucopian abundance by exploiting nature, and the ultimate spiritual pursuit of the millennium, the members of the Hartlib Circle who exerted the most actual dominion over nature through their projects were also the most keenly aware of what stewards they had to be for improvement to work. This ethos led to a meticulous approach to such improvement.

Why were famines so prevalent, farming so laborious, and the deficiencies of agricultural knowledge so profuse that improvement was thought necessary? The soteriological and eschatological dimension of this interpretation of nature cannot be overstated. As noted above, essentially every Christian in England accepted that they lived in a post-lapsarian world where labor, and especially agricultural labor, existed as a consequence of the Fall. It was more than symbolic that the location from which Adam and Eve had been expelled was a garden.[42] More broadly, it was not just humanity that had fallen from grace with this expulsion but the earth itself, which now required a great deal of work to bring forth its natural riches.

Cavert, *The Smoke of London: Energy and Environment in the Early Modern City* (Cambridge: Cambridge University Press, 2016), esp. 173-194. Cavert argues that *Fumifugium* was not actually an early declaration of environmentalist principles but rather the culmination of over a century of discussion aimed at improving London's air quality.

[41] Carolyn Merchant, *The Death of Nature: Women, Ecology, and the Scientific Revolution* (San Francisco: Harper Collins, 1980), 238, and more generally, 236-52.

[42] See Andrew Cunningham, "The Culture of the Garden," in *Cultures of Natural History*, ed. Nicholas Jardine, James A. Secord, and Emma C. Spary (Cambridge: Cambridge University Press, 1996), 38-56.

For the soil, though, another Biblical event exerted a stronger influence: the Noachian Flood. Even as the expulsion from Eden had been cause for a great deal of humanity's present woes, seventeenth-century Christians often pointed to the postdiluvian era as the origin of agriculturally based civilization, as Noah was considered the "first tiller of the soil" and all countries of the earth were populated by his progeny.[43] The effects of the Flood on the earth's crust were up for debate. Representative of the most pessimistic view was Godfrey Goodman's *Fall of Man*, *or the Corruption of Nature*, *proved by the Light of our Naturall Reason…*, which fused the concept of humanity and the earth as equally fallen with ancient Greco-Roman notions of a bygone golden age. "Nature," he wrote, was "now beginning to decay."[44] Moreover, Goodman viewed this degeneration as permanent as no degree of scientific ingenuity could ameliorate this condition. He claimed that God had given farmers "a fatness in the vpper crust thereof, but in the great inundation of waters, being spread and covered ouer with sand, it is now baked and grown."[45] However, this limited fertility provided only enough for subsistence "in this last and old age of the world," which need only endure until the return of Christ.[46] Neither international trade, nor imperial expansion, nor the acclimatization of exotic plants could ever make up for these deficiencies, for "God in his wisdom and prouidence would haue disposed our climat accordingly; what a madnesse or folly were it in vs, to seeke to equall other nations in their owne wares? We must conforme our selues to the soyle, and not thinke to reduce nature to

[43] Genesis 9:20.
[44] Godfrey Goodman, *The Fall of Man, or the Corruption of Nature, proued by the Light of our Naturall Reason Which being the First ground and Occasion of our Christian Faith and Religion, may likewise serue for the First Step and Degree of the Naturall Mans Conuersion* (London: Felix Kyngston, 1616), 385.
[45] Ibid., 285-6.
[46] Ibid.

our wils and appetites."[47] As the Second Coming approached, according to Goodman, it was inevitable that soil became more infertile, diseases and famines became more rampant, men and women grew smaller than their ancient counterparts in age of the patriarchs, and animals and plants grew weaker, less productive, and less nutritive.[48]

This was perhaps the pinnacle of such a viewpoint though, and Goodman received a great deal of criticism for these interpretations, most notably from George Hakewill, whose response *An Apologie or the Power and Providence of God* countered many of Goodman's tenets.[49] The general thrust of this work is a physico-theological defense of the glory of creation, a meditation on God's continuing power and providence in the world, and a vindication of humanity's continued ability to positively affect nature with God's blessing. Despite being an ostensibly theological tract, its extensive contents relied heavily on contemporary natural philosophy, and Hakewill made copious references to the motions of heavenly bodies, optics, the continuing efficaciousness of the four elements, the relationship between air and diseases, and in one chapter, "the pretended decay of the earth, together with the plants, & beasts, & minerals," as evidence that the earth was not degenerating but was instead prospering.[50]

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[47] Ibid., 164.
[48] On the historical context of Godfrey's postdiluvian pessimism, see W.H.G Armytage, *Heavens Below: Utopian Experiments in England, 1560-1960* (Abingdon: Routledge, 1961), 3-6; Hans Kohn, "The Genesis and Character of English Nationalism," *Journal of the History of Ideas* Vol. 1, No. 1 (1940): 72-76; and somewhat more recently, Rob Illife, "The Masculine Birth of Time: Temporal Frameworks of Early Modern Natural Philosophy," *British Journal for the History of Science* Vol. 33, No. 4 (2000): 438. On Goodman's life and works, see G.I. Soden, *Godfrey Goodman, Bishop of Gloucester, 1583-1656* (London: SPCK Publishing, 1953).
[49] For a point-counterpoint analysis of these positions, see Ronald W. Hepburn, "Godfrey Goodman: Nature Vilified," *The Cambridge Journal* 7 (1954): 424-34; and idem., "George Hakewill: The Virility of Nature," *Journal of the History of Ideas* Vol. 16, No. 2 (1955): 135-150.
[50] George Hakewill, *An apologie of the power and prouidence of God in the gouernment of the world. Or An examination and censure of the common errour touching natures perpetuall and vniuersall decay…* (Oxford: John Lichfield and William Turner, 1627), 128-143.

The earth's fecundity provided ample evidence of this, and Hakewill used terms like "virile," "nourishing," "fat," "fruitful," and "plentiful" to describe it throughout.[51] Hakewill wrote of "hearbes and plantes and flowers…suck[ing] their nourishment as so many infants from their mother's breasts," by which he meant dynamic soil, and he accorded "God and Nature" a powerful reproductive virtue so "one seede sometimes multiplies in one yeare many thousands of the same kind."[52] He argued for the cyclical character of fertility and suggested an equivalent material exchange between land and sea by noting that "as the rivers daily carrie much earth to the sea, so the sea sends backe againe much slime and sand to the earth."[53] Hakewill disagreed with the idea that there was a specific relationship between the soil and God's chosen people, and he cited scripture, ancient Roman authorities Columella and Pliny the Elder, and the thirteenth-century traveling ascetic Saint Brocard on the natural history of Palestine to claim that Biblical locations were agriculturally productive "before the entrance of [Moses's] people" and since being settled "by the Saracens…it hath not altogether lost its ancient fruitfulnes whatsoeuer."[54] Any deterioration of the soil in this or any other location, according to Hakewill, was evidence not of "any Naturall decay in the goodnes of soyle" but of "the Curse of God vpon that accursed nation, which possesseth it, or to their ill manuring of the earth."[55] Notably, the fault for unfertile land lay not with nature but with people being poor stewards, on whom God might place blame.

[51] For a list of some of these instances, see Hepburn, "George Hakewill," 148.
[52] Hakewill, *An apologie for the power and prouidence of God…*, 32.
[53] Ibid., 130.
[54] Ibid., 132-33.
[55] Ibid., 133.

This section of Hakewill's work continued with mostly rationalistic and experiential arguments for the earth's enduring prosperity. It included accounts of "miserable dearths in former ages," compared with stories of the abundance of certain crops in the seventeenth century.[56] It also encompassed a justification for why food seemed to cost more, with an explanation of the declining purchasing power of English currency, a discourse on climatic difference as a barrier to the growth of certain plants in certain places, and an account of the balance of global mineral wealth and the general importance of imperial exploration. "Though mines [of silver and gold] faile in the East Indies," he wrote, it is "most certain…that in the West Indies, that supposed defect is abundantly recompensed."[57]

As ideas about cornucopian improvement, the decay of the earth, and the practical uses of alchemy jostled with one another for explanatory power in the early seventeenth century, those who sought to reform husbandry pursued a resolution to this debate through practice. However, they did not discard traditional knowledge on these topics indiscriminately. Even as many of their influential predecessors from Paracelsus to Bacon had urged knowledge-seekers to abandon ancient sources in favor of modern experience, Baconian and Hartlibian agricultural reformers borrowed liberally from traditional sources of knowledge as well as practitioners of the most recent agricultural ideas. While highly critical of their forebears, there was no "quarrel of the ancients and moderns" among them regarding agriculture. Rather, theirs was a combinatory and synthetic attempt to understand fertility with whatever sources offered a reasonable answer.

[56] Ibid., 136-139.
[57] Ibid., 141.

Gabriel Plattes and the Alchemy of Plant Growth and Soil Fertility

An understanding of the alchemical interpretation of growth is integral to understanding the practical ways that agricultural reformers addressed the topic of improvement. Alchemy, transmutation, and the notion of material improvement were acutely interwoven concepts in the Hartlib Circle. Once the immediacy and calamity of the English Civil Wars had passed, Samuel Hartlib and many of his fellow intelligencers turned their attention to husbandry, particularly after about 1650. As his voluminous papers attest, Hartlib's interests ranged widely, but this turn to husbandry seems to have been a direct result of his association with Gabriel Plattes and his continued interest in his writings after Plattes's death. Most of Plattes's writings in the late 1630s and early 1640s advocated for a radically improved agricultural system based in large part on the physical and chymical understanding of natural capital as the cornerstone of an economically prosperous nation. "This treasure consisteth of improvements in Husbandry," Plattes wrote, referring to the titular topic of his *Discovery of Infinite Treasure,* "whereof the least is inestimable and infinite, for that thereby so many lives present and future are maintained."[58] An alchemical understanding of the physiology of plant growth and chymistry of soil fertility was economically necessary because according to Plattes, the possibility of "the transmutation of sublunary bodies" ensured that "any man may be rich that is industrious."[59]

Very little is known about Gabriel Plattes's early life, and almost nothing is known about him before his association with Hartlib. He was born around 1600 to a farming

[58] Plattes, *Discovery of Infinite Treasure*, sigs. C2*r-v.* For the importance of "infinity" in the context of Hartlibian political economy, see Paul Slack, "Material Progress and the Challenge of Affluence in Seventeenth-Century England," *Economic History Review* Vol. 62, No. 3 (2009): 576-603, esp. 589.
[59] Plattes, *Macaria*, 12.

family which “lived well upon a small Farme; and by their industry maintained and educated their children, in manner not much inferior to the sons of the best Knights and Gentlemen of the countrey.”[60] He gained experience farming with his father and developed an observational knowledge of contemporary mining practices in his youth.[61] His earliest known writings, dating from the 1630s, suggest that he had traveled extensively throughout southern and western England. He may have been employed at some point before 1638 by the military drainage engineer William Englebert, to whom he dedicated his two earliest published works, *A Treatise on Husbandry* and *A Discovery of Subterraneall Treasure*, and whom he mentioned in an undated petition to Sir Robert Harlowe concerning the patent rights to a coining machine then in possession of the London mint.[62] According to Webster, his emphasis on experimental methodology may have originated from his acquaintanceship with the mathematician John Pell, a noted advocate of experimentalism, who later became a member of an internal committee of the Royal Society concerned with mechanical and optical instruments. Pell was also responsible for recording and performing experiments on natural phenomena for the Royal Society and served on that

[60] Quoted in G.E. Fussell, “Gabriel Plattes: A XVII-Century Writer on Agriculture,” *Notes and Queries* 174 (1938): 78.

[61] On his parentage, see Ted McCormick, “Alchemy into Economy: Material Transmutation and the Conceptualisation of Utility in Gabriel Plattes (*c*. 1600–1644) and William Petty (1623–1687),” in *‚Eigennutz‘ und ‚gute Ordnung‘: Ökonomisierungen der Welt im 17. Jahrhundert*, Sandra Richter and Guillaume Garner, eds. (Weisbaden: Harrassowitz Verlag, 2016), 341. For more scant information on his early life and upbringing, see Charles Webster, “The Authorship and Significance of *Macaria*,” 34-48; idem., *Utopian Planning and the Puritan Revolution*, 14-21; and W. A. S. Hewins, rev. Anita McConnell, “Plattes, Gabriel (*c.*1600–1644),” *ODNB*, last accessed 16 August 2017, http://www.oxforddnb.com/view/article/22360.

[62] Hewins, “Plattes, Gabriel (*c.*1600–1644),” *ODNB.* On Plattes’s relationship with Englebert, see Webster, “The Authorship and Significance of *Macaria*,” 39. Little has been written on Englebert, and although obscure even in his own day, he seems to have been involved in several important fen drainage projects in the early seventeenth century. On him and his work more generally, see Eric Kerridge, *The Agricultural Revolution* (London, 1967), 229-30. For Plattes’s petition, see Gabriel Plattes to Sir Robert Harlowe, undated, HP 71/4A-4B.

institution's first agricultural board.[63] Plattes spent the last few years of his life in London, where, based on his own writings and posthumous discussions of his work, he met or corresponded with a number of the most prominent experts in chemistry, mining, metallurgy, and husbandry.

Some of his best-known works—*A Treatise on Husbandry*, *A Discovery of Infinite Treasure,* and *A Discovery of Subterraneall Treasure*, all published in the late 1630s—showcased Plattes's major interests and demonstrated the influence he eventually had on the reformers and improvers from the 1640s to 1660s. His *Treatise on Husbandry* offered both a practical manual and an erudite, if plainspoken, discourse on the intellectual content of husbandry as practiced in the seventeenth century. In it, Plattes described methods for pastureland enclosure, various forms of organic and inorganic fertilizing techniques, instructions for seed sowing and tree planting, up-to-date methods for effective grafting and pruning, and information on seed-steeping and pest control, in addition to more theoretical treatments of the chemistry of soil fertility. Similarly, the *Discovery of Subterraneall Treasure* was one of the first practical English texts concerning mineralogy and metallurgy, and it described the practical processes of mining, smelting, the assaying of ores, and metal-smithing, as well as his own hypothetical understanding of the origins and propagation of mineral deposits and metal seams in the earth. This emphasis on practical knowledge that was infused with theoretical discursions characterized much of his work and the work of those he influenced. For instance, John Beale called the fruits of

[63] Webster, *Utopian Planning and the Puritan Revolution*, 17. For his Royal Society appointments, see, Christoph J. Scriba, "Pell, John," *ODNB*, Oxford University Press, 2007, last accessed 11 April 2018, https://doi.org/10.1093/ref:odnb/ 21802.

agricultural labor his "infinite Treasures" in reference to Plattes's book, and he claimed to have studied much of his oeuvre.[64]

Like Francis Bacon, Plattes viewed the improvement of agriculture as part of a broader social and religious improvement that included the human mind, body, and soul, the body politic, and society at large. The ultimate goal of improved agriculture was to improve individuals physically through better nutrition and spiritually through the good work of pastoral labor and the use of one's augmented harvest as welfare for the poor. It combined the expertise of Baconian sciences with techniques designed explicitly for improvement, which were interlinked processes facilitating scientific advancement, social reform, and ultimately salvation.[65]

Much of this appeared in Plattes's quasi-utopian tract the *Description of the Famous Kingdome of Macaria*, originally published anonymously on 25 October 1641, which may have been intended as a petition to the Long Parliament.[66] While *Macaria* has often been interpreted in reference to the literary tradition of Thomas More's *Utopia* and compared with contemporaneous utopias like Johannes Valentinus Andreae's *Christianopolis* (1619) and Francis Bacon's *New Atlantis* (1626), its suggestions read as strikingly practical compared to its precursors'.[67] Plattes cited both More and Bacon, and although *Macaria* clearly owed some debt to their works, he confessed that "none of them giveth mee

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[64] John Beale to ?Samuel Hartlib, 12 March ?1657, HP 62/16/2B.

[65] Oana Matei, "Husbanding Creation and the Technology of Amelioration in the Works of Gabriel Plattes," *Society and Politics,* Vol. 7, No. 1 (2013): 90.

[66] Webster, *Utopian Planning and the Puritan Revolution*, 21-32.

[67] For the utopian and literary contexts of these works, see J.C. Davis, *Utopia and the Ideal Society: A Study of English Utopian Writings, 1516-1700* (Cambridge: Cambridge University Press, 1982); D.R. Dickson, *The Tesseara of Antilia. Utopian Brotherhoods and Secret Societies in the Early Seventeenth Century* (Leiden: Brill, 1998); and R. Appelbaum, *Literature and Utopian Politics in Seventeenth Century England* (Cambridge: Cambridge University Press, 2002). For an alternate interpretation of this work as a policy proposal, see Amy Boesky, *Founding Fictions: Utopias in Early Modern England* (Athens: University of Georgia Press, 1996), 91; and Webster, *Utopian Planning and the Puritan Revolution*, 21-32.

satisfaction."[68] More of a general policy proposal for a reformed commonwealth than a description of an ideal society, *Macaria* laid out plans for the economic development of the nation through increased and diversified trade, by treating information as an exchangeable commodity, by free disputation about economic policy amongst educated men in various trading councils, and by strictly regulating and developing the output of farms, forests, parks, and gardens.[69]

Plattes's work on the improvement of mixed husbandry stressed the natural bounty of the earth and suggested that the amelioration of land through conscientious agricultural usage contributed to a concomitant spiritual amelioration. As he wrote in *Macaria*, every "Parson of every parish" would also be a "good Physician" and would "execute both functions…[of] *cura animarum* & *cura corporum,"* remedying both soul and body.[70] In his *Discovery of Subteraneall Treasure,* Plattes noted that God would "heal" various parts of fallen nature only if humanity incorporated technological improvements to hasten the process. This notion of healing the natural world through the incorporation of the systematic problem-solving techniques echoed the Baconian philosophy of the "second creation," in which humanity played an active role in recreating the conditions of Eden through the technological manipulation of the natural world.[71] These developments enhanced the good works that Protestants believed were signifiers that they were in God's good graces and had been elected for salvation.

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[68] Plattes, *Macaria*, 9.
[69] Ibid., *passim.*
[70] Ibid., 6.
[71] See, for instance, Francis Bacon, *The Advancement of Learning* (Oxford: Leon Lichfield, 1605), I.11; and idem., *Novum Organum Scientarum* (London, 1620), II.52.

Comparing the use of seed steeps to speed up plant germination with the flourishing of human virtues, for example, Plattes argued that natural fertilizers should be enriched chymically and alchemically to provide the greatest possible nourishment for crops. This was a literal, physical argument to describe what was occurring with the plant matter as well as a metaphysical or spiritual one to describe the internal state of those cultivating and ingesting the harvest.[72] Crops, of course, were for human consumption, and any improvement in their growth would lead to a nutritional improvement in human beings. This situation was doubly constructive—through an appropriate stewardship of the land, England was to be rewarded spiritually as well as economically.[73] Plattes's early emphasis on the overlapping natures of spiritual, agricultural, and economic improvement—aided by the transformative power of alchemical techniques—inspired many projectors associated with Hartlib during the Civil Wars and Interregnum.

Plattes's attitude toward alchemy was a complicated one, but it is worth examining in some detail to understand precisely what he meant when he used alchemical terminology, particularly when the succeeding generation of reformers adopted it. On the one hand, in his posthumously published *Caveat for Alchemists* he called those who claimed to be able to transmute base metals into gold "charlatans" and "cozeners." Based on the technical details of a number of alchemical procedures contained within this work, Plattes clearly had at least some familiarity with traditional forms of laboratory and text-based alchemy. Yet, he admonished his readers that

> if any smoak seller, or Wandring Alchymist, shall come to any ingenious Gentleman that studieth this Art, though he bring with him a recipe that promiseth golden

[72] Gabriel Plattes, *The Discovery of Subterraneall Treasure* (London, 1639), 36-9. See also Oana Matei, "Husbanding Creation," 90.
[73] Matei, "Husbanding Creation," 87.

> mountains, and maketh affidivit, I mean that searcheth never so deeply, that he hath done it, or seen it done, which is a common trick amongst wandring Alchymists: believe him not…for if you do believe him having not that knowledge, I will give my word for him, that he shall cozen you.[74]

Elsewhere, Plattes referred to alchemical recipes as "Balderdash compositions" and "illiterate operations," though his complaint was less about the matter theory underlying transmutation and more about the intentions of the alchemists, who pursued gold-making not for the sake of scientific knowledge but for lucre. They "ayme only at profit," he wrote, which was "a very desperate hazard."[75] The warnings he dispensed were hard-won. He had uncovered the truth about alchemists like this firsthand because, by his own admission, they had swindled him in the past. Thinking himself "a very knowing man" he had paid £100 for the transmutation of an unnamed base metal into gold only to find himself

> soundly cheated, a fool, and so disdained not to learn wit at any bodies hands that could teach me, whereby I attained a considerable quantity of knowledge, which I will not give or change, for any mans estate whatsoever; but though I sped so well by being cheated, yet I wish all others to take heed, for fear least that their fortunes prove not so good as mine.[76]

Embittered by the experience, Plattes resolved to avoid itinerant alchemists in the future and to rely only on experimental results he could witness and confirm himself.

On the other hand, he fully accepted the concept of alchemical transmutation. In both his *Discovery of Infinite Treasure* and *Discovery of Subterraneanall Treasure*, he

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[74] Plattes, *A Caveat for Alchymists…*, in *Chymical, medicinal, and chyrurgical addresses: made to Samuel Hartlib…* (London, 1655), 58-9. For an early historical interpretation of this work, see D. Geoghegan, "Gabriel Plattes' Caveat for Alchemists," *Ambix*, Vol. 10, No. 2 (1962): 97-102. Geoghegan called this the first work devoted solely and explicitly to warning the unsuspecting of fraudulent alchemists on scientific and economic rather than moral grounds. For this tradition as found embedded in other works, particularly regarding the self-interest and profit motive of alchemists, see Smith, *Body of the Artisan*, 165-181; idem., *Business of Alchemy*, 213 and 215. For some examples of such embedded warnings near-contemporary to Plattes, see, for instance, Petrus Bonus, *Pretiosa Margarita Novella* (Venice, 1546), sig. [vi]*r*; George Ripley, "The Twelve Gates," Part 5, Stanza 44, in Elias Ashmole, *Theatrum Chemicum Britannicum* (London, 1652), 159; and Eireneus Philalethes [George Starkey], *The Marrow of Alchemy* (London, 1654), 50.

[75] Plattes, *Discovery of Infinite Treasure*, 25.

[76] Plattes, *A Caveat for Alchymists…*, 64. For more on these encounters, see McCormick, "Alchemy into Economy," 343-344.

described transmutation, as did the Paracelsians, as a widespread, natural process occurring in all instances of material or chemical change. "All treasure and riches are nothing but congealed vapours," he wrote in *The Discovery of Infinite Treasure*, referring to some contemporary notions about the sources of soil fertility,

> for what is corne, and fruits, the chiefest of all riches, but the fatnesse of the earth; *Iacobs* blessing elevated by the heate of the Sunne, and turned into vapour by the helpe of the Vniversall spirit of the world, then drawne together by the Adamantine vertue of the Seeds, and Plants, and so congealed into the same forme?[77]

Plattes was highly suspicious of the possibilities of *chrysopoeian* alchemy, or the transmutation of base metals into gold, and he cautioned against believing those who claimed to have done this. Nevertheless, he largely accepted a quasi-Paracelsian and Helmontian vision of nature as a place in constant flux, where all natural change could be considered alchemical and where humanity could gain some control over those changes. The botanical growth of plants, the transfer of nutrients from plants to animals, and the use of that energy in animal and human muscle for productive work all constituted forms of transmutation. Opportunities for improving these processes existed in a number of ways from boosting the soil fertility of farmland to enlarging the amount of harvestable crops, from more deliberately planned animal breeding to alchemically altered metals, minerals, and chymical substances used in manufacturing and agriculture. Even the education of children, the raising up of the poor, and the expansion of wealth through investment and interest bore a relation to this complex network of interactions.[78] Though he did not reduce these solely to chymical processes, he did assert that they were controllable through technical expertise and the application of the latest chemical and alchemical knowledge. He

[77] Plattes, *Discovery of Infinite Treasure*, [14].
[78] Wennerlind, *Casualties of Credit*, 57-58.

hoped that by educating farmers in these new methodologies he could "make them to excell their predecessors even as a learned Physician excelleth an Empiricke" for the good of the nation.[79]

In spite of his own negative experiences with alchemists, Plattes's difficulty accepting the spectacular claims of transmutation stemmed less from empirical denial and more from weighing the relative costs and benefits. Though he "affirme[d] the Art of Gold making to be true," he did not "affirme it to be lucrous in these times."[80] Accounting for the rarest, purest, and most fully congealed form of "fatness," gold *was* transmuted from other metals but this happened naturally, over very long periods of time, deep within the bowels of the earth, and without human intervention. Plattes believed it was possible for an alchemist to replicate this, and he even devoted a chapter to this sort of experiment in his *Subterraneall Treasure*. He described the transmutation of copper and iron into gold, which could be accomplished by mixing it with oil, butter, and yellow sublimate, "rectifying it three or foure times," adding equal parts amalgam of silver and mercury, heating it gently for a week or more, and then separating the resultant mixture with aqua fortis. Then, one could extricate small grains of "pure and good gold" but "the quantity would not pay for halfe the charges and labour."[81] Though Plattes was unequivocal about the reality of transmutation, the amount of time, effort, financial investment, and expertise necessary to mount such an effort far exceeded the ultimate value of the gold itself. "If any one doubt the truth of *Alchimy,* he may be satisfied by this trial," Plattes wrote, "but in stead of gaine he

[79] Plattes, *Discovery of Infinite Treasure*, [9].
[80] Ibid., [30].
[81] Plattes, *Discovery of Subterraneall Treasure*, 40-42.

shall pay for his learning, by going away with losse."[82] This had been his own personal experience and became a regular theme of Plattes's writings. He regarded the information gained from these efforts as the true treasure and the capital expended as the appropriate price. Most importantly for him, a far more attainable form of transmutation existed in converting barren soil into arable farmland, which was "more certain, and more profitable," not to mention more spiritually noble and socially conscientious.[83]

For Plattes, how did alchemy and chemical philosophy specifically influence concepts of soil fertility? Clearly, soil was a complicated substance. With reference to Gottfried Wilhelm Leibniz's habilitation thesis *De Arte Combinatoria* and Athanasius Kircher's highly popular *Mundus Subterraneus,* horticulturist John Evelyn, in his *Philosophical Discourse of Earth*, famously claimed, "there are reckoned no fewer than one hundred seventy nine millions, one thousand, and sixty sorts of earth."[84] The prospect of understanding something so complex was no doubt daunting, but natural, alchemical change seemed to provide some answers. As we have seen above, Plattes had argued that the "combustible fatness" in the soil accounted for its fertility. "Fatness," Plattes had written, was "the Treasure, and indeed the Fountaine of all Treasure and Riches in the World," and he claimed that productive agriculture was more important even than

[82] Ibid., 42. This became a common refrain among certain alchemists and was repeated, for example in Johan Rudolf Glauber, *Continuatio miraculi mundi* (1656); and, idem., *De medicina universalia* (1657). See Young, *Faith, Medical Alchemy, and Natural Philosophy*, 159.

[83] Plattes, *Discovery of Infinite Treasure*, 80.

[84] John Evelyn, *A Philosophical Discourse of Earth* (London, 1675), 11. Curiously, this information does not appear to be in Leibniz's work. This diversity and profusion of soils was often attributed to Athanasius Kircher, *Mundus Subterraneus* (Amsterdam, 1665). Though Kircher writes about the diversity, complexity, and profusion of soils, I have been unable to locate a reference to this specific number of soils outside of Evelyn. For an admittedly incomprehensive sampling of misattribution or partial attribution, see, e.g., Clifton Winthringham, *A Treatise of Epidemic Diseases* (York: Grace White, 1718), 66; "Jethro Tull's Husbandry," *The Farmers' Magazine* (July 1855), 342; Arthur Cassagrande, "Classification and Identification of Soils," *Transactions of the American Society of Civil Engineers*, 113 (1948): 901-991 [original pagination], in *A History of Progress: Selected U.S. Papers in Geotechnical Engineering*, ed. W. Allen Marr (Reston, VA: American Society of Civil Engineering, 2003), 407.

hospitals or medicine, for it "enableth an infinite number to both feede and clothe themselves."[85] Economically speaking, as the title of his most important work on this topic, *The Discovery of Infinite Treasure*, implied, his theory of fertility was cornucopian in nature, and he variously described the properties of fatness in soil as "inexhaustible" and "infinitely beneficiall," requiring only a knowledgeable improvement of agricultural techniques to unlock soil's limitless potential.[86] Notably, artificial saltpeter manufacturers sometimes described the nitrous earth used as a starting point for their projects as "fatty soil" and farmers preparing seed steeps referred to the process as "fattening."[87]

According to Plattes, the key to unleashing this fecundity depended on finding or creating soil with the appropriate amount of "combustible fatness," by which he meant a certain heretofore-unknown fertile property, that "cause[d] vegetation by its rarifying and vaporing quality" due to the light and heat of the sun and transported this "fatness" from the soil into plants via liquid water.[88] These vapors contained "the universall spirit of the world," or the vital property required for life, and in the presence of ample sunlight, they "congealed" and contributed to plant growth.[89] There were, however, two kinds of fatness: a combustible fatness and an incombustible, or fixed, fatness. In vaguely Empedoclean terms, Plattes described the former as lightweight and associated with the qualities of fire and air and the latter as denser and wetter and associated with earth and water. Obliquely analogizing Galenic humoral medical theory as well, Plattes argued that balance was

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[85] Plattes, *Discovery of Infinite Treasure*, [7] and [9]. "Fatness" was a concept with ancient roots, and one can find references to it as far back as Virgil. See G.E. Fussell, "Crop Nutrition in Tudor and Early Stuart England," *Agricultural History Review*, Vol. 3, No. 2 (1955): 103-4. Fussell briefly addressed alchemical enquiries into the topic but argued that they only "confused…[and] clouded the issue."
[86] Ibid., [7-8]
[87] Agricola, *De re metallica*, 561.
[88] Plattes, *Discovery of Infinite Treasure,* 23.
[89] Ibid., [29-30], [32-33], 23-24, 77-79, and 81.

necessary for soil to be productive: too much combustible fatness and the land would burn too easily when it was hot and dry whereas too little would not confer enough nutritive properties.[90]

Writers of husbandry manuals from the sixteenth and seventeenth centuries described how rural farmers tested for "fatness" and experimented with various methods for understanding these principles on the fields of their farms. A heady mixture of custom, folklore, oral history, and centuries of inherited advice developed into intricate methods of soil analysis. Farmers sifted handfuls of dirt between their fingers to test for moisture, clay or silt content, color, temperature, density, and clamminess. They "transplanted" soil from one location to another and examined whether the new soil split apart from the old. And they sought plots of land where elm, sloe, bullace, and crab apples grew, as these were considered signs of fertile soil. These techniques had developed independently of later chymical analyses, but all of them became tactile experiments lay farmers could perform to gain elementary knowledge about the qualities of soil, which developed fresh meanings within this new chymical context.[91]

The social implications of this expertise led to major disagreements over the legal and practical future of land management in England. Radical republicans like the Digger Gerard Winstanley argued that equality in the eyes of God required "everyone…[to] quietly have earth to manure" and he viewed the unequal distribution of chymically fertile soils as

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[90] Ibid., 23-24.

[91] See, for instance, Thomas Hyll, *A most high and pleasant treatyse for teaching how to garden…* (London, 1563), 15; and Barnabe Googe, *Foure Books of Husbandry…* (London, 1577), 18. For a discussion of these, and other forms of traditional chemical soil analysis, see Simon Schaffer, "The Earth's Fertility as a Social Fact in Early Modern Britain," 127-128; G.E. Fussell, *Crop Nutrition: Science and Practice before Liebig* (Lawrence, KS: Coronado Press, 1971), 57-59; idem., "Crop Nutrition in Tudor and Early Stuart England," 103; and Merchant, *The Death of Nature*, 55-56. Merchant notes that women in the field did much of this work. See, for example, Gervase Markham, *The English Husbandman* (London, 1613); and Walter Blith, *The English Improver Improved* (London, 1652), "Epistle Dedicatory," 4-5.

a reason to vehemently resist enclosure and advocate for more equitable property distribution.[92] Winstanley used language that resonated with microcosm-macrocosm parallels and prefigured later natural theological interpretations of the intricacies of life as evidence of God's handiwork. For example, he wrote that "the spirit or power of wisdom and life" instigated "motion or growth" and resided "within and govern[ed] both the several bodies of the stars and planets in the heavens above; and the several bodies of the earth below, as grass, plants, fish, beasts, birds, and mankind."[93] Meanwhile, utopian writers like James Harrington pointed to the importance of the private but equitable ownership of agriculturally productive land as a necessity for republican governance.[94]

In much the same manner that he viewed credible alchemy as human intervention to accelerate natural processes, Plattes also suggested that soil's fatness could be augmented via manuring, which transformed incombustible into combustible fatness. However, manuring only helped in areas where incombustible fatness predominated, as it would overload already fatty soil. To explain the purpose of dunging land, he asserted that there was nothing specifically important about the manure itself, "for there is no difference in dungs."[95] Rather, manure amplified latent fertility in the ground because of chemical interactions between the dung, the soil, and the seeds. In one experiment, he moved pigeon dung from one location with an abundance of combustible fatness to one with more

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[92] Gerrard Winstanley, *The Law of Freedom and other Writings*, ed. Christopher Hill (Harmondsworth, 1973), 20-25, quoted in Schaffer, "The Earth's Fertility as a Social Fact in Early Modern Britain," 128.
[93] Ibid., 256-57.
[94] James Harrington, *The Commonwealth of Oceana*, quoted in Schaffer, "The Earth's Fertility as a Social Fact in Early Modern Britain," 128. For an analysis of Harrington's views on soil fertility, land ownership, and republicanism, see J.G.A. Pocock, *The Machiavellian Moment: Florentine Political Thought and the Atlantic Republican Tradition* (Princeton: Princeton University Press, 1975), 383-396; and idem., ed., "Introduction," in James Harrington, *The Commonwealth of Oceana and A System of Politics* (Cambridge: Cambridge University Press, 1992), esp. xiii and xviii-xxii.
[95] Plattes, *Discovery of Infinite Treasure*, 27.

incombustible fatness, and "in the one soile, the Pidgeons dung cured the barennesse, in the other it poysoned the fertilitie."[96] Plattes devoted much of his short pamphlet *The Profitable Intelligencer*—which originated from a long letter to Samuel Hartlib entitled *Mercurius Lætificans*—to the importance of dung, which promoted the growth of "the vegetable spirit in the world, by which all things do encrease and multiply."[97] For Plattes, the significance of dung lay in the potentially infinite cycle of this vegetable spirit. Assuming that no manure was squandered from any animal or person that consumed vegetable matter from a particular plot of land and all was eventually returned to the ground as artificial fertilizer for crops, none of this "vegetable spirit" would go to waste. "Any parcell of good land, being kept in pasture, and having the dung, which it breedeth, spent upon it," Plattes wrote, "doth continue fertill for ever, without any other addition: so the excrements, and materials, which any family produceth, being well contrived, will produce yeerly as much bread, and drink, as that family spendeth for ever."[98] Even so, Plattes noted that other substances reproduced this effect with many times more potency. He called saltpeter derived from bird guano the "richest compost in the world," noted that animal flesh and blood had five times the nourishing power of the

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[96] Ibid.

[97] Plattes, *The Profitable Intelligencer* (?London: T.U. for the Bible in Woodstreet, 1644), unpaginated. *Mercurius Lætificans* was later published separately in Samuel Hartlib's *Legacy of Husbandrie*. The full title of *The Profitable Intelligencer* is instructive of Plattes's overall concerns of improving husbandry: "*communicating his knowledge for the generall good of the common-wealth and all posterity. Containing many rare secrets and experiments (having reference to a larger book) which being well observed, and industriously practised, according to the directions therein by all the inhabitants of England in generall, will recover the wealth of the kingdom now so miserably wasted by these unnaturall wars, and make it the most flourishing countrey in the world, and cause more naked to be clothed, more hungry to be fed, more poore virgins to be preferred in marriage, more sick to be healed, then Suttons Hospitall the Savoy, and all the hospitals and liberall gifts in England have ever performed, by certain wayes which require no charge nor labour, but what every active person shall be double payed for. A copie of the letter, wherein the discourse entituled, Mercurius Laetificans, was sent enclosed to the authors most worthy, and highly honoured friend, Mr. Samuel Hartlib.*" Hartlib's reprint included in the title the phrase "…*also many more outlandish and domestick experiments and secrets (of Gabriel Plats and others) never heretofore divulged in reference to universal husbandry*."

[98] Ibid.

equivalent weight in manure, and averred that the "skin, haire, wooll, horns, and hoofes" of various ungulates accounted for ten times the power.[99]

Comparing artificial fertilizers to "medicines…made for the diseases of man," Plattes alleged that soil quality mirrored the health of an individual.[100] While natural, bountiful land filled with combustibly fat soil was preferable, fertilization was often necessary, but Plattes viewed this as a prophylactic measure, just as one would take certain medicines or herbs to prevent illness.[101] This was no mere analogy, though, and the same substances involved in fertilizers often found transferable uses in spagyrical and iatrochemical medicines. The Dutch physicians and natural historians Arnold and Gerard Boate inferred from saltpeter's uses as a fertilizer that it had medical applications, and the practice of steeping seeds in "fructifying waters" containing substances like slaked lime, common salt, or boiled water to ward off various fungal maladies and smut diseases suggested other possible therapeutic uses for the human body.[102]

Plattes's skepticism of alchemists' *chrysopoeian* embellishments notwithstanding, it was a unified theory of subterranean growth, applying to both plants and minerals, that connected the knowledge he had developed while studying mining, metallurgy, and mineralogy with his concurrent proposals for agricultural improvement. The

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[99] Ibid.
[100] Plattes, *Discovery of Infinite Treasure,* 23.
[101] Matei, "Husbanding Creation," 90.
[102] For the transferability of saltpeter, see Matei, "Husbanding Creation," 100 n.47. For the Boate brothers specifically, see Newman and Principe, *Alchemy Tried in the Fire*, 236-7 and 237 n.102, and Webster, *The Great Instauration*, 64-65. These mentions appear in "Copy Extract Dr Boate & Hartlib," 29 March and 12 April 1653, HP 39/1/6B, and Samuel Hartlib, *Ephemerides 1650, Part* 2, February – May 1650, HP 28/1/58B. For the possible medicinal analogies of smut diseases and human ailments, see Smith and Secoy, "A Compendium of Inorganic Substances Used in European Pest Control before 1850," 1185 and 1187-88. For slaked lime, see e.g., Gervase Markham, *A Way to Get Wealth* (London, 1631), 88 and *passim*; Samuel Hartlib, *His Legacie of Husbandry* (London, 1651), 16; and Adolphus Speed, *Adam out of Eden* (London, 1658), 98 and *passim*. For common salt and boiled water, see e.g., Hartlib, *His Legacie*, 15-16 and 128; Blith, *English Improver Improved*, 127; Speed, *Adam Out of Eden*, 105; and Gabriel Plattes himself, in his posthumously published *Practical Husbandry Improved* (London, 1656), 62.

materialization of metal seams and mineral deposits deep within the earth and the germination of seeds just below the surface relied on the same essential mechanisms and one could readily learn about one by studying the other. For the former, Plattes imagined a deep natural history filled with dynamic events that altered both the earth's surface and underground from their static, uniform state following the Creation.

Arguing that God made nothing without humanity's purpose in mind, Plattes claimed that since "craggy Rocks and mountaines" appeared to fulfill no such purpose, they must have arisen naturally after the Fall.[103] The origin of these seemingly superfluous objects was "the vapours of Bituminous and Sulphurious substances kindled in the bowells of the Earth," which also accounted for "the veines of Mettalls…engendred in the crackes and crannies of the said Mountaines, out of the most clammy and glutenous part of the said vapours there adhering, where the cold gave them leave to bee congealed and condensed."[104] Furthermore, he reckoned that this could be demonstrated experimentally by taking a strong glass container and filling it halfway full of "Brimstone, Sea-coale, and as many bituminous and Sulphurious subterraneall substances as can bee gotten," padding the rest of it with "the most free earth from stones as can be found," and heating it with a "temperate" fire in an alchemical furnace.[105] The heat of the fire baked the material together, mirroring in miniature the natural, subterranean globe. The resultant product resembled "Earth petrified, [and] turned to stone," but most importantly, it was not a solid, uniformly dense material, but had "cracks and chinkes in it, filled with the most tenacious,

[103] Plattes, *Discovery of Subterraneall Treasure*, 4-5.
[104] Ibid., 7. For more on Plattes's theory of the formation of the earth, see Allen G. Debus, "Gabriel Plattes and the Chemical Theory of the Formation of the Earth's Crust," *Ambix* Vol. 9, No. 3 (1961): 162-165; idem., *The Chemical Philosophy: Paracelsian Science and Medicine in the Sixteenth and Seventeenth Centuries* (Mineola, NY: Dover, 1977), 93.
[105] Plattes, *Discovery of Subterraneall Treasure*, 6.

clammy, and viscous parts of the said vapours, which ascended from the subterraneall combustible substances."[106] Plattes argued that this emulated the formation of the diverse topography of the earth's surface and the heterogeneity of substances below the surface, both of which accounted for mineral richness.

The heat-activated, vitalizing power of these vapors also explained why countries in warm climates seemed to have both abundant mineral deposits and lush vegetation, provided that there was enough water in these locations. According to Plattes, this accounted for why gold was often found in riverbeds, as these streamed down off mountains, under which gold was produced, and the longer the warm and rainy season was, the longer these rivers would flow. The heat also affected the richness of the mineral deposits themselves. In the same way that "roasted meates are sweeter than boyled meates or raw meates," Plattes wrote, so too were minerals enriched by heat, "for…the rawish and unsavory part is exhaled by the heate of the fire, leaving the sweeter part behind."[107] These were the same vapors that accounted for the congelation of combustibly fat earth and ultimately plant growth.

According to Plattes, this basic matrix described all natural growth, and he unified the formation of metals, minerals, and plants under this theory, which he referred to as chymical generation, and which included nascent ideas about chemical cyclicality in soil, water, the atmosphere, and the living creatures that inhabited these spaces.[108] When read together, Plattes's works—almost all of which were published within the remarkably short

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[106] Ibid.
[107] Ibid., 38.
[108] Ibid., 36-39; and Plattes, *Discovery of Infinite Treasure*, 23-24 and 27. For more context on Plattes's notion of the similarities between the growth of minerals and the germination of seeds, see Webster, *Great Instauration*, 472; and Matei, "Husbanding Creation," 87 and 90.

period of the half-decade between 1639 and his death in 1644—provided a template for the technical improvement of farming, a theoretical accounting for why this was possible, and a political and socio-economic rationale for why it was a good idea.

Plattesian Chemical Philosophy of Soil among Hartlibian Agriculturists

Plattes's impact on the rest of the Hartlib Circle, as well as on an entire generation of agriculturists, is evident from the number of positive mentions he receives among their correspondence and the care Hartlib took with his papers and belongings after he died in poverty, possibly of starvation, on the streets of London in 1644 "having not so much as a shirt about his body."[109] Although numerous other improvements to husbandry had markedly more drastic and long-lasting effects, Plattes's theories provided a scaffold for a chemical philosophy of soil that endured for several decades.

It is difficult to verify whether many potential agricultural improvement methods were ever practiced, especially those that appeared in textbooks and husbandry manuals. It is likely that many recommendations were never implemented, and many of those that were occurred sporadically, in isolated locations, or only once on a particular farm.[110] Those that do not appear in later generations of agricultural manuals likely did not produce the desired results. However, we can say with some assurance that several of the experiments mentioned in Plattes's works were attempted and that a variety of reformers earnestly endorsed his theories.

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[109] Hewins, "Plattes, Gabriel (*c.*1600–1644)," *ODNB.* For his physical state at his death, see Samuel Hartlib to John Winthrop, Jr., 16 March 1660, HP 7/7/2B.
[110] Fussell, "Crop Nutrition in Tudor and Early Stuart England," 95.

One common theme, especially among Hartlib's French correspondents, was the similarity between Plattes's theories about the practical implications of soil chymistry and the works of the sixteenth-century potter, ceramicist, and engineer, Bernard Palissy, whose craftsman-like investigations into the materials with which he worked contributed to the development of early modern chymistry, geology, hydraulics, and agronomy.[111] Marin Mersenne, who had fostered a similarly diverse and expansive correspondence network based in France, wrote to Theodore Haak in 1639, then in England, about "a Frenchman named Palissy, who has observed things similar [to Plattes] on water, minerals, marl to manure the earth, etc.," and he offered to send Palissy's works to Plattes if he had not yet read them.[112] This offer was repeated the next month with specific reference to Palissy's *Discours Admirables* (1580), and Mersenne expressed belief that since neither knew Latin and both "proceed[ed] by common sense," there would be much to learn from a comparative analysis of their works.[113] Though Palissy's work predated Plattes's by nearly half a century, Mersenne and Haak noted an affinity to their approach to questions about soil chymistry. Hartlib concurred and remarked in his January 1640 *Ephemerides* that it was "profitable to observe in all Countrys, such men as Plattes in England, Palissy…in

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[111] On Palissy's contributions to early modern chemistry, see Allen G. Debus, "Pallisy, Plat, and English Agricultural Chemistry," *Archives Internationale d'Histoire de Sciences,* 21 (1968): 67-88; and Wallace Kirsop, "The Legend of Bernard Palissy," *Ambix* 9 (1961): 136–154. For more on his general contributions to early modern science, see Pamela H. Smith, *The Body of the Artisan: Art and Experience in the Scientific Revolution* (Chicago: University of Chicago Press, 2004), esp. 70-90, 149-153, and 224-227, and various essays in Lestringant, ed., *Bernard Palissy, 1510–1590: L'Ecrivain, le réforme, le céramiste,* esp. Bernard Rivet, "Aspects économiques de l'oeuvre de B. Palissy," and Frank Lestringant, "L'Eden et les tenèbres extérieures."

[112] Marin Mersenne to Theodore Haak, 24 November 1639, HP 18/2/3A-B. "*Il y a un autre Francois nommé Palissy, qui a semblablement observé beaucoup de choses, des Eaux, des Mineraux, de la marne pour fumer la Terre etc; s'il ne l'a veu, il y aura moyen de le luy envoyer, s'il* [*le*] *desire….*"

[113] Marin Mersenne to Theodore Haak and John Pell, 10 December 1639, HP 18/2/4A-B. "*Peut estre que ces deux hommes, qui ne sont pas lettrez* [i.e., in Latin] *et qui procedent par le sens commun, se seront rencontrez en plusieurs* [*choses*?]." The full title of Palissy's work is *Discours admirables, de la nature des eaux et fontaines, tant naturelles qu'artificielles, des metaux, des sels et salines, des pierres, des terres, du feu et des maux* (Paris, 1580), which covers "the nature of water and fountains, both natural and artificial, metals, salt and saltworks, stones, soil, and fire."

Fraunce etc. The Germans no doubt have written all what they know in several secrets Trades etc so that of necessity there must bee an excellent threasure in their bookes."[114] As with much of his intelligencer work, Hartlib hoped to disseminate these "true Phylosophies" more widely across Europe.[115] Mersenne later thanked Haak and Pell for furnishing him with more of Plattes's books and for Plattes's apparent resolution to "impart all of his works and experiences" for posterity's sake.[116] For Hartlib, Mersenne, and Haak, the works of Plat, Palissy, and Plattes stood as exceptional examples of artisanal knowledge in action, which they hoped to emulate and promote.

Following Plattes's death, Hartlib took possession of his papers with the hope that he had left something publishable.[117] Only his *Caveat for Alchymists*, after major edits, fit this description, even though Hartlib took great care of the rest of his papers after his death. Several of Hartlib's correspondents clamored for access to these documents. Cheney Culpeper, in particular, requested any and all information about his unpublished works, including eight requests over the course of one year concerning the creation of saltpeter using pigeon dung.[118] He voiced deep concerns about Plattes's works being lost, and although he thought it was tragic that Plattes had died before seeing the practical application of his theories, he expressed confidence that these would come to fruition in time. With long-term reform as the ultimate goal, Culpeper intimated that noticeable achievements would be a multigenerational project. "Mr Plats thowghts (thowgh they lye a

[114] Samuel Hartlib, *Ephemerides 1640, Part I,* January 1640, HP 30/4/39B. Hartlib's subheadings for this section were "*Eruditio*" ("learning") and "*Apodemica"* ("travel advice literature").
[115] Samuel Hartlib to Lord Robartes, 28 May 1640, HP 7/50/2A.
[116] Marin Mersenne to Theodore Haak and John Pell, 15 January 1640, HP 18/2/10A-B. "*Ie suis fort ayse que Monsieur Plattes se resolve de donner toutes ses oeuvres et experiences; la Posterité* [*luy*?] *en sera grandement oblige*."
[117] W. A. S. Hewins, "Plattes, Gabriel (*c.*1600–1644)," rev. Anita McConnell, *ODNB,* Oxford University Press, 2004, last accessed 16 August 2017, http://www.oxforddnb.com/view/article/22360.
[118] For a list of these references, see Oana Matei, "Husbanding Creation," 98 n.14; and page 88 n.20 above.

while undergrownd) will yet then (like corne that doth soe) afford the better harvest," Culpeper wrote to Hartlib, and "our resolution must be to plante to posterity thowgh our selues may not perhaps to injoy any other part of the fruuite of the action…"[119] In further letters to Hartlib over the course of 1644 and 1645, Culpeper commended Plattes's method of "clothinge corn with a riche Composte."[120] He extolled his hands-off approach to natural change, where detachment and inaction often yielded better results, and endorsed following that advice on the production of artificial fertilizers like saltpeter, which, if "left to the operation of nature onely" would "inlarge" and "accelerate."[121] He also found himself in agreement with Plattes's definition of alchemical transmutation, averring "that he whoe knowes how to restore to the Spirite of Nature its naturall motion in leade or any other imperfecte mettall he may be able [to]…" and perceiving this as an option for many materials, even while admitting that this seemed improbable for gold.[122]

Plattes had a significant impact on John Beale, as is evident from the number of positive mentions he received in Beale's correspondence with Hartlib and Oldenburg. Around late 1655 or early 1656, Beale and Hartlib began corresponding with one another roughly once a week, a practice they sustained until the latter's death in March of 1662. The peak of Beale's writings on agriculture prior to the founding of the Royal Society, to which he was elected on 21 January 1663, came between 1656 and 1659.[123] The only published book with Beale's name unambiguously attached to it was his *Herefordshire Orchards, a Pattern for all England* (1657), a short treatise expounding upon the economic advantages

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[119] Cheney Culpeper to Samuel Hartlib, 20 November 1644, HP 13/55A-55B.
[120] Culpeper to Hartlib, 21 January 1645, HP 13/66B-67A.
[121] Culpeper to Hartlib, ca. November 1645(?), HP 13/277B.
[122] Culpeper to Hartlib, 20 May 1645, HP 13/86B-87A.
[123] Patrick Woodland, "Beale, John (*bap.* 1608, *d.* 1683)," *ODNB*, Oxford University Press, 2004, rev. 2008, last accessed 14 October 2017, http://www.oxforddnb.com/index/1/101001802/.

of cider production, the improvement of arable land for the expansion of orchards, and various technical aspects of arboriculture. With the exception of a handful of papers published in the *Philosophical Transactions* in the 1660s and 1670s, mostly culled from his correspondence with Henry Oldenburg, all other works were either published in volumes with multiple authors or as short prefaces or "aphorisms" appended to larger works.[124] Between early 1656 and mid 1657, shortly before that peak, Beale wrote at least four letters to Hartlib discussing Plattes's impact.[125]

In the first letter, dated 23 February 1656, Beale touted his own prowess as an "experimentor" and boasted that he had "done more" than he "had yet read in…Gabriel Platt and others," indicating that by then he had likely read Plattes's works on experimental husbandry, which included at least his *Profitable Intelligencer, Treatise of Husbandry,* and the *Discovery of the Infinite Treasure*.[126] As late as 1675, while expounding upon the genius of Hugh Plat in a letter to Henry Oldenburg, Beale extolled Plattes's body of work, which taught common farmers how to transform "'stones into the finest bread, fat beefe & mutton' for ye Best Tables, and to fill the bellies of millions of the poor and hungry. To make of worst land in England, to be the richest, from the West to the Garden of England."[127]

Not all references to Plattes were uncritically adulatory, however. Beale clearly spent some time correcting Plattes's writings, applying his own knowledge to refute some

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[124] Leslie, "The Spiritual Husbandry of John Beale," 151. Beale was extremely reticent to publish throughout his lifetime. In the name of quasi-anonymity, he had signed a number of his works "by I.B. sometime F. of K.C. Cambridge," presumably meaning "Iohn Beale, sometime Fellow of King's College, Cambridge."
[125] These are the same letters that discussed Hartlib's fructifying water and Plattes's claim to putrefy rainwater. See pages 163-8 above.
[126] Ibid.
[127] Beale to Oldenburg, 17 April 1675, *Correspondence of Henry Oldenburg*, Vol. 11, 280. The internal quotation is Beale citing Plattes, who in turn was quoting Plat.

of his theories, and possibly replicating some of his experiments. Hartlib wrote to Beale on 27 November 1656 requesting "some animadversions upon the mistakes of Gabriel Plat, which I hear are not a few," to which Beale responded that he would offer Hartlib more than he required, though his eventual response is either lost or was never written.[128] In at least two further letters in April and May of 1657, around the time of the publication of his *Herefordshire Orchards*, Beale wrote letters to Hartlib "in the style of Gabriel Plattes," by which he meant that they used experimental, speculative, "Bombast[ic] expressions" that ventured far beyond what was known for certain.[129] The takeaway from these letters is that Beale was critically reading Plattes, reenacting some of his agricultural experiments, and assessing the agricultural theories that informed his writings.

Plattesian Chemical Philosophy in Hartlib's* Legacy of Husbandry: *The Annotations of Arnold Boate

As we have seen, husbandry manuals flourished from about 1650 onward and many of them incorporated Plattesian conceptions of soil fertility, chymical change, and methods for agricultural improvement. Among the most sophisticated treatments of these conceptions comes from Samuel Hartlib's *Legacy of Husbandry*, which contained a series of lists of "certain experiments for improving and inriching land" in a large section titled "Dr. Arnold Boati's [Boate's], Annotations upon the Legacy of Husbandry."[130] Several of these experiments followed Plattesian matter theory and a transmutational conception of the ways that plant, animal, and mineral matter might transform from one to another and back

[128] Beale to [?]Hartlib, 13 March [?]1657, HP 62/16/1A.
[129] See Beale to [?]Hartlib, 17 April 1657, HP 52/9A-10B; and Beale to Hartlib, 4 May 1657, HP 62/23/1A and 4A.
[130] Samuel Hartlib, *His Legacy of Husbandry…*, 189. "Dr. Arnold Boati" referred to Arnold Boate. The full section of Boate's annotations runs from pages 118-216, though the section on Plattes's work runs only from 189-216.

again. This section began with a report on various trials that Boate had reputedly either conducted or witnessed, mostly on composting, but also on everyday topics like where to build farmhouses, how to make cellars waterproof, how to cure sheep rot (a common foot and hoof disease of ungulates), and how to preserve grain so it neither spoiled nor was eaten by pests.[131] The final section comprised a series of four experiments demonstrating "how all sublunary bodies may be changed one into any other." They were 1) "how Minerals may be turned into vegetables," 2) "how this Corn may be turned into Animals," 3) "how this animal may be turned into vegetable again," and 4) "how vegetable may be turned back into minerals."[132]

Though short on both length and specifics, these few brief pages exemplified Plattes's influence on the theory of natural transmutation and the importance of understanding the alchemy of soils, plant growth, fertilizers, human and animal nutrition, and perhaps even fossil formation. These experiments existed both for those who "delighteth in the knowledge of the secrets of nature" and for those who "delighteth in the gaining of riches," and Boate clearly believed that those who focused on the former would inevitably receive the latter. Like the proper alchemist, those who conducted these trials in pursuit of knowledge would be repaid with material wealth as a happy by-product.

Boate reasoned that since all earthly creatures were born, propagated themselves, and died, "the God of Nature" must have a "great desire for changes," for if this were not the case, "there would have been more stability in sublunary things than hath ever been

[131] Ibid., 189-216.
[132] Ibid., 213-16. This section actually contained five experiments, but the fifth one, "shewing how weeping land may be drained where there is no level," had nothing specifically to do with transmutation.

found."[133] Distancing himself from della Portan and Aggripan generative natural magic, Boate assured his readers that these Plattesian techniques converted materials already held in common by each substance in ways that could be managed. "In these transmutations," he wrote, comparing natural transmutations to carving a fiddle out of a viol, "I mean not that the whole substance is changed, but that a share thereof: so much as is apt for the next body, into which it is to be turned, is really changed."[134] According to Boate, transmutation was partial, not total, and nature was parsimonious in the matter it converted.

The accounts of these transmutations are remarkably short, some of them totaling fewer than one hundred words, and they describe more than they analyze. The first experiment concerning "how Minerals may be turned into vegetables" bore some similarities to other alchemical recipes that claimed to show "vegetating" metals or metallic crystalline growth that seemed to rapidly accelerate natural processes that otherwise could only be seen as static, finished products in underground mineral seams or the stalactites and stalagmites in caves. Performed in laboratories, recreated in lecture halls, and exhibited in princely courts, these so-called "chemical gardens" or "silica gardens" were stunning spectacles that purported to display—depending on the philosophical predilections of the practitioner—Aristotle's "vegetative soul," the multiplication of Peter Severinus's and Van Helmont's "*semina*," the activation of Michael Sendivogius's "*sperma,*" or any number of alchemists' "*spiritus vitalis*."[135]

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[133] Ibid., 213-14.
[134] Ibid., 214.
[135] See Johann Rudolf Glauber, *Furni novi philosophici* (Amsterdam: Johan Jansson, 1646), 186-89. These demonstrations had become popular in mid seventeenth-century England. As prepared by Glauber, it involved dissolving iron in "spirit of salt" or modern-day hydrochloric acid (HCl)—creating modern-day ferrous chloride ($FeCl_2$)—boiling it until no liquid remained, and adding the resultant solid material to "oil of

Boate's quite literally down-to-earth example of this was the patina that formed on copper steeped in water or otherwise exposed to the elements "and putrified till it be green and fattish," which acted as both an illustration of metallic "vegetation" and as an indication that one had found fertile soil.[136] By comparing two equally well-watered plots of land—one with copper ore and one without and each sowed with an equal amount of the same type of seeds—Boate reported that "much more cometh of the one than of the other, the same that was produced by the vegetative part of the Minerals."[137] The second experiment very simply asserted that if one took any grains grown on this land and fed them to an animal, in Boate's example a pigeon, "then the increase must needs come from the vegetables that had their increase from the Minerals."[138] This held true when people ingested the improved grain as well.

In the final two experiments, these processes were simply reversed. Like the first experiment, the third was comparative. Boate instructed his readers to take two trees of equal size, one of which had been planted where a deceased animal had been buried and one of which had not, "and you shall see that the tree growing upon the grave will be greater than the other, for that it is nourished with the putrified Animal, and so the substance of the Animal is turned into the Vegetable."[139] The final transmutation, "shewing

sand" or "oil of glass," meaning modern-day potassium silicate (K_2SiO_3), after which silicate crystals appeared to "grow." For more on these presentations, see William Newman, "The Chymistry of Isaac Newton," last accessed 27 February 2018, http://webapp1.dlib.indiana.edu/newton/reference/chemProd.do; Anna Marie Roos, "The Chymistry of Francis Willughby: The Trinity College, Cambridge Community," in *Virtuoso by Nature: The Scientific World of Sir Francis Willughby, FRS (1635-1682)*, ed. Tim Birkhead (Leiden: Brill, 2016), 114-15; and Philip Ball, "The Crucible," 31 May 2011, https://www.chemistryworld.com/opinion/column-the-crucible/30050 43.article.

[136] Hartlib, *His Legacy of Husbandry…*, 214.

[137] Ibid.

[138] Ibid., 214-15.

[139] Ibid., 215. Though sometimes attributed to indigenous Americans in seventeenth-century New England, this farming technique dates back to at least medieval France, where coastal farmers used washed up fish

how this Vegetable may be turned back into Minerals," had a series of related examples, though the meanings were somewhat vague.[140] Boate made some ambiguous assertions about having seen "both Wood and Fishes turned into Stones" in mines and quarries, which may have been references to petrified wood and fossilized fish.[141] From the context, however, it is unclear whether Boate was claiming to have observed the final artifact disinterred by miners or whether he had witnessed their transmutation himself. This section ended with a brief, alchemically inflected description of the smelting of ores, wherein these stones "may be melted into Iron or other fusible substances, and if Iron you may turn part thereof into good Gold."[142] Again, as the pinnacle of material substances, the change into gold was viewed as the potential final transmutation, even as it existed at the end of a continuum of all material change.

Conclusions

Plattes did not originate all aspects of his chemical philosophy of soil fertility, plant growth, and the alchemical transmutation of mineral to plant to animal and back again, and these general theories did not dissipate once his specific influence began to wane. His importance lies in the fact that he was among the first to suggest a specific agricultural application for this knowledge. Hugh Plat, Bernard Palissy, and Bacon's sources among craftsmen, tradesmen, and artisans had laid much of the groundwork, and many of his contemporaries, such as Ralph Austen, Walter Blith, and especially Samuel Hartlib,

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carcasses as fertilizers. In England, it was first reported in John Mason, *A Brief Discourse of the New-Foundland* (London, 1620).

[140] Ibid.

[141] Ibid.

[142] Ibid.

subscribed to these concepts even as they adapted and amended them. And, as we shall see in the following chapter, many of his ideas—particularly the transferability of transmutation and other operative forces from alchemical to agricultural contexts—found an audience among several Restoration-era agricultural writings, including John Beale's *Herefordshire Orchards*, as well as a few unpublished manuscripts and several articles in the *Philosophical Transactions,* Robert Sharrock's *History of the Propagation and Improvement of Vegetables*, Kenelm Digby's *Discourse Concerning the Vegetation of Plants*, John Worlidge's *Systema Agriculturæ*, and John Evelyn's *Philosophical Discourse of Earth*.[143]

Though the specter of food dearths remained, outright famines all but disappeared in England over the latter half of the seventeenth century, and while the general push for agricultural reform certainly contributed to this decline, innovations such as enclosure, the draining of the fens, the Norfolk four-course crop rotation, the sowing of turnip, clover, and various fodder grasses, and the development of the Dutch swing plow unarguably had a much greater impact than the alchemical manipulation of soil, water, and plants.[144] Yet the

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[143] See John Beale, *Herefordshire Orchards* (London, 1656); idem., "Concerning the Transmutation and Improvements of Plants," Royal Society Papers, RB/1/34/9; *Philosophical Transactions of the Royal Society of London* (hereafter *Phil. Trans.*), Vol. 3 No. 43(1668): 853-862; *Phil. Trans.* Vol. 4, No. 56 (1669): 1131-1134; *Phil. Trans*. No. 4, Vol. 56 (1669): 1135-1141; *Phil. Trans.* No. 6, Vol. 71 (1671): 2144-2149; Robert Sharrock, *The History of the Propagation and Improvement of Vegetables, by the Concurrence of Art and Nature* (Oxford, 1660); Kenelm Digby, *Discourse Concerning the Vegetation of Plants* (London, 1661); John Worlidge, *Systema Agriculturæ* (London, 1668); John Evelyn, *A Philosophical Discourse of Earth* (London, 1675); and below, pages 264-75.

[144] On these, and other late seventeenth- and early eighteenth-century developments of what has been called the British agricultural revolution, in general, see, again, Overton, *Agricultural Revolution in England*; Thirsk, *Agrarian Improvement of England and Wales*, Vol. 2, Pts. 1 and 2; and Kerridge, *The Agricultural Revolution*. On the notion, specifically, of improvement, see Drayton, *Nature's Government: Science, Imperial Britain, and the 'Improvement' of the World;* Slack, *The Invention of Improvement*; and McRae, "Husbandry Manuals and the Language of Agrarian Improvement." On sown grasses, see Mauro Ambrosoli, *The Wild and the Sown: Botany and Agriculture in Western Europe, 1350-1850* (Cambridge: Cambridge University Press, 1997). On the rise in crop yields and agricultural output per capita, see James B. Ang, Rajabrata Banerjee, and Jakob B. Madsen, "Innovation and Productivity Advances in British Agriculture, 1620-1850," *Southern Economic Journal* Vol. 80, No. 1 (2013): 162-86; and Alexander Apostolides, Stephen Broadberry, Bruce Campbell, Mark Overton, and Bas van Leeuwen, "English Agricultural Output and Labor Productivity, 1250-1850: Some Preliminary Estimates," 26 November 2008, http://www.basvanleeuwen.net/bestanden/agriclongrun1250to1850.pdf.

cornucopian motives and the drive for improvement not only in agriculture but also in governance, social welfare, economic security, and spiritual wellbeing remained, and alchemical notions of multiplication and transmutation undoubtedly accentuated these concerns.

Many early modern alchemists and chymical philosophers drew significant distinctions between the didactic, methodical, laboratory practices of chymistry, elite text-based theory, and the Paracelsian chemical philosophy that pervaded popular interpretations of material change.[145] However, shared accounts of the underlying causes of material change, contested though they so often were, united the seemingly disparate theories and practices of those involved in both alchemy and agricultural improvement. Gabriel Plattes stands as a remarkable example of these interdisciplinary influences at the opening of the Hartlib Circle's prominence in the affairs of agricultural improvement, which endured as these republican-era trials gave way to Restoration-era science and the early Royal Society's Georgical Committee on agricultural affairs. For Plattes and his contemporary reformers in the Hartlib Circle, the multiplicative capacity of alchemical production, the potential for agricultural improvement, and the drive for cornucopian natural and economic rewards all depended on studying the same natural processes and the laboring for the same material change.

According to Apostolides et al., wheat, rye, barley, oats, peas, and beans production, collectively, saw a three and a half fold increase per capita between 1650 and 1850, with nearly half of that occurring between 1650 and 1750.

[145] Owen Hannaway, *The Chemists and the Word: The Didactic Origins of Chemistry* (Baltimore: Johns Hopkins University Press, 1975), esp. xi-xii, 75-91, and 117-151. Hannaway compares chemistry textbooks, such as Jean Beguin, *Tyrocinium Chymicum* (Paris, 1610), Nicolas Lemery, *Cours de Chymie* (Paris, 1675), and most especially, Andreas Libavius, *Alchemia* (Frankfurt, 1597), which contained step-by-step technical instructions on chemical and alchemical laboratory procedures, with Oswald Croll, *Basilica Chymia* (Frankfurt, 1609), whose work dealt with Paracelsian and Hermetic chemical philosophy, a very different field according to Hannaway. For a more recent investigation of the topic, see Bruce T. Moran, *Andreas Libavius and the Transformation of Alchemy: Separating Chemical Cultures with Polemical Fire* (Sagamore Beach, MA: Science History Publications, 2007).

CHAPTER 5

"CONCERNING THE TRANSMUTATION AND IMPROVEMENTS OF PLANTS": ALCHEMICAL OPERATIONS, BOTANICAL CHANGE, AND THE MEANINGS OF TRANSMUTATION

"The ancient teachers of [chemistry]…promised impossibilities and performed nothing. The modern masters promise very little; they know that metals cannot be transmuted and that the elixir of life is a chimera. But these philosophers seem only made to dabble in dirt, and their eyes to pore over the microscope and the crucible, have indeed performed miracles. They penetrate into the recesses of nature and show how she works in her hiding-places. They ascend into the heavens; they have discovered how the blood circulates, and the nature of the air we breathe. They can command the thunders of heaven, mimic the earthquake, and even mock the invisible world with its own shadows."

--Mary Shelley, *Frankenstein: Or, the Modern Prometheus*, 1823

"The changing of Bodies into Light, and Light into Bodies, is very conformable to the Course of Nature, which seems delighted with Transmutations."

--Isaac Newton, *Opticks*, 2nd Edition, 1718

Introduction: The Meanings of Transmutation

In the previous four chapters, I have considered the material substances that both farmers and alchemists had in common. In many ways the broad divisions I have used have mirrored the four elements of Empedocles and would have been familiar to any natural philosopher in the early modern era, whether they subscribed to that hoary matter theory or not. For the agricultural reformer interested in the composition of topsoil, the causes of soil fertility, metallogenesis, minerallogenesis, and the early development of what we would call geochemistry, earth was the subject. For those interested in fructifying waters, seed steeps, mineral springs, an emergent understanding of hydrology, and the drainage and irrigation of farmlands, it was water. To those who thought they had discovered in saltpeter the *spiritus vitalis*, qualities of both soil and water seemed to be present. The apparent discovery of niter's aerial form and its long, well-known association with the combustible properties of gunpowder suggested affinities with air and fire.[1] Though their chemical philosophy was rarely reducible to such straightforward Neo-Aristotelianism, agricultural reformers who used alchemical approaches as a means of understanding the material world fixated on these constituents of matter.

This final chapter will examine the interactions of these substances. To explain these interconnections, agricultural reformers relied on the language of alchemy. Common alchemical operations and goals, particularly transmutation, but also various laboratory methods like distillation, putrefaction, calcination, congelation, fermentation, and others appear frequently in the manuscripts and published texts of agricultural improvers.[2] Crucially, reformers used these terms neither rhetorically nor metaphorically. Rather, for processes like transmutation, congelation, and fermentation, they saw the same functional processes at work in the growth of plants as in the growth of metals, whether in nature, the laboratory, the farm, or the garden. Agricultural reformers readily transferred experimental techniques like calcination, distillation, and putrefaction—long hallmarks of

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[1] Discovering the constituents of matter to construct a integrated cosmology is arguably one of the oldest pursuits in natural philosophy, and many of the earliest Western thinkers spent considerable time describing the location of the "first principle" or "originating point"—what Paracelsus called the *archeus* and what other early moderns, as we have seen, described as *semina*, *sperma*, the *spiritus vitalis*, or *spiritus mundi*—leading previous generations of historians to pinpoint the origins of Western science in the pre-classical Aegean littoral. Thales sought it in water. Anaximenes placed it in air (or aēr, a denser version that may have included water vapor). Heraclitus located it in fire. Though these debates continued unabated into the early modern era, the terms and concepts changed considerably. On Thales, see Aristotle, *Metaphysics* 1.3 983*b*6-27 and *On the Heavens* 2.13 294*a*28-34; on Anaximenes, see Theophrastus, quoted in Simplicius, *Commentary on Aristotle's Physics* 24.26-25.1, Pseudo-Plutarch, *Opinions* 876AB, and Cicero, *On the Nature of the Gods* 1.10.26; and on Heraclitus, see Plutarch, *On the E at Delphi* 338*d-e*, Maximus of Tyre, *Dissertations*, 41.4, all consulted in Cohen, et al., *Readings in Ancient Greek Philosophy*, 12-35.

[2] For standard early modern definitions of these procedures as well as explanations on their modern chemical meanings, see Newman, "Alchemical Glossary," http://webapp1.dlib.indiana.edu/newton/reference/glossary.do; and Giunta and Butuzov, "Alchemical and Archaic Chemistry Terms," http://www.alchemywebsite.com/al_term1.html, both accessed 10 July 2018.

laboratory alchemy—from text and lab to field and farm. They also found alchemical analogues in their own traditional homegrown methods.

In this context, the *meanings* of transmutation are important. Many of the experiments practiced by agricultural reformers concentrated on isolating and manipulating the vital spirit in matter, wherever it might be found. Improvement and the resultant cornucopian bounty depended on harnessing its power. As we have seen, multiple contenders existed from the mid-sixteenth century onward for the source of this spirit. Sendivogius, Duchesne, de Vigenère, de Nuysement, and their followers among the *sal nitrum* school, like Benjamin Worsley, sought it in saltpeter. Van Helmont sought it in water. Harvey, Willis, Lower, Mayow, and many physiologists at Oxford in the 1660s and 1670s sought it in air. Plattes, Hartlib, and to some extent Walter Blith and Ralph Austen, thought that soil acted as the integral medium, without which the vital spirit could not be transported to plants. Research conducted in multiple settings throughout the seventeenth century began to reveal the extraordinary complexity of all these substances. Thus, an understanding of how each related to one another became essential.

To explore these issues, I focus primarily on John Beale. In his short, unpublished (and mostly forgotten) tract "Concerning the Transmutation and Improvements of Plants" from 1659, Beale described his personal understanding of transmutation and improvement in horticulture, particularly as it pertained to grafting, transplanting, acclimatization, and seed-steeping.[3] The use of the term "transmutation" was not figurative, and the context of this document, in addition to his other writings, demonstrates both the importance of alchemical applications for "the improvements and propagation of plants" and the more

[3] John Beale, "Concerning the Transmutation and Improvements of Plants," Royal Society Papers (hereafter RS), RB/1/34/9.

expansive meanings of transmutation. This chapter details these correlations using Beale's treatise as a case study of the broader uses that botany, horticulture, agricultural improvement, and the nascent "life sciences" had for alchemical operations in the mid to late seventeenth century. Using this manuscript and his articles in the *Philosophical Transactions*—which account for some of his only publications outside of his *Herefordshire Orchards*—and his numerous missives, particularly to and from Hartlib, Oldenburg, Evelyn, and Boyle, I demonstrate how plant growth came to be seen as a form of transmutation in an agricultural setting. Finally, I end with some prominent examples of Restoration-era, English botanical works focused on vegetable philosophy that engage with these theories.

John Beale's Early Life and Esoteric Education

John Beale was born in 1608 and is best-known as an Anglican clergyman and a writer on natural history, agriculture, horticulture, apple orchards, and cider production. His father, Thomas Beale, was a lawyer and provincial farmer in Herefordshire, in the West Midlands, near the Welsh border, and his family owned an estate, locally known for its large apple orchard and cider production. This parental, professional influence remained with him his entire life, and he never deviated from agricultural or horticultural study, though his education and personal connections led him to novel agricultural theories. He attended the Worcester Cathedral School between 1618 and 1622, after which he matriculated at Eton College, where he studied under the noted Latin and Greek grammarian Henry Bright and acquired an acute interest in classical literature, particularly

Ovid. He also developed an empirical mind, later commenting on his childhood experiments with insects, animals, and mechanical devices.[4]

Beale made some notable friends and colleagues in the 1620s, including Henry Wotton, John Hales, and Edmund Bacon. Wotton, in particular, became a mentor for Beale and nurtured his growing interests in Hermeticism, various occult philosophies, and unorthodox religious thought. After studying Aristotle's corpus intensely and finding it wanting, Beale reported that he "took no small pains to search out to the bottom all the branches of the wisdom of the East, and of the learning of Egypt."[5] Wotton also introduced him to the utilitarian philosophy of Francis Bacon and instilled in him an interest in optics, observational astronomy, and astrological reform, all of which Beale later explored in more depth during the 1630s and 1640s. Mayling Stubbs has suggested that these scientific and occult interests affected how he envisioned alchemy as well as his expansive ideas about the possibilities of material transmutation by the 1650s.[6]

Based on letters, mostly to Hartlib, in the late 1650s, it appears that Beale participated in a secret society (referring to it only as "*sub rosa*") where regular topics of discussion included "angelic cosmology" and the potential metaphysical uses of the telescope to peer into the empyrean realm beyond the planetary orbits.[7] Earlier interests in Italian Renaissance humanism, Neoplatonism, Hermeticism, Rosicrucianism, and natural

[4] John Beale to Robert Boyle, 2 November 1663, in Thomas Birch, ed., *The Works of the Honourable Robert Boyle* (London, 1744), Vol. 5, 439. These were not, as Keith Thomas has noted, always innocent, disinterested experiments, and he has described the cruelty of some of Beale's encounters with animals as a young boy. Beale had written to Boyle, for example, that he had skinned frogs alive "in sport to see what shift they would make when flayed," and while a student at Eton, that he "threw many frogs into the Thames to see how far they could swim" before exhausting themselves to death. See Keith Thomas, *Man and the Natural World: A History of the Modern Sensibility* (New York: Pantheon Books, 1983), 147.
[5] Woodland, "Beale, John (*bap.* 1608, *d.* 1683)," *ODNB.*
[6] Mayling Stubbs, "John Beale, Philosophical Gardner of Herefordshire, Part I: Prelude to the Royal Society (1608-1663)," *Annals of Science,* Vol. 39 (1982): 469-70.
[7] Ibid., 473. In this, he participated with Wotton and Edmund Bacon. It may have been a Rosicrucian order to which Wotton had professed membership.

magic remained with him well into his later life, and these esoteric endeavors impelled him to make study of several unconventional Protestant positions, including Socinianism and Arminianism.[8] As was the case with many natural philosophers in the mid-seventeenth century, various incompatible—or at least difficult to reconcile—ideas jostled with one another in his own mind. While at Cambridge he professed adherence to both a mechanistic and Hermetic worldview. Here, Beale was in good company, as many contemporary natural philosophers combined seemingly disparate matter theories to describe the world.[9] His regular correspondent Robert Boyle, for example, adhered to a mechanistic matter theory but from at least the late 1640s until around 1670 described growth in terms of *seminal* corpuscles that contributed to plant, animal, mineral, and metallic origins, revising this to exclude minerals, metals and crystals in the early 1670s.[10]

All these various schools of thought contributed to Beale's understanding of alchemy and agriculture by the 1650s. He clearly drew inspiration from Paracelsus and Paracelsian iatrochemistry. We know, for example, that he read the writings of alchemist and Paracelsian matter theorist Joseph Duchesne while traveling through continental Europe between 1636 and 1638, and in 1647 Beale donated an English translation of a work by the French Paracelsian surgeon Ambroise Paré to the King's College library at Cambridge.[11] It was around this time that Hartlib's attentions took a sharp turn toward

[8] Ibid.
[9] Ibid., 473-4.
[10] On the often-uneasy relationship in Boyle's corspuscularian, seminal, vitalist, and mechanistic tendencies, see Robert Boyle, *The Origine of Formes and Qualities According to the Corpuscular Philosophy* (London: 1666), 30. For more context on these positions, see Antonio Clericuzio, *Elements, Principles, and Corpuscles: A Study of Atomism and Chemistry in the Seventeenth Century* (Dordrecht: Kluwer, 2003), 125-7; Peter Anstey, "Boyle on Seminal Principles," *Studies in the History and Philosophy of Biology and Biomedical Sciences*, 33 (2002): 597-630; Newman and Principe, *Alchemy Tried in the Fire*, 18-21, 31, 256, and 261-262; Hunter, *Boyle,* 3, 104, 117, 120, and 213; Newman, *Promethean Ambitions*, 75-76.
[11] Stubbs, "John Beale, Part 1," 482.

husbandry, and he and his associates heavily emphasized the goal of uniting practical, scientific study with broader notions of social and spiritual reformation. He also promoted the study of alchemy to any and all of his correspondents, and for Beale, alchemy and agriculture became natural allies during this decade. Given the diversity (and irresoluteness) of his theoretical commitments, Beale never dedicated himself completely to Paracelsianism or any other vitalist matter theory, but letters to Hartlib, Evelyn, Boyle, Oldenburg, and a handful of others in the second half of the 1650s demonstrate that he subscribed to a number of Paracelsus's tenets, as well as to a broad interpretation of Helmontian chemistry. Beale by and large agreed with Paracelsus's doctrine of signatures, in which specific parallels between macrocosm and microcosm existed, and he noted herbal and vegetable correspondences with the growth and chymical preparation of minerals and metals. Citing authorities as varied as Apollonius of Tyana, Giordano Bruno, Robert Fludd, and Giovanni Pico della Mirandola, Beale discussed the wide-ranging scientific implications of vitalist matter theory, the celestial influences on plant, animal, and mineral growth, and the role of God in the physical operations of nature.[12] All of this primed him to develop the notion that plant growth could be improved through alchemical transmutation.

Beale's "Concerning the Transmutation and Improvements of Plants": Sources, Theories, Interpretations

It was against this theoretical and vocational backdrop that Beale wrote his extended letter, entitled "Concerning the Transmutation and Improvements of Plants," dated 18 October 1659, and originally intended for direct delivery to Hartlib. It was never

[12] Ibid.

published and, in fact, there is a curious history to the archival document itself, as it appears never to have been circulated as anticipated. Judging from a series of letters between Beale and Hartlib between November 1659 and March 1660 and one between John Evelyn and Hartlib shortly thereafter, Beale's work "of transmutation," as he referred to it, was either misplaced by the office of postage or intercepted and stolen. "Sir, that you mistake not the *Hortulan parado* [idle gardener?], as were sent above 5 weeks ago," Beale wrote,

> and I conclude they are lost from us. That of transmutation is surely in the warehouse at London. If it should be lost, it is not in my power to repeat it, or to recover it. For 'tis the first draught, I as [*sic*] soon as I have engrossed, I am want to discharge my memory: and my memory holds me to that Coven[ant] of immunity; I as the beast will not feed on blowen fodder, so do my spirite desire fresh air, as free perambulations.[13]

Beale informed Hartlib that he would not rewrite the treatise for he could no longer recall the important details, which was a curious position for Beale to take, given earlier boasting, while a reader at King's College, Cambridge, in the late 1620s, that he had been able to recite the bulk of Ovid's *Metaphorphoses*, Philip Melanchthon's *Logicks*, Johannes Magrius's *Physica*, and Zacharias Ursinus's *Theologica* from memory. He had claimed to "learn them by heart faster than [he] could read them."[14]

In February of 1660, Beale was still discussing the work with Hartlib. Clarifying comments he had made in a letter to Evelyn, Beale relayed to Hartlib that he had conducted an experiment to test the "validity and invalidity of transmutation of plants by colors, and other like enforcements," then asked if he had received a packet containing "a large account historically and practically of the resu[sci]tation of flowers from their ashes, and in their

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[13] Beale to Hartlib, 1 November 1659, BL, Add. MS 15948, f. 82a.
[14] Woodland, "Beale, John (*bap.* 1608, *d.* 1683)," *ODNB*. From *Works of the Honourable Robert Boyle*, Vol. 5, 426.

Waters in satisfaction."[15] Beale briefly lamented what he considered the declined state of chymistry in France, suggested that Hartlib's chemically knowledgeable son-in-law Frederick Clodius could determine whether the "chymicall manner of raising sallades from their Vrnes of Ashes" amounted to anything, and told Hartlib that, if he ever received the packet, it contained "about a quire of paper."[16]

By March 1660 Beale had discovered, unfortunately, that his treatise had indeed been stolen, though it is unclear how he came by this information. "I have been informed of a very rude gentlemen, that lay in wait to intercept our letters," he wrote, "but if the post houses be altered, we shall be safer. Of the packet sent by [the] carrier I am hopeless."[17] Shortly thereafter, Hartlib wrote to Evelyn that he was "troubled" that Beale's letters "of very choice and delicate subjects" had "miscarried," but he received assurances that Beale had changed his mind and would reproduce "the chiefest and choicest Contents of it."[18] There is no way to determine for certain if Beale's "Concerning the Transmutation and Improvements of Plants" was the stolen packet or if so, whether the current document in the Royal Society archives is Beale's recreation or the original, but given the description of its contents in these letters, it seems likely to be one or the other.

Ostensibly, the text details cutting-edge horticultural knowledge and discusses a variety of operational and theoretical topics such as techniques for grafting and transplanting trees and shrubs, chymical steeping and ensuring the proper germination of

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[15] Beale to Hartlib, 28 February 1659/60, BL, Add. MS 15948, f. 87a. This likely refers to an experiment designed by Joseph Duchesne and supposedly confirmed by Athanasius Kircher. Kenelm Digby attempted to replicate it around the same time and delivered the results at one of the first meetings of the Royal Society, after which it was published as Kenelm Digby, *A Discourse Concerning the Vegetation of Plants….* (London: J.C. for John Dankins, 1661). See below, pages 246-50.
[16] Ibid.
[17] Beale to Hartlib, 6 March 1659/60, BL, Add. MS 15948, f. 89a.
[18] Hartlib to Evelyn, 7 April 1660, BL, Add. MS 15948, ff. 98b-99a.

seeds, how to stave off premature putrefaction of bulbs, the preservation of young plants, the acclimatizing of crops and trees not native to England, and which fertilizers work best for which plants. True to Beale's diverse and expansive philosophical musings, the treatise combined reporting on experimental results, his own observations and those of trustworthy individuals, citations from the latest works of botany, matter theory, and natural history, as well as practical how-to instructions for horticultural processes accompanied by more esoteric digressions that aimed to get at the heart of the matter theory that underlay the activities he was describing. It was both speculative and practical. Beale never fully committed to any specific philosophy explaining plant growth, fertility, or the nature of transmutation, but the text is brimming with practical advice for horticultural improvement, some of which depended on adherence to one theoretical approach or another. References to Aristotle's botanical descriptions, tensions between Baconian and Paracelsian matter theory, and analyses of Kenelm Digby's revivifying experiments sit comfortably alongside Columella's advice on sowing and reaping, commonplace guidance on ridding farmland of "maggots and vermine," explanations for the construction of drilling devices for "the stem, and root of some plants, and of any sort of grafts," and which types of fertilizers produced which tastes in fruits and vegetables.[19]

Apart from the classical authors of the *rei rusticae* tradition so beloved by the Hartlib Circle's vegetable philosophers, Beale also made heavy use of recently published works on natural history and horticulture, making frequent references to the German-born Spanish physician Juan Eusebio Nieremberg's *Historia naturae maxime peregrinae*, Peter Lauremberg's *Horticultura*, and Richard Ligon's *True and Exact History of the Island of*

[19] John Beale, "Concerning the Transmutation and Improvements of Plants," RS, RB/1/34/9, f. 447.

Barbadoes. Niermberg's 1635 work, an encyclopedic compendium devoted to the flora and fauna of the Americas, particularly Mexico, had been largely compiled out of the unpublished manuscripts of the sixteenth-century Spanish naturalist and physician Francisco Hernández de Toledo.[20] While earlier descriptive texts had recounted the medicinal uses of various New World plants, Nieremberg's was among the first to systematically organize the information, compare previous natural histories to depict rival descriptions of the same plants and animals side by side, provide details of their native habitats, and acknowledge original names from indigenous sources. Based on his citations, Beale considered him an authority on certain topics, even as he was skeptical about others.

Nieremberg came from very different religious, educational, and scientific traditions than Beale: he was a professor of natural history and the Holy Scriptures at the University of Madrid, a Jesuit priest with a tendency toward mystical interpretations of scripture, and a devoted but not inflexible neo-Aristotelian.[21] In addition to his *Historia naturae*, he had also written a similar work in 1630 covering natural wonders, marvels, and curiosities titled *Curiosa filosofía y tesoro de las maravillas de la naturaleza*, which he had expanded in 1633 to include a section on occult philosophy (*oculta filosofía*). Though Beale did not quote directly from this work, it clearly influenced his interpretation of Nieremberg's

[20] See Juan Eusebio Nieremberg, *Historia naturae* (Antwerp: Officiana Platiniana Moreti, 1635). For the work upon which much of this is based, see Johann Faber, *Animalia Mexicana descriptionibus scholiisque exposita*, in *Praescriptiones Lycenae Academiae* (Terni: Tommaso Guerrieri, 1624), much of which itself had been based on the unpublished notebooks of Francisco Hernández and his work, *Quatro libros de la naturaleza y vertudes de plantas y animales…en la Nueva España* (Mexico City, 1615). For more information on Nieremberg's contributions to natural history, see D. Scott Hendrickson, *Jesuit Polymath of Madrid: The Literary Enterprise of Juan Eusebio Nieremberg (1595-1668)* (Leiden: Brill, 2015), 86-125; Víctor Navaro, "Tradition and Scientific Change in Early Modern Spain: The Role of the Jesuits," in *Jesuit Science and the Republic of Letters,* ed. Mordechai Feingold (Boston: MIT Publishing, 2003), 334-336; and Juan Pimentel, "Baroque Natures: Juan E. Nieremberg, American Wonders, and Preterimperieal Natural History," in *Science in the Spanish and Portuguese Empires, 1500-1800*, ed. Daniela Bleichmar, Paula de Vos, Kristine Huffine, and Kevin Sheehan (Stanford: Stanford University Press, 2009), 93-111.

[21] Navaro, "Tradition and Scientific Change in Early Modern Spain," 334.

natural history. In Nieremberg's section on occult philosophy, he wrote mostly on the curious and unknown properties of plants, minerals, animals, and people in the tradition of both Renaissance natural magic and alchemical books of secrets.[22] This mode of inquiry made its way into his *Historia naturae*, whose organizational structure and synthetic goals mirrored some of the early Hartlib Circle's attempts at developing a cohesive vegetable philosophy. Like Francis Bacon's *Sylva sylvarum* or Ralph Austen's *Observations on…Bacon's Naturall Histories*, Nieremberg's *Historia naturae* attempted an intellectual fusion of the classical tradition of natural history, its Renaissance humanist interpretations, and recent observations made by contemporary explorers, botanists, and physicians, particularly in Latin America. According to Víctor Navarro, Nieremberg asked similar questions in *Historia naturae* about the cosmological and astrological significance of plants, animals, minerals and their relationships with humanity and the cosmos as he had in the *Curiosa filosofía*.[23] Based on Beale's citations, of which there are over a dozen, he clearly found those same relationships vitally important for understanding plant growth.

Both Beale and Nieremberg showed special interest in creatures like sponges, corals, and sea anemones that were difficult to classify in either traditional natural history or the new taxonomic arrangements of Renaissance humanists and encyclopedists.[24] For Nieremberg, the difficulty of placing organisms that seemed part plant and part animal into the fissures of the great chain of being greatly exercised his mind, while for Beale, the prospect of the instability of seemingly discrete natural categories suggested to him that living creatures were, to some degree, changeable from one to another. The biological

[22] Ibid. 334-35.
[23] Ibid., 336.
[24] Pimentel, "Baroque Natures," 104.

world was full of examples of partial "transmutations" performed by nature. Nieremberg had recounted, among other things, ivy that grew from the antlers of a deer, gold-eating fish, mice and worms that spontaneously generated from reeds in the rivers of New Spain, and eels that spawned from seaweed due to an unknown effect of seawater.[25]

Despite the seriousness with which he approached the text, Beale found many of Nieremberg's claims incredible. Though he could be a visionary or quixotic thinker, Beale was also a cautious one, and he rarely succumbed to naïve acceptance of outlandish and difficult-to-verify claims. He was especially critical of merchants, international traders, and "Spagyricallmen," or those selling *materia medica* and exotic pharmaceuticals, "who do love to be courted into the largest hopes."[26] For example, in a letter to Oldenburg disapproving of a recent spate of interest in "the horn and other parts of the fallow deer," Beale wrote that hopes of its supposed curative properties sounded like the

> old reputation of the unicorn's horn, whether fishbone, or mineral, or some monster out of Affrica. T*ruly tis to ye reproach of Physicians, philosophers, practical Scholars, and gentlemen, that they suffer Merchants to cheat our country with so many of their reputed medical, but really costly Rarity's, the unicorn's horn, the toad Stone, the bezoar stone, Etc.*[27]

Nevertheless, in general, Beale regarded Niermberg's *Historia naturae* as "a good store…[of] examples" of the wonders of nature, including the liminal spaces between plant, animal, and mineral and the possible transmutation of various animals and plants.[28] Beale claimed to have observed a number of these things himself. "We need not doubt it," he wrote, "for by trial I have found many kinds of animals following the nature of the plants of which they are descended or [bred] and the maggots which I took upon the leaves of

[25] Ibid. Several of these can be found in the works of José de Acosta, Giambattista della Porta, and Aristotle.
[26] Beale to Oldenburg, 12 October 1668, *Correspondence of Henry Oldenburg,* Vol. 5, 81.
[27] Ibid., 82. Emphases in original.
[28] Beale, "Concerning the Transmutation and Improvements of Plants," RS, RB/1/34/9, f. 447.

several plants had some predominant color resembling the blooms of the plant," though he cautioned that these were not necessarily the same as the transmutations that could be adapted to improve horticulture and husbandry.

Also referenced liberally was Peter Lauremberg's 1632 *Horticultura*, the first text to use the term "horticulture," as it was translated into English. Beale obviously thought it was an important source for information on the cultivation of trees and shrubs and the landscaping of gardens.[29] Lauremberg was also known for his promotion of the idea of universal education and religious tolerance, which were important reforms also promoted by many members of the Hartlib Circle, especially Jan Comenius, and it is possible that these aligned interests attracted Beale to him. Among other things, Beale cited Lauremberg on the proper way to graft the limbs of certain trees, often in comparison with Virgil and Columella, the speed at which various seeds and stems "are apt to degenerate" and thus the order in which they should be planted or grafted, the time and season in which certain trees and shrubs should be transplanted, and the delicate nature of grafting tulip bulbs and other plants with tuberous roots.[30] He made copious references to Nieremberg's systematized anatomy of plants and Lauremburg's cultivation methods throughout his treatise.

As the title suggests, though, Beale's "Concerning the Transmutation and Improvements of Plants" was primarily concerned with agricultural and horticultural improvement and the possibilities of transmuting plant matter. The use of the term "transmutation" was no rhetorical tool here, and Beale's work—like Worsley's saltpeter projects and Plattes's tracts on the chemical philosophy of soil—reveals the seldom-

[29] See Peter Lauremburg, *Horticultura* (Frankfurt, 1632).
[30] Beale, "Concerning the Transmutation and Improvements of Plants," RS, RB/1/34/9, ff. 470, 471, and 477.

addressed connection between alchemy and agricultural improvement in seventeenth-century England. Though he sometimes employed "transmutation" as shorthand for grafting, seed-steeping, fertilizing, and other practical agricultural procedures that delivered observable changes, the context of many usages of this term discloses deeper connotations and suggests that he understood this as the actual, physical transformation of plant matter at the microscopic level. Much as Gabriel Plattes had argued that the nutritive transfer of plant to animal and animal to muscle movement was a type of natural transmutation, so Beale maintained that "we can undertake the transmutation of plants into animals and again of animals back into plants," referring both to the nutrition of vegetables and the fertile properties of animal manure.[31] He advised those who wished to improve agriculture "to take notice how large the field of nature is to yield soil, compost, life, or nutriment to several kinds of plants," and advised that those who endeavored to "prosecute the design of transmutation at full" should acquaint themselves with Pliny the Elder's "three principles [of] soil, air, and water, their varieties, properties, and appendances."[32] Though not formally organized, Beale's work broadly explores the role of these three substances in fertility, plant growth, the vital properties of living tissue, and the transmutation of organic material.

The proper knowledge of soils was a fundamental starting point for Beale, and he wrote extensively in this treatise and others on its importance. Comparing plants that derived their primary nutrients from soil suffused with decaying plant matter to cannibals, he wrote that

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[31] Ibid., f. 447.
[32] Ibid., ff. 448-9.

> some plants are bred, begotten, and nourished of the concased seeds, roots, branches, and stems of plants all this compass I took, to show the large field of soils which have the greatest and most fundamental conducement to the Improvement or alteration of plants…And if a man contain himself within the common values of nature, what is more easy than the transmutation, Improvement, or degenerating of plant.[33]

The important thing for Beale, as for Plattes and Hartlib, was that these forms of transmutation between plants and animals were reciprocal and reversible, and he believed there were ample natural instances demonstrating plant life emerging in some way from animal and vice versa. Beale wrote, "though, neither by the help of Friar Bacon, nor of Paracelsus, with the addition of the old legend of…King Mandrakes, we cannot transform a plant into a Man, (*ex planta homunculum*)," yet he also argued

> that plants may be raised, not only of the putrefying carcass of a dead man, but also out of a living human body, we find in many credible and authenticall histories. Plutarch recordes it, that a man troubled with the strangury, bred in his bladder a Barley corn, shooting out of the blade… And why not plants as well as stone and gravel in the kidneys and bladder, and rather than worms and vermine of so many sorts, yea tadpoles and monsters begotten in the bodies of living men, as I have seen or heard from credible testimonies.[34]

Beale commented on the knowledge that decaying carcasses eventually contributed to fertile soil and that the human body could produce what appeared to be vegetable seed and minerals from the bladder and kidneys. He made possibly one of the first references to human semen as seen through a microscope. He later went on to recount contemporary notions of the spontaneous generation of insect larvae out of decaying leaves as a reversion of the transmutational process.

Of Pliny's "three principles" of air, water, and soil, Beale, like Plattes, emphasized soil, in part because his own horticultural observations and experiences convinced him of

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[33] Ibid., f. 450.
[34] Ibid., ff. 449-50.

its importance. He wrote a great deal about the composition, texture, and consistency of soil, its moisture content, whether it contained clay or sand, how quickly water filtered through it, and so on, and then cross-referenced these with descriptions of how different types of plants grew in each. For leaves that curled intricately and had alternating colors, he recommended "an attenuated soil, if at first sprouting of the seeds it be sifted over with dust,"[35] while altering the soil or compost of eglantine flowers would inform an observant horticulturist if it would "be enforced to exchange its sweet leaf for the more fragrant and manifold blossoms of the Damask rose."[36] Like crop rotation in farmers' fields, Beale recommended experimenting with soils from different geographic locations, commenting that "seed from a native soil…or from a congenial soil, or at least from a remote soil, is another help for improvement," but he advised that those planting herbs and small shrubs should "avoyd consanguinity."[37]

Soil was a complex substance and Beale took note of how it combined with other substances, especially plant and animal matter. The organic detritus that infused into soil fascinated him, and he recounted the "varieties and extensiveness of soil for plants, some growing and impregnated by the flesh, fish shells, scales of all sorts of animals, fish, serpents, reptiles, both living and dead, some growing in water Springs and fountains," as well as more specific chymical and alchemical qualities to be detected.[38] "That the Earth is not necessary to the first sprouting of plants, and that they will come faster in water than in Earth," he conceded, but then he wrote that "we must take heed of overstreining these arguments to the neglect of soil; but hints we may interfere, that it is good to intermixe

[35] Ibid., f. 465.
[36] Ibid., f. 454.
[37] Ibid., ff. 467-8.
[38] Ibid., f. 450

with the Heavenly dues such Liquors or vigorous liquids, as may (in the very moment of the change from the corruption of the seed to the generation of the plant) give A peculiar kind, tincture or relish."[39] Here, Beale referred to the common technique, as we have seen, of submerging or soaking seeds in what were often called "fructifying waters" until germination occurred, after which they would be planted. He recommended the chemical manipulation of waters to accomplish this, and references in many of his other works attest to his experimentation with various liquids.

Though Beale emphasized the chymical importance of soil, he spent an equal amount of time discussing the importance of water and air for understanding transmutation. He viewed neither water nor air as a homogeneous substance, and in fact seemed to regard water as *more* chemically complicated than soil. "There may be as many kinds of soil as of vegetable plants," he noted, but there were "more kinds of water than of soil. Apparently there are hungry, fat, quick, faint, light, heavy, durable, changeable, Metaline, mineral, snowy, terrestrial, [and] Celestial Waters."[40] Here, Beale referred in part, to experiments Francis Bacon had performed. According to Beale, it was possible to transmute certain types of waters from one to another and then to use these to modify the composition of soils and plants and "make as many kinds of soil as of vegetable," for example

> by casting upon the [herb] beds (especially about the time of sprouting and sooner and whilest the blade is tender and hasteneth growth) the small leaves or strippings of rosemary and lavender, dried anise seeds, or mustard seeds beaten to powder, juniper berries, tarragon, rocket, and such fragrant or spicy woods and their ashes or (as we love the word) calcined, the dews hanging a while upon these, and then passing (as a lie) from them, carry a powerful infusion to the seed or root of the plant, and from these diversities of infusions is oftentimes the diversity of colors,

[39] Ibid., ff. 478-9.
[40] Ibid., f. 490.

> and of other qualities, both in flowers and other plants, as Lord Bacon notice, experiment 510.[41]

That is to say, different waters, which were manipulable by the savvy horticulturist, conferred different properties to the soil, which then affected the seeds, the growth of the plants, and eventually even aesthetic and morphological aspects like color and the shapes of leaves and petals.

According to Beale, air, unlike soil and water, never caused seeds to germinate on their own, and thus he devoted less time explicitly to its effects. However, air could be important either as a carrier or medium—sometimes termed a matrix, receptacle, or womb—in which various vital spirits "impregnated" the soil or water. In many mid-seventeenth century vitalist matter theories, as we have seen, certain substances—precisely which were up for vigorous debate—possessed a vital spirit (*spiritus vitalis*) or seminal principle that reorganized otherwise inert matter and produced the living tissues of plants and animals. It is unclear if Beale subscribed to these theories, or if he did, what he considered the vital matter, but the language he used throughout his treatise concerning transmutation and improvement indicates that he at least understood air as a possible medium for this type of alchemical process.

The vital spirit existed in many potential locations. For example, in one section on leeching grape seeds, skins, and stems for winemaking, he noted that the "maceration of seeds in Virgil's days" was done with the aid of "nitre, and tartare or lees of wine." To that, Columella had added "the juice of senegreen and the decoction of crabfish." After detailing other contemporary Italian techniques, Beale wrote that some attributed the "greatest Force to the spirit" of wine and equated it with the same spirit found in air and human

[41] Ibid., ff. 490-91.

blood.[42] During the mid-seventeenth century, the connections between the respiration of plants and animals, the movement of blood in humans and animals and vascular fluids like sap in plants, and substances in a heterogeneous air began to come to light.

Beale's interpretation of this vital spirit, equivalent across these media, bore striking resemblance to the concept of "spirit" being simultaneously developed among a group of Oxford physiologists, of which Beale became aware through his correspondence with Boyle and Oldenburg.[43] Some of Boyle's experiments in the late 1650s and early 1660s had provided strong evidence that the same force that caused combustion also sustained the lives of animals through respiration.[44] Richard Lower and John Mayow had both made progress around the same time demonstrating that the deep red color of arterial blood had something to do with its contact with air from the lungs, with Mayow eventually arguing that the air bestowed its "nitro-aerial spirits" on animals to keep them alive while unhealthy vapors from venous blood were expelled.[45] After Lower performed the first successful artery-to-vein blood transfusion in dogs at Oxford in late February 1666, Beale responded to Boyle's news exuberantly, recommending that the "superabounding blood" of healthful young people might be used as an anti-aging remedy, derived from "the vital

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[42] Ibid., f. 468.

[43] See Frank, *Harvey and the Oxford Physiologists,* esp. 142-94. For more on the concept of "spirit" as it applied across medical, chymical, and metaphysical contexts, see Clericuzio, "The Internal Laboratory;" and Debus, "Chemistry and the Quest for a Material Spirit in the Seventeenth Century."

[44] Hunter, *Boyle*, 155-6 and 210-11. For Boyle's discussions of blood, respiration, and aerial combustion, see Michael Hunter, Antonio Clericuzio, and Lawrence M. Principe, eds., *The Correspondence of Robert Boyle*, 6 Vols. (London: Pickering and Chatto, 2001), Vol. 2, 599-602; Vol. 3, 164-5, 299-300, 304-5, and 360-62; and Boyle, *Works*, Vol. 12., xiv, 70, and 92-5.

[45] Frank, *Harvey and the Oxford Physiologists*, 169 and 228; Hunter, *Boyle*, 154-5 and 159. On Lower's experiments and his correspondence with Boyle, see Thomas Birch, *The History of the Royal Society of London for Improving Natural Knowledge….* (London, 1756-7), Vol. 2, 83-4, 98, and 115; Hunter, et al., *Correspondence of Robert Boyle*, Vol. 2, 3-4, 280-82; Vol. 3, 175-7, 182-86, and 217-19; and Boyle, *Works of the Honourable Robert Boyle*, Vol. 5, 540-46. On Mayow's experiments, see Debus, *The Chemical Philosophy*, 492-96. For their published works on these topics, see Richard Lower, *Tractatus de Corde* (London, 1669); John Mayow, *Tractatus duo* (London, 1668); and idem., *Tractatus quinque* (London, 1674), esp. 68-9, 147-52, and 257.

spirits, or congenial heat, which may possibly have in some respects more virtue than…[the] salt of human blood."[46] In a letter to Oldenburg written around the same time as his longer work on transmutation and improvement, Beale had argued similarly for the respiration of plants, noting that after conferring with Hartlib on the topic, they had concurred "that trees do breathe, draw and give breath, as animals do, huge animals: they drink up in diffuse the Spirit of the world and grow to their vast bulk of body branches and roots not by devouring the Earth…but by drinking nitrous water."[47] Although it is a bit unclear from the context, it seems that both Beale and Hartlib supposed that the vital spirit was indeed a "nitrous spirit," as a number of saltpetermen and members of the *sal nitrum* school of chemical philosophy had argued, but based on their observations of plants, this spirit could be obtained in different ways either from water or the air.

Beale's interpretation of vital spirits was in line with these latter-day Paracelsian and Helmontian understandings of the chymistry of air, and he followed up his description of the vital spirit found in wine, air, and human blood with its equivalent in plant seeds. With reference to unnamed Paracelsians, he wrote of "the seed which is indeed the seed," meaning the animating force of growth to be found within the physical seed casing: "some confess the part purely seminal to be so atomical, as to be rather a spirit than a body."[48] Like Boyle, Beale took up a position somewhere between a quasi-mechanical corpuscularianism and strict vitalism, in which the life force could be envisioned either as minuscule, physical particles that one could conceivably discover by anatomizing a seed under a microscope, or a seminal spirit, which was incorporeal and thus required an

[46] Beale to Boyle, 31 March 1666, *Works of the Honourable Robert Boyle*, Vol. 6, 397. On Lower's experiments with canine transfusion at Oxford, see Frank, *Harvey and the Oxford Physiologists*, 176-77.
[47] Beale to Oldenburg, 30 September 1659, *Correspondence of Henry Oldenburg*, Vol. 1, 318-319.
[48] Beale, "Concerning the Transmutation and Improvements of Plants," RS, RB/1/34/9, f. 469.

experiment designed to search for evidence of its force interacting with soil, water, or air. More research was necessary before definitively deciding.

Beale was optimistic that an experimental resolution to this question was imminent, and he professed the utmost confidence in Boyle's abilities to produce such results, for "what more sacred or honourable evidence" was there, he wrote to Oldenburg in 1661, than the "fidelity" of Boyle's "experimentall demonstrations."[49] He had been "the first that gave vs *th*e knowledge of *th*e state of qualities of *th*e Aire, w*hi*ch is intermingled with *th*e breath of life in vs all: & *th*e first that taught vs *th*e causes & degrees, by w*hi*ch all bodyes are individuated to solidity, or dissolved into fluidity."[50] For Beale, the only piece of the puzzle that remained was "the Prince of Activity, the Fiery Operatour," which he equated with the vital principle of life. [51]

Beale ended the section on airs by revealing that, regardless of the nature of the vital principle, one could dilute the generative power of any seed by subdividing it into pieces until it was no longer viable. The year before his "Concerning the Transmutation and Improvements of Plants," Beale had written to Hartlib that "a strange spirituall vigour does agitate in the generation of all considerable substances," whether animal or plant, and he had estimated that the "mansion or receptacle of that seminall virtue" to be thousands of times smaller than the seed itself. By Paracelsus's reckoning, he wrote, in wheat grains, mustard seeds, and cypress seeds, the vital principle, or "Internal starr," as he called it,

[49] Beale to Oldenburg, 28 September 1661, *Correspondence of Henry Oldenburg,* Vol. 11, 396. Also found in HP 31/1/75A-B.
[50] Ibid.
[51] Ibid.

measured just “the 8200th part of the seede or graine.”[52] Whether atomic, corpuscular, or spiritual, the virtue could be extinguished.

Not all agreed that vitality could be sapped so easily. After his section on airs, Beale continued his analysis of the analogues for alchemical operations and botanical processes, where he compared the sowing of seeds to the impregnation of animals, which made “the soil of the most extensive capacity, for the reception of foreign and unknown plants. For such as refuse dung and violent composts, here is plain Earth: and for such as require a mellow and rich soil, here is the riches of the land impregnated with the Heavenly influences.”[53] He continued by describing the vital, cosmological influence on vegetable growth and the possibility of plants—in a phrase borrowed from Hugh Plat—“manured with the Stars,” which

> will bring forth such glorious plants, fruits and flowers, as none of all the herbalists, that ever wrote till this day, nor any other (except Adam himself or alive again) could either know or give true and proper names onto such most admirable simples. Thus he, Sir Kenelm Digby's late discourse of sympathetic powder…his expression is, that the Earth in the year it rests from bearing, recovers its vigour by attraction of the vital spirit it receives from the air. Which agrees with the mystical secret, *Spiritum Mundi*…which operation may be precipitated by a bibulous soil, and advanced, as…by vegetables as I lately enlarged upon the copious juice or liquor of the birch tree Etc:[54]

Kenelm Digby, another one of Hartlib’s regular correspondents and later a Fellow of the Royal Society, who was deeply immersed in alchemical study for much of his later life, had argued that soil derived the vital properties it bestowed on plant life from the air. Here,

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[52] John Beale to Samuel Hartlib, 27 September 1658, HP 51/23B. This number is identical to the fraction given by Sendivogius, the alchemist highly influenced by Paracelsus, who had been instrumental in founding the *sal nitrum* school so prominent among the Hartlib Circle in the 1640s and 1650s. On Sendivogius’s use of this fraction, see Michael Sendivogius, *Novem lumen chemicum*, transcribed by Jerry Bujas, (Prague and Frankfurt, 1608), I.3, last accessed 9 July 2018, http://www.levity.com/alchemy/newchem1.html.
[53] Beale, “Concerning the Transmutation and Improvements of Plants,” RS, RB/1/34/9, f. 473.
[54] Ibid., ff. 473-74. See also, Mukherjee, “‘Manured with the Starres’: Recovering an Early Modern Discourse of Sustainability,” 604; and above, page 146.

Beale referred to Digby's first mention of the topic, in his *Late Discourse…touching the cure of wounds by the Powder of Sympathy*, where he had suggested that crop rotation replenished the soil by allowing it to "recover its vigor by attraction of the vital spirit it receives from the air."[55] Because this vital spirit lay outside of plants and animals, Digby at first intimated and later certified that damage could be done to living creatures up to the point of death, and the proper experimental procedure could revivify them. In spite of Beale's uncertainty, Hartlib harbored fewer doubts, and even Oldenburg found the research promising, writing to the former that he was in his debt for the "secret of reviving decayed trees, and making them very fruitful. So I am of opinion that a secret of making trees beare moderatly, is best of all because it keep us them longer in vigour."[56]

This was neither his last nor most authoritative word on the subject. Digby's later, more expansive text on this theme, *A Discourse Concerning the Vegetation of Plants*, was published in the form of a long pamphlet in August of 1661. It was based on a lecture he had delivered earlier that year at Gresham College for the recently organized Royal Society "at a meeting for promoting the philosophical knowledge of experiments."[57] In this controversial work, Digby investigated the chemical substances of plant nutrition and the origins of fertility, chiding those who placed the seat of vitality solely in solid, crystallized saltpeter in the soil or in some unknown, essential element inherent to soil itself. He wrote

[55] Kenelm Digby, *A late discourse made in a solemne assembly of nobles and learned men at Montpellier in France touching the cure of wounds by the powder of sympathy: with instructions how to make the said powder : whereby many other secrets of nature are unfolded* (London: R. Lownes and T. Davies, 1658), 51. Digby had delivered this work as an address to the medical faculty at the University of Montpellier while he was in self-imposed exile in France during the Interregnum.
[56] Oldenburg to Hartlib, 9 November 1659, BL Add. MS 15948, f. 73.
[57] Digby, *Discourse Concerning the Vegetation of Plants….*, frontispiece. Digby's lecture occurred on 23 January 1661 and the pamphlet based on his talk was published 14 August 1661. Oldenburg wrote to Beale about the presentation on 30 May 1661. See *The Correspondence of Henry Oldenburg,* Vol. 1, 410. For more on the lecture, see Birch, *History of the Royal Society*, Vol. 1, 13 and 41; and Frank, *Harvey and the Oxford Physiologists*, 323 n.79.

that this source "would soon be exhausted…and could not furnish matter to so vast a progeny."[58] Rather, he wrote that saltpeter was like a magnet that "attracteth a like Salt that foecunditeth the Aire, and that gave cause…to say there is in the Aire a hidden food of life."[59] In similarly alchemical terms, Digby had referred to the growth of plants as a type of "fermentation" and asserted that if the "spirituall parts get loose from the viscous ones," meaning the combustible properties of saltpeter, which were "fixed" in plants, "then that which followeth is a total Putrefaction, Dissolution, and Destruction of the compound."[60]

In the same work, Digby claimed to have arrived at this knowledge not through the theories of others but via experiment. By the time he composed this work, he had settled into a semi-Aristotelian, semi-Cartesian corpuscularianism. Essentially, Digby rejected the Aristotelian notions of form and *prima materia* but maintained Aristotelian qualities and a division of matter into four elements. He followed Descartes in arguing that matter is inert and void is impossible, but like Boyle, claimed that the smallest constituents of matter were corpuscles, though they were not indivisible. Like Sennert and Sendivogious, he believed that they could be combined in ways that would induce life.[61] He had performed and recorded experiments purporting to demonstrate the palingenesis—or the artificial, chemical reincarnation of life using the same starting matter—of plants and possibly even animals.[62] With assurances from Athanasius Kircher, who claimed to have successfully

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[58] Ibid., 64.
[59] Ibid. This is similar to Sendivogius's theory that nitrous salts gave life to plants and animals by acting like a magnet to attract a vital or universal principle in air. See Clericuzio, *Elements, Principles and Corpuscles*, 85.
[60] Ibid., 13.
[61] On Digby's matter theory, see Clericuzio, *Elements, Principles, and Corpuscles,* 81-5.
[62] For more on palingenesis in the context of alchemical experimentation in the seventeenth century, see Newman, *Promethean Ambitions*, 164-237, esp. 201-6, 224, and 227-37; Jacques Marx, "Alchemie et Palingénésie," *Isis*, Vol. 62 (1971): 275-89; Allen G. Debus, "A Further Note on Palingenesis," *Isis* Vol. 64 (1973): 226-30; and François Secret, "Alchemy and Metempsychosis in Renaissance Medicine," *Ambix* Vol. 26 (1979): 81-92. For contemporary and near-contemporary works to Digby other than Kircher and Duchesne,

performed it, Digby had attempted an experiment of Joseph Duchesne, whereby he "calcined a good number of Nettles, Roots, Stalks, Leaves, Flowers; in a word, the whole plant," though he did not name the species.[63] After filtering the resultant ashes through clean water and earth, he congealed the mixture in the cold on his windowsill in winter, where he discovered the nettles with which he had begun were now white and appeared to have no life left in them. After thawing, refreezing, and thawing them again,

> a main part of the Essentiall substance of a Plant is contained in his fixed Salt. This will admit no change into another Nature; but will alwayes be full of the qualities and vertues of the Plant it is derived from; but for want of the volatile Armoniacall and Sulphureall parts, it is deprived of colour. If all the Essentiall parts could be preserved, in the severing and purifying of them, I see no reason but at the reunion of them, the entire Plant might appeare in its complete perfection, so one could finde a fit medium to dilate it in.[64]

He replicated the same experiment with crayfish instead of nettles in an alembic, with the important extra step of adding sand and water to the vessel at the end of the process, at which point he claimed that crayfish offspring had hatched from palingenically-produced eggs in his mixture.[65] In any case, Digby declared that living things could be revivified even

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Newman cites [Pseudo?]-Paracelsus, *De rerum natura*, Vol. 11, 313-17; Paracelsus, *Astronomia magna*, Vol. 12, 322-27; William Maxwell, *De medicina magnetica libri iii…* (Frankfurt, 1679); Pierre Borel, *Historiarum et observationum medicophysicarum centuriae iv* (Frankfurt, 1661); Werner Rolfinck, *Chimia in artis formam redacta, sex libris comprehensa* (Jena, 1661); and Robert Boyle, *Some Physico-Theological Considerations about the Possibility of the Resurrection*, in *The Works of Robert Boyle,* Vol. 8, ed. Michael Hunter and Edward B. Davis.

[63] Clericuzio, *Elements, Principles, and Corpuscles*, 76. Here, Digby referred to Josephus Quercetanus [Joseph Duchesne] *Ad veritatem hermiticae medicinae ex Hippocratis veterumque decretis ac Therapeusi* (Frankfurt, 1605). On this work, see Newman, *Promethean Ambitions*, 228-9; and Kahn, *Alchimie et paracelsisme en France à la fin de la Renaissance*, 211-239, 291-313, and 542-607.

[64] Ibid., 79-80.

[65] Ibid., 83-4. Presumably, crayfish eggs were present in the sand or water that Digby added in the final step, or he was simply less than truthful about the outcome. For more on Digby's interest in the alchemy of palingenesis as a clue to understanding the material function, chymistry, and mechanics of bodily resurrection in the End Times and proving the immortality of the soul, see Michael Martin, *Literature and the Encounter with God in Post-Reformation England* (New York: Routledge, 2014), 94-8; and Ann Blair, *The Theater of Nature: Jean Bodin and Renaissance Science* (Princeton: Princeton University Press, 1997), 26. A 1669 edition of his works included *A Discourse concerning the Vegetation of Plants*, *Powder of Sympathy*, and his 1644 tract on natural philosophy *Of Bodies and of mans soul to discover the immortality of Reasonable Souls*.

after burning and calcining because the essential salt remained and could still attract the vital spirit from the air.

While Beale seemed to have entertained these ideas, he, again, preferred to remain uncommitted to any specific theory until further study warranted. "Whether the air does of itself beare any plants, I refer it to future discovery. That the air or influences do prepare and impregnate the Earth and sometimes seminate the Earth, and begets whole plants which are most congenial to the soil, is the judgment of many sober and wise men."[66] In this, he was aware that a number of natural philosophers, both ancient and early modern, had asserted that the air was capable of bringing forth life in various ways. Beyond the experimental trials of Duchesne, Kircher, and Digby, he observed that many notable figures had remarked on the air's generative qualities: In his *Meteorologia*, Olympiodorus claimed that when meteors stirred up the air, they begat quails; Jacob Ziegler of Strasbourg had claimed that air could impregnate vultures, mice, and some fish; Julius Caesar Scaliger and Fortunio Liceti, themselves citing Isidore of Seville and an unnamed bishop of Uppsala, had claimed that lemurs emerged from the air; and several unnamed scholars had claimed that "infectious ayres" caused the growth of grasshoppers, butterflies, locusts, and other insects, while tadpoles and even adult frogs had been known to fall from the sky like rain in other places.[67] Beale also recounted the well-known and often repeated story that birds of paradise, or "the Sparrows of the Sun, as the Portuguese call them, and the *Mamucodiata* [birds of God], bred and [were] sustained in the air without use or need of feet or regard of

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[66] Beale, "Concerning the Transmutation and Improvements of Plants," RS, RB/1/34/9, f. 450.

[67] Ibid. Other than Olympiodorus's *Meteorologia*, Beale gave no indication as to which texts these references were to be found. On Scaliger and Liceti's claim regarding lemurs, in Beale's text it reads "lemmers" and it is likely that he meant lemmings, which, from at least the 1530s onward, were reported to fall from the sky during stormy weather and even explode upon landing. See Jacob Ziegler, *Quae intus continentur Syria, Palestina, Arabia, Aegyptus, Schondia, Holmiae....* (Strasbourg, 1532).

Earth, trees, or other rest during life."[68] However, in all of these cases, he proclaimed that while some seemed plausible, all were at best hypothetical, and he "dare not affirme that there is any such aerial plant, bred and sustained in the air," with the possible exception of a Barbadian plant that had been described by Richard Ligon in his recently published *True and Exact History of the Island of Barbadoes*.[69]

Though it did not dwell on recondite abstractions, Beale's work was highly speculative. Yet, at its core, it contained practical advice and observational evidence, so far as Beale knew, concerning the methods for transmuting and improving plants. The closest Beale came to a theoretical commitment concerning the causes of biological generation and the origins and operations of vital spirits in that process was in a disagreement with Bacon, who had argued that "the Earth is such a dull sufferer, as to contribute no ayde toward generation."[70] Beale averred that the seemingly endless varieties of soil meant that such speculation was premature and "the difference from invisible infusions, innumerable grains…and imperceptible Spirits," left him open to consider "a free domination of liquids, in the moment of generation, and of radical influence toward augmentation, alteration or diminution. The vigour being in the spirits, and the spirits having a near Affinity to the liquor, as air and water are one remove nearer in kindred, than air and Earth."[71] That is,

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[68] Ibid. On the endurance of this legend, see Ogilvie, *The Science of Describing,* 248-52. Curiously, the first European to describe them, Antonio Pigafetta, who had sailed with Ferdinand Magellan during his circumnavigation of the globe (1519-1522), had described their feet. Ogilvie suggests that the origins of the legend may derive from the fact that the first European known to have described them from observation, Maximilianus Transylvanus, saw only their skins. The hunters of the Aru Islands in the East Indies who had provided him with samples had used a preservation technique that involved cutting off their legs. See Maximilianus Transylvanus, *De Moluccis insulis* (1st ed. Cologne, 1523; 2nd ed. Rome, 1523).

[69] Ibid., f. 451. Beale referred to Ligon's description of a so-called "Negroe's Head plant," an unfortunate—not to mention ambiguous—name that denoted several possible species. See Richard Ligon, *A True and Exact History of the Island of Barbadoes* (London, 1657), 101.

[70] Ibid., f. 490. For more on Beale's reluctance to commit to a particular matter theory, see *Phil. Trans.* Vol. 3, No. 40 (1668): 797-802.

[71] Ibid.

after a seed had germinated, one could focus on the liquids involved in the alchemical manipulation of agricultural improvement, since air and water, being more alike than air and soil, exchanged the vital spirit more easily. In essence, throughout his work, Beale developed a chronological understanding of when each of Pliny's three agricultural principles was most active in the sustenance of a plant: soil was the matrix or receptacle in which growth must occur; waters of various types, liquors, and menstrua became important upon germination as the attractor of the vital spirit, and air became important as a continued conveyor of this once the plant began to reach maturity. Though he never claimed to have discovered the ultimate source of the vital principle of plant life or vegetable growth, Beale concurred with Plattes and others that an alchemical understanding of the interactions between the basic materials with husbandry was the key to answering such a question.

Beale's Later Writings on Plant Transmutation and Alchemical Processes in Botany and Horticulture

While his unpublished and unsent letter "Concerning the Transmutation and Improvements of Plants" marks Beale's most comprehensive entrée on the topic, he wrote a handful of shorter works in the 1660s and 1670s on agricultural improvement, the possible roles of transmutation, and the potential uses of various alchemical operations in husbandry experiments. He did so first in letters to Henry Oldenburg and then in the pages of the Royal Society's *Philosophical Transactions*, several of his contributions to which were culled out of those earlier letters. Beale was not a founding member of the Royal Society but he was elected as a Fellow in January 1663.[72]

Though the Royal Society had been founded, in part, on Baconian ideals of sharing empirical knowledge and conducting experimental trials for gentlemen to witness, the early years of the Society also featured the variety of Baconianism championed by Samuel Hartlib and Jan Comenius. Beale and other likeminded reformers such as William Petty, John Evelyn, Theodore Haak, and John Winthrop, Jr.—who had been integral members of Hartlib's correspondence network before he died the year the Royal Society was granted its royal charter in 1662—sustained this outlook. Foremost among these, as we have seen, was the idea of educational, social, and economic improvement through applied natural philosophy. The full name of the Royal Society from 1663 onward was "the Royal Society of London for Improving Natural Knowledge," suggesting that this reformative ethos was present in some way at its inception. Michael Hunter and Mayling Stubbs have both argued that the early Royal Society and the eventual abortive plan to create its own college on the model of a research institute owed a significant debt to Bacon's "House of Solomon" from the *New Atlantis*.[73] Even earlier, Charles Webster had traced a lineage dating back to Plattes's assorted "Councells" of trades from *Macaria* and Hartlib's "Office of Address," neither of which were intended to be apolitical, disinterested, knowledge-making enterprises.[74] Beale and this cohort proved to have an outsized influence on prioritizing agriculture, horticulture, botany, agronomy, natural history, and the promotion of trades

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[72] Woodland, "Beale, John (*bap.* 1608, *d.* 1683)," *ODNB.*
[73] Michael Hunter, "A 'College' for the Royal Society: The Abortive Plan of 1667-1668," *Notes and Records of the Royal Society,* Vol. 38, No 2 (1984): 160; and Mayling Stubbs, "John Beale, Philosophical Gardener of Herefordshire, Part II: The Improvement of Agriculture and Trade in the Royal Society (1663-1683)," *Annals of Science* 46 (1989): 324-25.
[74] Webster, *The Great Instauration*, 88-99.

and on emphasizing the dissemination as well as the production of knowledge in the Society's first decade and a half.[75] One of the earliest prolonged experiments implemented by Fellows of the Royal Society included an effort to chemically analyze may-dew and extract a Sendivogian *sal nitrum* from it, demonstrating, for instance, just how much sway this theory had in Restoration England.[76] Compared to the succeeding generation of Fellows, the early Royal Society was composed of a disproportionately large share of natural philosophers with primary interests in these topics, particularly as they pertained to the improvement of artisanal and mechanical trades, technology, and proactive political reform, including Evelyn, Beale, and Oldenburg, all of whom kept this reformative spirit alive.[77] Within the society, Beale was instrumental in the founding of the Georgical Committee, which focused on botany, gardening, horticulture, and agricultural improvement.[78]

These Baconian and Hartlibian influences clearly affected Beale's early expectations of the Society. He noted to Oldenburg that their "proper and fundamentall Worke" there was to "set right Ld Bacons method in his N[ovum] Organ[um]."[79] He advocated for a focus

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[75] Stubbs, "John Beale, Part II," 323-7; Webster, *The Great Instauration*, 249, 470-74, and 480-81; Thirsk, *Agrarian History of England and Wales*, Vol. 5, Pt. 2, 546-49; and Debus, "Palissy, Plat, and English Agricultural Chemistry," 85-6.
[76] See Alan B. H. Taylor, "An Episode with May-Dew," *History of Science* 22 (1994): 163–84; and Frank, *Harvey and the Oxford Physiologists*, 115-139 and 221-45.
[77] Stubbs, "John Beale, Part II," 324-5. For evidence of this spirit, see Thomas Sprat, *History of the Royal Society of London* (London, 1667), 87-8, 149-50, 400, and 422-3.
[78] On the development of this committee, and others, see Michael Hunter, *Establishing the New Science: The Experience of the Early Royal Society* (Woodbridge: Boydell, 1989), 73-122, esp. 78-83 and 97; Stubbs, "John Beale, Part II," 323-363; Graham Parry, "John Evelyn as Hortulan Saint," in *Culture and Cultivation in Early Modern England: Writing and the Land*, Michael Leslie and Timothy Raylor, eds. (Leicester: Leicester University Press, 1992), 130-150; Reginald Lennard, "English Agriculture under Charles II: Evidence of the Royal Society's 'Enquiries,'" *Economy History Review*, Vol. 4, No 1 (1932): 23-45; and Joan Thirsk, ed., *The Agrarian History of England and Wales,* Vol. 2, 1640-1750, Part I, *Agrarian Change* (Cambridge: Cambridge University Press, 1985), 372, 444, and 562-565.
[79] John Beale to Henry Oldenburg, 24 June 1671, *Correspondence of Henry Oldenburg*, Vol. 8, 122. See also, Stubbs, "John Beale, Part II," 328, n.17.

on practical science "for the Public good," a "serviceable" role for the Royal Society to aid the nation in times of famine and to rectify the deficiencies of farming through a robust experimental program during times of plenty.[80] He also hoped to inculcate "a new and *active spirit* in all ye gardeners about London, England, Scot[land], and Ireland," and to properly manage "the public in all things for peace, trade, strength, piety, [and] religion."[81] With this attitude in mind, many of his writings for the *Philosophical Transactions* from 1665 to 1677—of which there are at least a dozen, several published anonymously—were on practical topics on which he had the most expertise: the grafting of apple trees, methods of apple pressing for cider production, the domestication of exotic plants, and caring for ill sheep.[82] The very first edition of the *Philosophical Transactions* contained "Agricultural Enquiries," the report of the Georgical Committee on how to turn unused meadowland into arable farmland, which he helped to write.[83]

Much like his long, unsent letter, however, several of his missives to Oldenburg and articles for the *Philosophical Transactions* delved into theoretical aspects of horticulture and botany, many with input from alchemy and chemical philosophy. They included conjectures on the movement of sap in vascular plants and the sources of plant nutrition. They examined the relationship between the putrefaction of organic matter and the development of salts, metals, minerals, crystals, and gems deep underground, and the origins of mineral springs and their potential uses as medicine and for "altering chemical

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[80] John Beale, "Some Politicals to be considered in Agriculture," RS, Evelyn Letters, B1, f. 42; John Beale to Henry Oldenburg, 3 April 1675, *Correspondence of Henry Oldenburg*, Vol. 11, 251; both quoted in Stubbs, "John Beale, Part II," 325-26.

[81] John Beale to John Evelyn, 13 December 1662 and 7 February 1662/3, Evelyn Collection, MS 3.1. ff. 26 and 35, quoted in Stubbs, "John Beale, Part II," 325-26.

[82] See, for instance, *Phil. Trans.*, Vol. 1, No. 1 (1665): 91-4; *Phil. Trans.,* Vol. 6, No. 71 (1671): 2144-2149; *Phil. Trans.*, Vol. 9, No. 103, (1674): 48-53; and *Phil. Trans.*, Vol. 11, No. 131 (1676/7): 796-7.

[83] Stubbs, "John Beale, Part 2," 330; *Phil Trans.* Vol. 1, No. 1 (1665): 91-4.

liquors." There were analyses of contemporary thought on spontaneous generation, from reviews of Francesco Redi's *Esperienze intorno alle generazione degl'insetti* (*Experiments on the Generation of Insects*) in 1671 and debates with Martin Lister, John Ray, and Oldenburg over the reproduction of ichneumon wasps.[84] Importantly, he continued to connect various alchemical concepts and operations including transmutation but also multiplication, putrefaction, and fermentation to the experimental processes of improving agriculture and horticulture. He also continued to investigate the origins of the vital spirit in plant life that he hoped would lead to a unified theory of growth, and he pressed other members of the Royal Society, in particular Boyle and Oldenburg, to investigate the chymistry of plants.[85]

How did Beale's interpretation of these topics evolve during the 1660s and 1670s? Like his investigations on transmutation through careful study of Pliny's three agricultural principles of soil, water, and air, Beale increasingly came to view all material substances found in nature as heterogeneous mixtures and noted that any attempt to isolate any vital principle would involve extricating and isolating it from these compounds. He wrote that air, water, and even flames possessed "globular Parts which do not intermingle as often as they seem to intermingle," yet they did contain "all those differing substances of spirits (whether together inanimate or animate) w*ch* are vulgarly called ayre."[86] The similarities

[84] See, *Phil. Trans.* Vol. 3 No. 43 (1668): 853-862; *Phil. Trans.* Vol. 4, No. 56 (1669): 1131-1134; *Phil. Trans.* No. 4, Vol. 56 (1669): 1135-1141; *Phil. Trans.* No. 6, Vol. 71 (1671): 2144-2149; Beale to Oldenburg, 30 September 1659, *Correspondence of Henry Oldenburg*, Vol. 1, 318-319; Beale to Oldenburg, 18 January 1664/5, *Correspondence of Henry Oldenburg*, Vol. 2, 348-49; Beale to Oldenburg, 7 January 1666/7, *Correspondence of Henry Oldenburg*, Vol. 3, 306; Beale to Oldenburg, 13 May 1671, *Correspondence of Henry Oldenburg*, Vol. 8, 52-56; and Beale to Oldenburg, May 1675, and Beale to Oldenburg, c. early July, *Correspondence of Henry Oldenburg,* Vol. 11, 317 and 381-89. Redi's work was published in 1668 but not reviewed by the Royal Society until 1671.

[85] See, for instance, Beale to Hartlib, 18 January 1657, RS, Boyle Letters, RB/3/7/3. On the chemistry of cider production and its comparison to winemaking, see Birch, *History of the Royal Society*, Vol. 1, 366.

[86] Beale to Oldenburg, 18 January 1664/5, *Correspondence of Henry Oldenburg*, Vol. 2, 349. In this, Beale was arguing against Francis Bacon's Experiment 31 from his *Sylva sylvarum*, in which he concluded that "flame

among these, along with the fact that plants appeared to sustain life through respiration—which, as Beale noted on several occasions, might be more important than soil and water after a plant had germinated—suggested that isolating the vital spirit in air was the most promising possibility among many. This marked a shift in Beale's thinking. Soil had been his focus throughout much of the 1650s. The importance of soil, then water, and then air as a plant progressed through the stages of its life emerged in his long letter to Hartlib in late 1659. Air came to the fore from the mid-1660s onward.

Constantly frustrated by the lack of "infallible experiments" to test these assertions, Beale contented himself with making copious observations based on his extensive experience and expertise with arboriculture.[87] One of his articles for the *Philosophical Transactions*, entitled "Queries concerning vegetation, especially the motion of the Juyces of Vegetables," inaugurated an ongoing botanical debate between Beale and others on the motion of sap.[88] Beale later claimed that these deliberations stirred in him "deeper thoughts concerning Alterations, Mixtures, and Movements of vegetables partly by Graftings and much more by other applications," the lack of reliable experiments for which had steered him away from making theoretical pledges. In another article for the *Philosophical Transactions* on the causes of mineral springs and their effects on "the liquors and juyces" inside plants, Beale commented that vastly different types of trees "seem[ed] to draw their whole sustenance… from the Liquors they find in the same piece of ground, and from the ambient air, and dewes," but when experimenters anatomized their roots, they

doth not mingle with flame, as Air doth with Air, or Water with Water." See A. Rupert Hall and Marie Boas Hall, eds. *Correspondence of Henry Oldenburg*, Vol. 2, 351 n.4.

[87] Stubbs, "John Beale, Part II," 340. For more on his desire for more experimental trials, see *Phil. Trans.*, Vol. 3, No. 40 (1668): 797-802.

[88] *Phil. Trans.*, Vol. 3, No. 40 (1668): 797-802. For the anonymously published early round of these debates, entitled "Communications relating to queries about vegetation," see *Phil. Trans.*, Vol. 3, No. 43 (1668): 853-62.

could not "distinguish the Liquors or salts" at all.[89] By contrast, when plants seemed to receive the bulk of their nourishment from the air—as with mosses that grew on dry stones, trees that grew in the crevices between craggy rocks on mountains and cliff sides, and the ivy-like growth that appeared annually on the antlers of deer—then "the roots, stems and leaves of trees" appeared to "generate the peculiar saps and juyces."[90] These liquids could be fermented and boiled to reveal particular salts that could not be found in plants growing under normal circumstances with equal and adequate amounts for soil, water, and sunlight. According to Beale, this meant that air contained something both necessary *and* sufficient for life, at least in these particular examples.

Like those of the experimenters and projectors working with saltpeter during the Civil War and Interregnum, Beale's experiments had a dual purpose. They were an intellectual endeavor to uncover the vital spirit and a practical one to determine how this might aid husbandry for both the individual farmer and the nation as a whole. This meant converting some of his more abstract hypotheses about vegetation into a more tangible and accessible explanation for fertility. In a letter from early July 1675 to Oldenburg, published later that month in the *Philosophical Transactions*, Beale attempted such an account, relying on an understanding of the interaction between water and minerals or metals in the soil and the movement of that water and the resultant vapors underground. "First, 'tis vulgarly known," he wrote,

> that the surface of some ground is so Hollow, light, and swoln by a hot and working ferment, but it must needs send up a warming steam; as appears by the quick riddance of all the snow that falls on it. And in many places within my knowledge dissolving the snow before it falls on the ground: that some Stones by an innate

[89] *Phil. Trans.*, Vol. 4, No. 56 (1669): 1132.
[90] Ibid., 1133. It is unclear if, by ivy-like growth, Beale was referring to pre-calcified antler velvet or simply vines of some sort he had observed tangled in deer antlers.

> warmth, and some Waters to impregnate the Earth; and that other Stones by their contrary qualities, or by their positions, have a quite contrary operation; that streams of water running over Lime-stone or through veins of Marle, or of that sort of shock which is kind for manure (for there is a sort of Chalk which is barren) doth fertilize…[91]

In this passage, Beale portrayed the earth as having an innate heat through fermentation and relayed that some stones and minerals contained fertile properties that were redistributed through the soil due to the movement of underground waters and vapors. After proceeding to describe various "metallizing," "petrifying," and "mineralizing" waters and "steams," Beale noted that the existence of these inside plants indicated, as Plattes had argued, the links between vegetating minerals and plants. This had led to some surprising discoveries, such as "Quicksilver found in the roots and in the juyce of a Plant" in Italy and "Mineral-juyces" in places as geographically distant as Moravia, Hungary, and Peru. Neither could he contradict the reports in the recently published *Miscellanea curiosa* of Phillip Jacob Sachs, who had written in a section titled "*Aurum Vegitabile*" "that all minerals, and Gold it self, is continually generated."[92] After citing the experiments of Boyle and William Brouckner demonstrating that fire and "even perhaps the Solar beams" could add weight to metals through certain chymical reactions, Beale argued that the same must be true of the soil and minerals within it that "allow the Sun to give potent assistance in the generation of all things."[93]

Beale's interpretation was not unlike Isaac Newton's quasi-alchemical hypothesis on light formulated around the same time as his work, which involved aether condensing and

[91] Beale to Oldenburg, c. early July 1675, *Correspondence of Henry Oldenburg*, Vol. 8, 383, reprinted in *Phil. Trans.* Vol. 10, No. 116 (1675): 357-67. My quotations come from Beale's letter to Oldenburg.
[92] Ibid., 383-4 and 390 n.13. On Beale's citation, see Phillip Jacob Sachs, *Miscellanea curiosa… Ephemeridium physicarum Germanicarum* (Leipzig, 1670), 290.
[93] Ibid., 384. On the experiments of Boyle and Brouckner, see Boyle, "New Experiments to Make Fire and Flame Stable and Ponderable," *Works of the Honourable Robert Boyle*, Vol. 3, 342; and Sprat, *History of the Royal Society,* 228-9.

rarefying.[94] It is possible that Newton derived this theory from his earlier alchemical work, "Of Natures obvious laws & processes of vegetation," which focused on mineral and metallic transmutation but clearly envisaged analogues in the biological domain. Unlike the agricultural reformers of the mid-seventeenth century who had, largely, begun with alchemical sources as a new way to understand and describe the botanical realm, Newton reversed this and claimed it was the alchemist who should learn by observing the process of growth in plants and animals in order to understand the formation of metals and minerals. Probably written in 1672, "Of Natures obvious laws & processes of vegetation" noted that metals "vegetate after the same laws" as plants, that "salt chiefly excites to vegetation," and that saltpeter formed "the ferment of fire & all vegetables the other most apt to take fire & most promoting vegetation of all salts."[95] This document was, in part, one of Newton's early attempts to reconcile mechanical philosophy with alchemical vitalism. Newton's conviction that inert particles of matter could not spontaneously organize themselves into living beings led him to describe a latent, potentially active spirit in all matter that guided the formation and growth of vegetable, animal, and mineral matter through a "vital agent," "fermental virtue," or "vegetable spirit."[96] Though he did not cite them directly, Newton's language clearly echoed a number of *sal nitrum* theorists since at least the time of Sendivogius.

After describing the correspondences between plant and mineral growth in his letter to Oldenburg, Beale then "returned to his Vulgarities" and went on to recount his

[94] See Isaac Newton, "Hypothesis explaining the Proprties of Light, discoursed of in my several papers," in Birch, *History of the Royal Society*, Vol. 3, 248-60.

[95] Isaac Newton, "Of natures obvious laws and processes of vegetation," Smithsonian Institution, Dibner Library for the History of Science and Technology, MS Dibner 1031B, ff. 1*r*-2*r.*

[96] On these terms, see Betty Jo Teeter Dobbs, *Alchemical Death and Resurrection: The Significance of Alchemy in the Age of Newton* (Washington, D.C.: Smithsonian Institution Libraries, 1990), 3.

own personal experiments attempting to grow various crops in soils with dissimilar types and amounts of stones and pebbles and those that had been imparted to him by other trusted observers. He noted that there seemed to be little rhyme or reason why in some locations removing stones seemed to be a great aid in fertility while in others it drastically reduced crop yields. He ultimately reckoned that it must be, not the plants, but the stones that made the difference, some of which were "intrinsically warm and impregnating" and others "cold" and not.[97] Beale had added stones to the list of materials about which one needed to inquire to discern the true causes of fertility, and in the process, reinforced the bonds between theory and practice necessary for the improvement of husbandry. Interesting and important as the former was, unearthing the "best remedies against Sterility" was a more pressing goal than detecting the "minute and curious rarities, and…Occult Qualities" that inhered in soil and stones.[98]

Though Beale lived until 1683, his output of both published and unpublished writings on natural history, botany, and agriculture began to dwindle in late 1677. Oldenburg's death earlier that year marked the end of the first incarnation of the *Philosophical Transactions*, and in his 1679 renewal of the journal, Robert Hooke published a narrower range of papers, often relegating agricultural writings to secondary status or disregarding them entirely.[99] For the final three years of his life, from his provincial parsonage in Yeovil, Somerset, Beale remained in contact with Evelyn, Hooke, and Nehemiah Grew, though less regularly and less prolifically than he had with Oldenburg and Hartlib. Beale's handwriting had grown shaky and illegible beginning in 1677, and his age

[97] Beale to Oldenburg, c. early July 1675, *Correspondence of Henry Oldenburg*, Vol. 8, 385.
[98] Ibid., 388.
[99] Stubbs, "John Beale, Part II," 351.

and increasing frailty kept him from writing as much as he had hoped.[100] Still, he found the time and strength to write, often reviewing recent books and pamphlets or sending copies of them to his correspondents to promote. These included works on the benefits of mercantilist economic policy, recommendations that the state restrict exports of unfinished wool and agricultural raw materials and imports of foreign manufactured goods, campaigns for the creation of a national bank, proposals for improving the navigability of inland waterways, and advice on opening up national markets to domestic agricultural surplus.[101] He collaborated with Evelyn to print John Houghton's *Collection of Letters for the Improvement of Husbandry and Trade* beginning in 1681, which some historians consider the first scientific journal specifically devoted to agriculture.[102] On the eve of his death, he was working on a refutation of Houghton's promotion of luxury consumption and an "anti-atheist" tract against Hobbesian defenses of "Christian vice."[103] With Beale's death, one of the last voices from the old Harltibian guard was gone, even though, to some degree, his influence remained.[104]

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[100] Hall and Boas Hall, eds., *Correspondence of Henry Oldenburg*, Vol. 13, 341 n.2. Beale, apparently, did not have a regular amanuensis.

[101] Stubbs, "John Beale, Part II," 352-3. These included Thomas Moffett, *Healths Improvement* (London, 1655); Hugh Plat, *The Jewel House of Art and Nature* (London, 1594); John Evelyn, *Sylva, or a Discourse of Forest-Trees and the Propagation of Timber…to which is annexed Pomona* (London, 1664); idem., *Navigation and Commerce….* (London, 1674); Nehemiah Grew, *The Anatomy of Plants* (London, 1682); John Collins, *Salt and Fishery* (London, 1682); and Roger L'Eastrange, *Discourse of the Fishery* (London, 1674). On these, see John Houghton, *Collection of Letters for the Improvement of Husbandry and Trade*, Vol. 8 (London, 1682), 75-7; and *Phil. Trans.* Vol. 9, No. 101 (1674): 19.

[102] See James R. Jacob, "Restoration, Reformation, and the Origins of the Royal Society," *History of Science* Vol. 13 (1975): 155-176; idem., "Restoration Ideologies and the Royal Society," *History of Science*, Vol. 18 (1980): 25-38; Stubbs, "John Beale, Part II," 352; and Anita McConnell, "Houghton, John (1645-1705)," *ODNB*, last accessed 4 July 2018, https://doi.org/10.1093/ref:odnb/13868. The original *Collection of Letters for the Improvement of Husbandry and Trade* lasted from 1681 to 1683 (though the final few volumes did not come out until 1685) with a second iteration from 1692 to 1703. It underwent numerous editions, including a four-volume set containing an edited and abridged edition of the letters in 1727 and 1728.

[103] Stubbs, "John Beale, Part II," 362-3.

[104] Of the major, original correspondents of Hartlib who had written on the relationship between chymistry, alchemy and agriculture, only Boyle (d. 1691), Haak (d. 1690), and Petty (d. 1687) remained.

Alchemical Operations in Restoration-Era Agricultural Writings

If anything, Beale's death marked the start of the waning of the reformative spirit still to be found among some members of the Royal Society and their colleagues rather than the waning of the impact of chemical philosophy and alchemical techniques among botanists and agricultural improvers. Still, one of the hallmarks of his later writings was the ease with which the common farmer could adopt the basic operative principles of the alchemists for the betterment of his plot of land. This style of inquiry remained common throughout the final two decades of his life even though the manner in which scholars used alchemical language and concepts outside of strictly chymical settings began to change drastically toward the end of the seventeenth century. As we shall see, this transformation had much to do with the way agriculture and alchemy were defined, how the locations of their practice diverged, and how their practitioners ceased to intersect in ways that had been customary throughout much of the sixteenth and seventeenth centuries.

There are myriad examples of Plattesian chymical analyses of soil fertility and Bealian transmutational improvement in the final few decades of the seventeenth century. One exemplary early work, titled similarly to Beale's long letter to Hartlib, was Robert Sharrock's *History of the Propagation and Improvement of Vegetables, by the Concurrence of Art and Nature* (1660), which, after considerable pressure from Beale, was funded almost entirely by Robert Boyle, to whom Sharrock wrote a glowing dedication.[105] The second part of this title was important, as it conveyed the commonly held belief that human intervention into the botanical world for the purpose of enhancing yields depended on artifice emulating nature. Like Paracelsus's recommendations to physicians and Plattes's

[105] Hunter, *Boyle*, 123 and 325 n.10.

advice to farmers, Sharrock's counsel was that the best instructions for the experimenter were to be found in nature. Sharrock's work, like the works of Austen and Beale on fruit trees, owed much to the experimental style of philosophy developed by John Wilkins at Oxford. Unlike Beale and Austen, however, Sharrock showed little interest in deploying his work in the name of economic reform and public welfare and still less in the development of explicitly regional natural histories like Beale's Herefordshire, Robert Plot's Staffordshire and Oxfordshire, or even Gerard Boate's Ireland.[106] As an experimental technician and assistant to Jacob Bobart the Elder at the Oxford Physic Garden, Sharrock had developed a keen understanding of the anatomy, physiology, and medicinal uses of plants.[107]

In this work, Sharrock displayed familiarity with at least some aspects of experimental chymistry and alchemical operations as well. In one section on the "relations of transmutation, and the possibility of a change of one species to another," Sharrock denied claims made by unnamed agriculturists that seeds could be so materially altered that one could plant corn that would give rise to oats. While arguing that this was impossible, Sharrock conceded that "sensible qualities" such as color, shape, and size could be "transmuted" with an end result "not at all in another divers kind; but in severall small diversities of the same kind" that might in fact yield wheat grains that more resembled mustard seeds in their morphology or even their taste.[108] This meant that while one could

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[106] Webster, *The Great Instauration*, 478-9. For a work arguing that Sharrock continued the broadly reformative work of the Hartlib Circle, see Joan Thirsk, ed., *Agricultural Change: Policy and Practice, 1500-1750* (Cambridge: Cambridge University Press, 1990), 280-1. At least on the issue of the uses of alchemical operations in the improvement of husbandry, I am in general agreement with Thirsk.
[107] Anita McConnell, "Sharrock, Robert," *ODNB*, last accessed 27 June 2018, https://doi.org/10.1093/ref:odnb/25243; Frank, *Harvey and the Oxford Physiologists*, 68-9 and 76-7.
[108] Robert Sharrock, *The History of the Propagation and Improvement of Vegetables, by the Concurrence of Art and Nature* (Oxford, 1660), 29-30.

never transmute one species into another, one could create considerable diversity within species to the point that one seed might masquerade as another in particular ways. This would be useful, Sharrock tacitly intimated, if one hoped to convert a low-yield seed of a particular variety of crop into a high-yield one. According to Sharrock, those who claimed to see oats grow abundantly out of land sown with corn simply mistook a wild version for the domesticated one.

The possibility of the natural transmutation of “vegetable, animal, and mineral” lingered as an open question in the text, and Sharrock clearly thought that the same physical processes operated regardless of which of the three categories one examined. Following the writings of his former overseer Bobart indicating that under some circumstances crocuses had morphed into gladiolas and leucojum into hyacinths, Sharrock had conducted experiments with Boyle, and though he was able to get “divers bulbs growing, as if they were on the same stoole,” he was unable to get any flowers to grow from bulbs of different species. Nevertheless, he demurred from calling the entire process into question, saying “the change-time had passed,” meaning, presumably, that if transmutation were possible, it would occur before he harvested and replanted the bulbs. Sharrock simply conceded ignorance and stated he was willing to accept the views of those more expert than he.[109]

For animals, he gave standard examples of transmutation dating back to at least the sixteenth century and popularized by Bacon under that term, such as silkworms, “cadiz” (Gadira moths), and caterpillars of all kinds, which transmuted from one form to another during their lifetime. For minerals, his examples were of typical *chrysopoeian* alchemical

[109] Ibid., 30.

models, including the philosopher's stone and the "perfecting medicine."[110] As with the vegetable examples, Sharrock was skeptical of the direct transmutation of one metal into another, and instead he alleged that due to the variegated composition of mineral ores, alchemical operations merely separated out pure metals from the aggregate material. He referred to Daniel Sennert's experiments that had purportedly transmuted iron into copper by precipitating it in a solution of blue vitriol and, citing Boyle, alternatively proposed that copper merely separated from the iron.[111] He claimed a similar reaction in an apparent attempt to transform mercury into lead in a solution of aqua fortis. After providing further examples, including reports of the petrifaction of wood into stone in England, a lake in Ireland that supposedly converted dense wood into whetstones, and the perennial exemplar of coral, which "may well be imagined to be originally a vegetable bearing root, stalk, and leafe; and that afterward…turned into its hardnesse by the peculiar property of the water," Sharrock remained neutral on the reality of mineral and metallic transmutation.[112] Still, he ended this section by noting that "Vinegar and Wine are the same parts transposed" and yet seemed more dissimilar from one another than a number of

[110] Ibid., 31. Here, Sharrock presumably was referring either to the *panacea* or the "elixir of life," the former a cure-all medicine and the latter a substance extending the recipient's life.

[111] This refers to the well-known *reductiones ad pristinum statum* ("reduction to a pristine or original state") alchemical process. In modern chemical terms, this operation involves the ionic transfer of solid iron in a liquid solution of blue vitriol (copper sulfate, or $CuSO_4$), which dissolves the iron and releases copper from the sulfate. The resultant liquid becomes green vitriol (ferrous sulfate, or $FeSO_4$), the iron having bonded with the sulfate and the copper having become solid. It can be performed with numerous metals, including gold. This process is illustrated in Agricola, *De re metallica*, 574. For the steps in the process, see Cathy Cobb, Monty L. Fetterolf, and Harold Goldwhite, *The Chemistry of Alchemy: From Dragon's Blood to Donkey Dung—How Chemistry Was Forged* (New York: Prometheus Books, 2014), 288-93. For Sennert's role in its popularization and its influence on Boyle (from whom Sharrock, a protégé of Boyle, learned it), see Newman and Principe, *Alchemy Tried in the Fire*, 18-22.

[112] Sharrock, *History of the Propagation and Improvement of Vegetables*, 32-3.

vegetables from diverse species or from closely related plants that were morphologically or taxonomically distinguished.[113]

Another prime example of alchemical transmutation as a tool for understanding agricultural practice comes from the writings of John Worlidge, whose *Systema Agriculturæ, or the Mystery of Husbandry Discovered….* (1668) demonstrated familiarity with the previous two generations of English agriculturists' incorporation of chemical philosophy into their works. Notable citations include Hugh Plat, Gabriel Plattes, Richard Weston, Robert Child, Walter Blith, and Samuel Hartlib, as well as a number of Continental writers from the sixteenth century such as Palissy and della Porta, and the usual litany of ancient Roman authorities.[114] Worlidge clearly viewed agriculture as a science in the Baconian sense, and he urged his readers to accord it that status alongside related fields like botany and chymistry. Referring to Plattes's natural history of soils, Beale's empirical investigations of plant transmutation, and Richard Weston's attempt to define a natural philosophy of husbandry, Worlidge similarly hoped to explain in his *Systema Agriculturæ* the importance of the proper treatment of arable land and the entwined nature of economics and agriculture through the language and methodology of natural history, chemical philosophy, and alchemy. To Worlidge, agriculture was a "Science, that principally teacheth us about Nature," including the "Properties and Qualities" of various natural materials like soil, water, plant matter, and animal flesh, as well as both the "natural and artificial" production of "Creatures, whether Vegetable, Animal, or Mineral."[115] In language similar to Sharrock's, and in the tradition of Paracelsus and Plattes, Worlidge regarded

[113] Ibid., 33.
[114] John Worlidge, *Systema Agricultræ, or the Mystery of Husbandry Discovered…* (London, 1668), *passim*. References to Plattes alone occur over forty times.
[115] Ibid., 1.

himself as a mere facilitator of natural processes and specifically saw agriculture as the artificial handmaiden to nature.

Like other husbandry manuals of the mid-seventeenth century, the bulk of Worlidge's work provided instructions for rudimentary operations to improve farmland, with chapters on the importance of enclosure, how plowing styles must change depending on soil consistency, proper irrigation methods, and basic remedies for drought, excessive rains, and insect infestations. However, the first chapter of the book after the dedicatory preface, proem, and summary, contained a highly theoretical discourse on the scientific principles of agriculture in a scant ten pages, which reads like a short exposition on vitalism and the alchemical means to uncover the secrets of organic matter.

Much of Worlidge's dense, theory-laden first chapter simply reiterated prevailing notions about soil fertility that had become increasingly common among the writers of husbandry manuals who strove to imbue their works with natural philosophical depth and who saw themselves as contributing to a more complete natural history of the botanical world by recording, disseminating, and sometimes replicating experiments on organic matter, many originally performed in alchemical contexts. Again, like Beale, Worlidge employed alchemical terminology neither metaphorically nor rhetorically but as actual, material descriptions of physical change. Nor did he compose this short section to mask a lack of erudition and to prop up an otherwise conventional manual intended solely for practical use. Instead, he continued the trend dating back to at least Hugh Plat and Bernard Palissy, encouraged by Bacon, and inaugurated as a matter of course by Plattes, of substantiating specific agricultural practices with chemical philosophy and alchemical techniques. The major development from at least Beale onward was the consistent and usually technically accurate usage of alchemical terminology and particularly that related to alchemical operations, including especially transmutation, but also fermentation, distillation, multiplication, congelation, fixation, calcination, and putrefaction. Both Sharrock and Worlidge employed many of these to describe both the functions of nature and the operations available to the skilled cultivator to improve agriculture with knowledge of contemporary chymistry. To ensure that plants received enough nutrients from the earth, Sharrock recommended a mixture of different types of soil to guarantee an abundance of salt with "due proportion of other principles mixt" without which "nothing will grow…for there is no fermentation without mixture of contrary parts of Elements."[116] Referring to the composting experiments of Bacon, Columella's emphasis on the potency of pigeon dung, and Virgil's reminder that different trees require very different soils, Sharrock claimed that the point of manuring land was to induce fermentation in seeds. He called this the artificial "melioration by Richness, or other convenient Minera[ls] in the Soyl, for the feeding and better nourishment of several plants."[117]

Clearly influenced by Paracelsian matter theory as well as more contemporary investigations into vegetable philosophy, Worlidge incorporated both the suppositions of vitalists and the language of alchemy when describing fertility, germination, the movement of bodily fluids in plants, and nutrient transfers between plants and soil, water, and air. The first three sections of the first chapter recapitulated Paracelsus's *tria prima*, as so many contemporary agricultural tracts did, and included discussions on "the universal spirit, or Mercury"—sometimes referred to as the "philosophical mercury" to distinguish it from the physical substance—the "universal Sulphur," and the "universal Salt," as well as

[116] Sharrock, *History of the Propagation and Improvement of Vegetables….,* 135.
[117] Ibid., 134.

disquisitions on how these substances "abound[ed]" in water, where "fatness" was to be found in the soil, and how to create an "equal commixture of these Principles" for the greatest productivity.[118] Worlidge described "The Globe of the Earth" and "all other *Creatures Sublunary*" as "impregnated with the Spirit most subtile and ethereal, as it were, *divinioris Aurea particula* (as the Learned *Willis* terms it) which the *Original Father* of *Nature* hath placed in this World, as the Instrument of Life and Motion of everything."[119] Conceptually, this was not unlike the astral emanations of Paracelsus, the *sperma* of Sendivogius, or the nitrous sprit of Glauber, Moriaen, and Worsley.

These short passages contained a number of alchemical references. Worlidge had equated the *spiritus vitalis* with divine, undivided gold, adhering to the tradition of identifying gold as the purest physical substance and thus the material equivalent of the non-material spirit. Embedded within the soil and the bodies of living creatures, this spirit—ultimately created by God—accounted for the origin of living beings, their development, and their locomotion. He continued:

> This Spirit is that which incessantly administers unto every Animal its Generation, Life, Growth, and Motion; to every Vegetable its Original and Vegetation: It is the Vehicle that carrieth with it the *Sulphureous* and *Saline* parts whereof the Matter, Substance, or Body of all Vegetables and Animals are formed or composed. It is the Operator or Workman, that transmutes by its active heat the *Sulphureous* and *Saline* parts of the Earth or Water into those varieties of Objects we daily behold or enjoy, according to the different Seed or Matrix wherein it operates: It continually perspires through the pores of the Earth, carrying with it the *Sulphureous* and *Saline* parts, the only treasure the Husband-man seeks for….[120]

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[118] Worlidge, *Systema Agriculturæ*, preface, unpaginated.
[119] Ibid., 2. Emphases in original. Here, Worlidge referred to Thomas Willis's notion of "animal heat" and the fermentations that produced everything from plant growth and animal digestion to alcohol and decomposition, in Thomas Willis, *Diatribae duae medico-philosophiae—quarum prior agit de fermentatione* (London, 1659), which was circulated earlier in the 1650s in an unpublished form usually referred to as "De fermentatione." See Frank, *Harvey and the Oxford Physiologists*, 165-69; and idem., "Thomas Willis and His Circle: Brain and Mind in Seventeenth-Century Medicine," in *The Languages of the Psyche: Mind and Body in Enlightenment Thought*, ed. G.S. Rousseau (Berkeley: University of California Press, 1990), 107-146.
[120] Ibid.

Much is at work in this passage. The vital spirit not only accounted for the life, growth, and motion of each individual plant or animal but also accounted for the very possibility of *all* life. Transmutation occurred due to an "operator" or "workman," which were typical English translations for Paracelsus's *archeus* or that from which all life sprang and which assured the continued sustenance of living matter. Similarly, in his "Hypothesis explaining the Properties of Light," Isaac Newton called nature a "perpetual worker," which is "generating solids out of fluids and fluids out of solids, fixed things out of volatile, and volatile out of fixed…"[121] There are echoes of the heterogeneity and chymical complexity of water and soil from Kircher, Evelyn, and Beale as well as the "subterraneal treasures" of Plattes.

Worlidge went on to describe an unnamed "ingenious Artist" who had "mechanically proved" through a distillation experiment in an alembic—in which a "Spiritual Liquor" containing saline, sulfurous, and mercurial spirits had been condensed—that the *prima materia*, or "original matter," of Aristotle could be chemically isolated. It carried with it all "Matter of Vegetables" and could be put to use "in advancing and maturating the Growth of the more excellent Flowers or Curiosities," if it could be obtained in great quantities, which Worlidge argued was easily possible.[122] The best method for doing so, he proposed, was to simply place "the more natural *Receptacles,* the Seeds and Plants in the Earth, which gives it [to] us transmuted into such Forms and Substances as are most desired and necessary."[123] That is, simply planting an abundance of seeds would naturally draw the spiritual liquor or

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[121] Newton, "Hypothesis explaining the Proprties of Light," in Birch, *History of the Royal Society*, Vol. 3, 251. See also, P.M. Heimann, "Nature Is a Perpetual Worker": Newton's Aether and Eighteenth-Century Natural Philosophy," *Ambix*, Vol. 20, No. 1 (1973): 1-25.
[122] Worlidge, *Systema Agricultræ*, 2.
[123] Ibid.

prima materia to the earth's surface, where it both nourished individual plants and could be harvested for use elsewhere. Well-planted plots of land acted as a matrix to attract the vital spirit, and by the second half of the seventeenth century, the use of plants to capture this spirit had become a common theme among agricultural writers.

This attractive virtue had roots in alchemical theory. In a glossary of "rustick terms" that he included at the end of *Systema Agriculturæ*, Worlidge defined "ferment" as the action that caused "Beer, Cider, or other drinks to work" but continued to describe that "working" as the cause of "dregs or impurities… mov[ing] upward or downward."[124] This movement applied to growth as well, and he employed the term to refer to the process of the vital spirit animating a seed, sap moving throughout a plant, and tendrils sprouting from the soil. In Chapter 4, Section 8, Worlidge explained the germination of a seed—which contained "the very *Quintessence* of the Plant that produced it, and is as it were the Life and Spirit of the Vegetable, coagulated into a small compass"—as a type of "fermentation."[125] After being planted in a suitable soil, with ample water and sunshine, and "cast in its proper *Matrix* or *Menstruum,*" a seed naturally attracted the alimentary virtues necessary to sustain it, after which it "transmuted [into] another thing, now into its own being, substance or nature, and thereby doth dispand its self, and encrease into the *form* and *matter* by *Nature* designed."[126] Both the terms "matrix" and "menstruum" possessed alchemical connotations—the former as a receptacle or natural vessel (sometimes described as a "womb" or "uterus") in which alchemical operations occurred and the latter

[124] Ibid., 313 and 316. Unfortunately, Worlidge did not provide definitions for any other terms typically associated with alchemical operations.
[125] Ibid., 53. Again, Worlidge cited Willis's "De fermentatione" on this point.
[126] Ibid.

usually meaning a liquid solvent. Beale had used both of these terms at one point to describe fertile soil and fructifying water respectively.

Among contemporary alchemists with whom seventeenth-century agriculturists were familiar, the term matrix also suggested a sort of magnetic quality that could draw a substance to it. Jean d'Espagnet and Nicolas le Fèvre, both Neoplatonic followers of Sendivogius, had written about the "Magnetick virtues" required to entice the "Universal Spirit" to the earth, which differentiated all matter into its multifarious forms. For instance, in his *Enchyridion Physicae Restitutae*, d'Espagnet wrote that when the vapors over the earth grow thin they "suck in that Spiritual *Nectar*" from the heavenly bodies "and attract it to them by a Magnetick virtue," which then eventually falls to earth in the form of rain, snow, frost, or dew.[127] Similarly, le Fèvre had written in his *Compleat Body of Chymistry* that "this [universal] sprit is specificated in such or such a Matrix…[and] that this Spirit is Imbodyed in such and such a Compound, according to the different Idea it hath received by means of a particular ferment," having been attracted by the matrix.[128] That is, a Platonic Idea determined the specific form that the universal spirit produced in the physical material and the matrix acted as a kind of magnet to draw them all together. While clearly interested in the ultimate explanation for these activities, Worlidge took Beale's advice and counseled the yeoman farmer to simply allow experience to be his guide. After passing

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[127] [Jean d'Espagnet], *Enchyridion Physicae Restitutae*, 99-100, quoted in Teeter-Dobbs, *Foundations of Newton's Alchemy,* 39.

[128] Nicolas le Fèvre, *A Compleat Body of Chymistry…* (London: O. Pulleyn Junior, 1670), 16, quoted in Teeter-Dobbs, *Foundations of Newton's Alchemy,* 38-9. Le Fèvre's book was actually published two years *after* Worlidge's, but Worlidge may have been familiar with his work more generally through Evelyn. Appointed to positions under both Louis XIV in France and Charles II in England, le Fèvre had been a demonstrator of chemical experiments at the *Jardin du Roi* in Paris in the 1640s and 1650s, and Evelyn witnessed some of them on 28 February 1647. On 20 September 1662, Evelyn presented a petition to Charles II "and afterward accompanied him to Monsieur Lefebure, his chemist," where he referred to him as "formerly…my master in Paris." See John Evelyn, *The Diary of John Evelyn*, E.S. De Beer, ed. (Oxford: Oxford University Press, 1959), 240 and 404.

responsibility for dissecting seeds to someone "more learned" than he, Worlidge contented himself with homegrown experiments in his "Rural Habitation" to discover the most potent menstruum or matrix for such improvement.[129]

Agricultural textbooks, husbandry manuals, discourses on the nature of soil, and histories of trades in the 1670s and 1680s were replete with these types of references. In John Evelyn's *Philosophical Discourse of Earth*, based on a presentation delivered at the Royal Society on 29 April, 1675, he referred to the "salts and ferments" involved in the vegetation of all plants and wrote sympathetically of Digby's notion that leaving fields fallow periodically was necessary so that the soil could naturally recharge its "Vital Spirits…from the Aire, which endowe[d] simple Earth the qualities promoting fermentation."[130] He described calcination experiments that bore a resemblance to those performed by Johann Glauber, Henry Jenney, and Kenelm Digby, though he used various soils rather than vegetable matter as his starting point. In one experiment, he claimed that calcining soil "dispose[d] it to produce great variety…and increase[d] the very weight of the Mould," either from a "certain magnetisme" or some other unknown chymical process.[131] According to Evelyn, calcination, due to its high temperature, artificially mimicked the natural heat of animal dungs spread across farmland as fertilizer.[132] Again, like Beale and Worlidge, Evelyn was adamant that these processes could be taught to "the industrious farmer without much inconvenience" and that arriving at an "indispensible…principle of Vegetation" depended solely on instructing farmers in the rudiments of "*Calcination,*

[129] Worlidge, *Systema Agricultræ*, 53.
[130] John Evelyn, *A Philosophical Discourse of Earth*, 9 and 67-68.
[131] Ibid., 78.
[132] Ibid., 89.

Resolution, Percolation, Evaporation, and *Separation*, put into honest *English,* and easily to be learn'd."[133]

John Houghton's *Collection of Letters for the Improvement of Husbandry and Trades* continued these explorations in both the 1681 and 1692 editions. Houghton printed lengthy weekly editorials along with letters from his regular correspondents, which included fellow agriculturists Beale, Worlidge and Evelyn, as well as Royal Society members with sundry interests such as Robert Plot, Edmond Halley, and John Flamsteed.[134] Other correspondents included yeoman farmers, agrarian merchants, and rural women who worked the land and shared their expertise.[135]

This diversity showcased the goal of the *Collection* as an inclusive journal for both the "Theoretical Gentleman" and the "Practical Rustic" alike, just as writers from Beale to Worlidge to Evelyn had advised. As such, it contained the results of agricultural experiments but also price lists of agricultural products and manufactured goods, the current whereabouts of various merchant vessels, and, beginning in the 1692 version, current stock prices of the East India, Africa, and Hudson Bay Companies.[136] Many letters from the *Collection* are liberally peppered with alchemical terminology applied to plant growth but more frequently to actual procedures a farmer might undertake in order to test various methods of improvement or hypotheses about the sources of fertility based on observation. Taken somewhat at random, one can find arguments for soil's lack of inherent nutrients and the liming processes farmers must undertake to enrich it; quasi-atomistic

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[133] Ibid., 110-111. Emphases in original.
[134] McConnell, "Houghton, John (1645-1705)," *ODNB.*
[135] Ibid.
[136] John Houghton, *A Collections of Letters for the Improvement of Husbandry and Trades* (London, 1681-83 and 1692-1703), Nos. 1 and 3-9, quoted in Stubbs, "John Beale, Part II," 353; Simon Schaffer, "The Earth's Fertility as a Social Fact in Early Modern Britain," 130; and McConnell, "Houghton, John (1645-1705)," *ODNB.* McConnell notes that this is likely the earliest periodically updated, English language stock ticker.

explanations for the "globular" composition of water; and a "spagyrical experiment" showing the chymical similarities between animal fat and human blood to explain nourishment.[137] One letter from 28 July 1693 gave recommendations on how to condense liquids and artificially ferment various types of plant matter so that the necessary nutrients "be thin enough that they can pass through the smallest pores of plants."[138] Almost all major agricultural and chymical writers from the preceding century make appearances in these letters.

Conclusions

It is difficult to record all instances of these types of references because the terminology, operational procedures, and experimental techniques derived from chymistry permeated both elite and more prosaic tracts on agricultural improvement so thoroughly that it is often more notable to find works in the second half of the seventeenth century that make *no* mentions of these topics.[139] Although the explicitly reformist character of these works began to dissipate during the Restoration, many members of the first generation of the Royal Society, and particularly those who had been involved with Hartlib during the Civil Wars and Interregnum, continued these efforts. Whereas reform had been far more broadly construed from at least the time of Francis Bacon through the 1650s, the later Stuart era narrowed this definition, at least within agriculture, to the realm of agronomics and economics.

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[137] John Houghton, *A Collection for the Improvement of Husbandry and Trade* (London, 1727-28), Vol. 1, 24, 28-31, and 357-9. These come from the four-volume re-edited abridgement of the otiginal periodical publication.
[138] Ibid., 143-5.
[139] Though it is a bit of an oversimplification, works that did not address these issues tended to be more traditional herbals and *herbaria*, taxonomic works, lists of collections of natural objects, and non-chymical medical texts, such as those that followed strict Galenic guidelines.

This interest in chemical philosophy was no less important outside the confines of these relatively elite circles and institutions. As large-scale projects like the draining of the fens, the reclamation of coastal farmland from the sea, and the movement toward widespread enclosure broadened the size and scope of English farming estates, the locations of these experimental efforts expanded. The ever-present scourge of famine always seemed to be lurking in the shadows, and there is some evidence indicating that the fear of future food deprivations led to a continued conservative and traditional approach to agriculture, at least among subsistence farmers with small landholdings. However, as earlier historians of agriculture such as Eric Kerridge and Joan Thirsk have demonstrated, the British, or "second," Agricultural Revolution began much earlier and in more diverse ways than historians arguing for its traditional starting point in the mid-eighteenth century have conceded.[140] According to more recent estimates measured in terms of the percentage of bushels per acre of major grain and legume crops, agricultural productivity increased by over fifty percent between 1650 and 1700 before doubling again in the eighteenth century.[141] Other estimates of land reclamation suggest between a ten and thirty percent jump in arable farmland in the British Isles over the course of the seventeenth century.[142] The number of significant, nation-wide food shortages also began to plummet throughout

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[140] On these, see especially, Eric Kerridge, "The Agricultural Revolution Reconsidered," *Agricultural History* Vol. 43, No. 4 (1969): 463-76; idem., *The Agricultural Revolution* (London: Allen and Unwin, 1967); and Joan Thirsk, *Alternative Agriculture: A History from the Black Death to the Present* (Oxford: Oxford University Press, 1997), esp. 23-146, although Thirsk mostly discusses crops that were alternative to those typically grown for subsistence. For more recent "counter-revisionism," see Mark Overton, *The Agricultural Revolution in England: The Transformation of the Agrarian Economy, 1500-1850* (Cambridge: Cambridge University Press, 1997), which argues for a later start to the agricultural revolution more in line with the origination of the concept in the 1880s, though even he argues that the later revolutionary nature of agricultural change came in the form of mechanization and changes to the social and institutional framework of farming rather than the earlier increases in agricultural productivity and output.

[141] Alexander Apostolides, Stephen Broadberry, Bruce Campbell, Mark Overton, and Bas van Leeuwen, "English Agricultural Output and Labor Productivity, 1250-1850: Some Preliminary Estimates," 26 November 2008, http://www.basvanleeuwen.net/bestanden/agriclongrun1250t o1850.pdf.

[142] Ibid.

the second half of the seventeenth century. Though much remains to be done explaining this phenomenon, recent work on the decline of famine in the British Isles points to a combination of these improvements to land management with the the rise in crop yields, fewer bad harvests, fewer poor growing seasons, better food distribution systems, and more stable grain prices.[143] These data all imply that food scarcity had been alleviated to the point that more experimental forms of agriculture could flourish, at least among those with the land, labor, and time to spare.

The expansive field of early modern chymistry, the experimental methods of alchemy, and the development of a vegetable philosophy all contributed to this particular version of alternative agriculture. Both Plattes and Beale, along with their intellectual successors like Sharrock and Worlidge, were important for popularizing and adding some empirical heft to the notion that alchemical modes of transmutation applied to vegetable matter, that the alchemical principle of multiplication had direct corollaries in the increase in crop yields, and that basic alchemical laboratory procedures like calcination, distillation, and fermentation were directly applicable in the field in ways that would increase practitioners' understanding of how to improve husbandry. For Beale, as his writings on agriculture from the late 1650s until his death demonstrate, the improvement of plants was practically synonymous with their "transmutation," in every sense of that word. This

[143] For the argument that food scarcity (as opposed to famine) was essentially a "man-made" phenomenon in England and France from the seventeenth century onward, see Amartya Sen, *Poverty and Famine: An Essay on Entitlement and Deprivation* (Oxford: Oxford University Press, 1981); and Robert William Fogel, *The Escape from Hunger and Premature Death, 1700-2100: Europe, America, and the Third World* (Cambridge: Cambridge University Press, 1992), 5-7 and 53-4. On a modification to this claim, which argues that market fluctuation and distribution was of secondary importance to harvest failures, see Karl Gunnar Persson, *Grain Markets in Europe, 1500-1900: Integration and Deregulation* (Cambridge: Cambridge University Press, 2000). On the decrease in back-to-back harvest failures and the stabilization of grain prices, particularly after about 1700, see Bruce Campbell and Cormac Ó Gráda, "Harvest Shortfalls, Grain Prices, and Famine in Pre-Industrial England," *Journal of Economic History*, Vol. 71, No. 4 (2011): 859-886.

vitalist chemical philosophy and the belief in the capacious transformative power of alchemical transmutation affected how early moderns viewed the physical, material world, including life, and it stimulated new interpretations of the potential cornucopian bounty of natural goods, the possibilities of agricultural improvement, and the very meanings of transmutation itself.

CONCLUSIONS

"Facilius est aurum construere quam destruere."

"It is easier to create gold than to destroy it."

--Unknown, attributed to Roger Bacon

What changed about the relationships between alchemy, agriculture, the "life sciences," improvement, and conucopianism around the turn of the eighteenth century? As Newman and Principe have demonstrated, the second or third decade of the eighteenth century was when something approaching modern "chemistry" distinguished itself from "alchemy" in a way that is recognizable today.[1] To differentiate between them before this time is, as they called it, an "etymological error" borne out of seventeenth-century textbooks and lexica that were received uncritically by nineteenth-century scholars.[2] Can the same be said of the agricultural reform that was so intertwined with alchemy in the Hartlib Circle for much of the mid seventeenth century? In many ways, the answer is yes—changes in practices, definitions, and social status fundamentally altered the reception of alchemy in agriculture and botany. I do not intend to conclude with an analysis of the "decline" of alchemy in the eighteenth century nor with a description of the ways that the farmers involved in the eighteenth-century "agricultural revolution" discarded the

[1] Newman and Principe, "Alchemy versus Chemistry: The Etymological Origins of a Historiographical Mistake," esp. 38-40. On their interchangeability, see for instance Michael Sendivogius's *Novum lumen chemicum* (Frankfurt and Prague, 1604), usually translated as *New Light of Alchemy*, but for which a more literal translation would be *New Light of Chemistry*; and Andreas Libavius's *Alchymia* (Frankfurt, 1597). The former is largely about transmutational alchemy, while the latter dispenses with gold-making altogether and is, in fact, sometimes regarded as the first "chemistry" textbook. See, Hannaway, *The Chemists and Word*, 75-91.

[2] Ibid., 42.

alchemical aspects of the previous century of agricultural reform. Explanations for the transformation of agriculture, the genealogy of modern chemistry, the development of life sciences deprived of vitalism, and the way these were all disentangled in the eighteenth century are far beyond the scope of this study. Yet, alchemical concepts did not simply vanish into the ether—to say nothing of the technical, laboratory methods that are still used in modern chemistry—and a brief analysis of their afterlives goes a long way toward elucidating the vestiges of these earlier juxtapositions.

Some earlier histories of "the occult," many of which were embedded within larger social scientific appraisals of past knowledge-making enterprises, have gone to great lengths to explain the "decline and fall" not only of alchemy but also of astrology, natural magic, Hermeticism, and witchcraft, all of which were presumed to have become defunct by the eighteenth century. Numerous scholars have demonstrated that although the dominant intellectual culture of the Enlightenment scorned these, all of them survived to some degree clandestinely or more safely corralled into harmless, popular culture.[3] It is simply that the increasingly professionalized, bureaucratized, and secularized sciences of the eighteenth and nineteenth centuries reclassified and redefined their mission in ways that excluded these prior ways of thinking about the cosmos, matter, and the interrelations between people and their environments. Borrowing from Friedrich Schiller, Max Weber called this the "disenchantment of the world" (*Entzauberung der Welt*), and although he was referring to the cultural trajectory away from spirituality and toward rationality, historians and sociologists of science from an earlier era adapted this thesis to explain the

[3] Leventhal, *In the Shadow of the Enlightenment*; Coudert, *Religion, Magic, and Science in Early Modern Europe and America*; Kléber Monod, *Solomon's Secret Arts*; and William E. Burns, *Science and Technology in Colonial America* (Westport, CT: Greenwood Press, 2005).

deterioration of the worldview that made alchemy possible.[4] For instance, Keith Thomas, in his magisterial *Religion and the Decline of Magic*, wrote that astrology discharged a bevy of useful functions in the early modern world that explained the vagaries of human behavior, assuaged fears of the unknown, and solved problems of uncertainty. It flourished thanks to the psychological need for risk management. Once social, financial, and technical instruments like actuarial tables, comprehensive insurance programs, and statistical analyses of seemingly random events mitigated the potentials for material damage (just as religion continued to play that role for individual souls), astrology had outlived its usefulness.[5] Some corollaries exist in the history of alchemy.

There is a limited functionalist argument to be made about the direction of saltpeter studies and the decline in interest among alchemists in England. As I noted in chapters one and two, after about 1660 England had secured more than enough saltpeter through the English East India Company that manufacturing it domestically ceased being a national priority. Contrast this with the French, who never secured supplies from any colonial locale and continued to seek ways of producing it artificially to supply their much larger military and agricultural industry. Many of the major advances in the chemistry of salts in the late seventeenth and early eighteenth centuries were made in France and much of this was done apart from any previous alchemical traditions. For example, French chemist Louis

[4] Max Weber, *From Max Weber: Essays in Sociology*, edited by H.H. Gerth and C. Wright Mills (London: Routledge, 1991), 155, quoted in Patrick Curry, *Ecological Ethics: An Introduction* (Cambridge, UK: Polity Press, 2011), 151. On the "disenchantment of the world" thesis, as applied to natural science, see, notably, Keith Thomas, *Religion and the Decline of Magic* (Oxford: Oxford University Press, 1971).

[5] On astrology's social and intellectual functions, see Thomas, *Religion and the Decline of Magic*, 323-49. On its decline, see ibid., 349-57 and 656-68. It should be noted that I am not attempting to make a strict functionalist argument for alchemy's "decline." Indeed, I do not even think "decline" is the appropriate term. Rather, I am suggesting that the parallel between the social transformation of astrology and alchemy between roughly 1680 and 1730, given their similar social and scientific postions, merits a comparison of their societal functions. It may be more appropriate to discuss political, social, and environmental causes for these changes to avoid a sort of historical reductionism here, but for the sake of space and the focus of this dissertation, I will have to leave this discussion for another time.

Lemery, son of the noted opponent of *chrysopoeian* alchemy Nicolas Lemery, denied all previous work done under the auspices of the *sal nitrum* school and repudiated the aerial niter theory of saltpeter formation. Nevertheless, he upheld the organic origin of saltpeter, described its gradual genesis in topsoil, and recognized the role that plants, animals, and soil played in its production in ways that were highly reminiscent of earlier alchemical contexts.[6] While functionalism can give us a partial explanation for the decline of various "occult" practices and for the continued modes of saltpeter study, it is much more difficult to make such a functionalist social argument for other aspects of alchemy at the opening of the eighteenth century. Rather, the social, geopolitical, and environmental realities that faced the French (and others) during the early eighteenth century caused their approach to the chemistry of saltpeter to veer off in a wildly different direction from the English.

How should we characterize the extrication of alchemy from agriculture and botany during this time? It is perhaps instructive to inventory the number of alchemical books published in England. Much of my study has examined the non-laboratory and non-textual side of alchemical practice, yet many of Hartlib's correspondents and their latter-day allies during the first few decades of the Restoration nevertheless were reading and oftentimes writing these books. Though many of the sources of seventeenth-century alchemy were rooted in language coded in cypher, books of secrets, and the esoteric traditions of the later Middle Ages and sixteenth century, English alchemists wanted to announce their findings for the same reasons Bacon had argued that knowledge should be directed toward

[6] On these details, see R.P. Aulie, "Boussingault and the Nitrogen Cycle," *Proceedings of the American Philosophical Society*, Vol. 114, No. 6 (1970): 435-479; and Mi Gyung Kim, *Affinity, that Elusive Dream: A Genealogy of the Chemical Revolution* (Boston: MIT Press, 2008), 151-8. For Lemery's findings, see Louis Lemery, "Sur l'origine du nitre," *Histoire* (1717): 29-34.

utilitarian application and the public good.[7] Of course, this was not the case with *all* alchemists. Samuel Hartlib, Robert Child, and Frederick Clodius all recorded growing weary of the secrecy of Starkey and tiring of the opaque language of Glauber.[8] Conversely, Isaac Newton infamously scolded Robert Boyle for too freely exposing alchemy's secrets to non-adepts.[9] However, the fact that the number of books written in English about alchemy rose sharply around 1650 and remained high though the 1670s before declining again after about 1680 suggests that the socio-political, economic, and agricultural reform movements instigated by the circle around Hartlib during the Civil Wars and Interregnum very much brought certain types of alchemy into the light.

Historian Lauren Kassell has raised this point in her study of London stationer, bookseller, and compulsive list-maker William Cooper.[10] Cooper created a catalogue of "chymical books" published in English between 1527—the date of the first book mentioned, Hieronumous von Braunschweig's *Vertuose Boke of distyllacyon of the waters of all maner of herbes...*—and 1688, the year of the catalogue's final edition. He counted 422 original, English-language works on alchemy during a nearly two-century span, and fully 278 of them, or roughly two-thirds, were published between 1650 and 1679. This marked a ten-fold increase over the years from 1527 to 1649. While the list is of interest simply for the lengthy register of titles, much more important is the way that Cooper defined alchemy. Cooper listed these books neither alphabetically nor chronologically but by subject. On the

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[7] Eamon, *Science and the Secrets of Nature*, 319-350; Long, *Openness, Secrecy, Authorship*, 143-174 and 244-5; Steven Shapin, *A Social History of Truth: Civility and Science in Seventeenth-Century England* (Chicago: University of Chicago Press, 1994), 104-107.
[8] See Samuel Hartlib, *2 Extracts & Notes on Glauber's Alkahest*, 30 December 1650, HP 31/8/6B; Robert Child to Samuel Hartlib, 2 February 1652, HP 15/1/18A; and Samuel Hartlib to John Winthrop the Younger, 16 March 1660, HP 7/7/3B.
[9] Newton to Oldenburg, 26 April 1676, Cambridge University Library, MS Add. 9597/2/18, f. 53*r*. See also, Kassell, "Secrets Revealed," 62.
[10] Kassell, "Secrets Revealed," 61-78.

one hand, the subject headings contained books covering typical alchemical territory, such as "Chymistry," "Mercury," "Salt," "Salt niter," "Earths and mines," and so on. On the other hand, it also contained subjects typically outside the purview of modern historians of alchemy, including "Of Cold, Ice, and Snow," "Of Natural Products and Curiosities of Country," "Of the flux and reflux of the sea," and "Of Husbandry."[11]

Several books not usually associated with alchemy, especially from the 1660s and 1670s, populate this list. It includes, among other works, Robert Hooke's *Micrographia*, Nehemiah Grew's *Anatomy of Plants*, Robert Plot's *Natural History of Oxfordshire*, John Evelyn's *Philosophical Discourse of Earth*, Thomas Sprat's *History of the Royal Society*, and Gabriel Plattes's *Subterraneall Treasure* and *Infinite Treasure.* It also includes works by John Ray on plant and animal nomenclature, William Simpson's work on hydrology and mineral spas, Johann Schroeder's zoological treatises on the uses of animal products in human surgery, the entirety of the *Philosophical Transactions*, and an anonymous description of the Spanish-controlled West Indies.[12] Kassell has argued that the spike in the production of books of alchemy between 1650 and 1680 is a result of the controversies over what constituted alchemical studies in the first place—everyone wanted to weigh in. This thirty-year span witnessed an upturn in medical topics and natural histories, and by the 1660s, a decline in "mystical" works. Kassell concludes that English authors, booksellers, and

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[11] On these, see Kassell's appendix, which contains a list of all books recorded by William Cooper. Kassell, "Secrets Revealed," 73 and A1-A38.

[12] See, John Ray, *A Collection of English Words not generally used, with their significations and original…With Catalogues of English Birds and Fishes, and an account of the preparing and refining of such metals and minerals as are gotten in England* (London, 1674); William Simpson, *Hydrologica chymica: or The Chymical Anatomy of Scarborough, and other spaws in York-Shire…* (London, 1669); idem., *Hydrological essayes: or, A vindication of Hydrologica chymica, being a further discovery of the Scarborough spaw…* (London, 1670); Johann Schroeder, *Zoologia, or The history of animals as they are useful in physic and chirurgery* (London, 1669); Anonymous, *America: or, An exact description of the West-Indies: more especially of those provinces which are under the dominion of the King of Spain* (London, 1655).

readers began to define alchemy as a part of natural philosophy, natural history, and medicine.[13] However, this would be a short-lived phenomenon. Less than a generation after "alchemy" expanded to include non-traditional alchemical topics represented in Cooper's survey of English books, the number of new works on alchemy in English plummeted.

The topics addressed in the *Philosophical Transactions* from the 1680s onward and early husbandry periodicals like Houghton's *Collection of Letters for the Improvement of Husbandry and Trade* certainly add some heft to this interpretation. In the former, husbandry, and especially its economic dimensions, occupied fewer and fewer pages of the journal under the editorship of Robert Hooke as it gravitated more toward comparative plant anatomy and entries on topics like sap movement, respiration, and morphology. The latter continued to provide a welcome location for the discussion of husbandry as a trade, and there are plentiful examples of the practical chymistry of agricultural improvement within it until its cessation in 1703, two years before Houghton's death. Evidence of explicitly alchemical interpretations of botanical change and agricultural improvement became scarcer and scarcer after this time, however, at least in print. The same was true for alchemy *in toto*.[14] Had Cooper been able to continue his *Catalogue* past the 1680s (he died in 1689), it would never have recorded another peak as it had during his lifetime. Alchemical interpretations of botanical growth remained, to some degree, in the various recipes for seed steeps and fructifying waters throughout the eighteenth century, but even

[13] Kassell, "Secrets Revealed," 63-4 and 77-8.

[14] Kléber Monod, *Solomon's Secret Arts*, 50-52 and 120-34. Interestingly, Latin works, published both in England and elsewhere, remained relatively high until around 1700, after which they too declined precipitously. See the list of alchemical works by Adam MacLean at http://www.alchemywebsite.com/statists.html. This might put a dent in the argument that alchemy, like astrology, simply relocated to more receptive popular audiences, if the readership of alchemical texts were predominantly literate in Latin. However, if could also simply be that the elites still practicing or studying alchemy maintained its traditional secrecy, in this case from those non-elites unlettered in Latin.

here, there was a movement toward explanations of chemical change in terms of the compounding and separating of discrete chemical substances rather than previously familiar topics like germination through fermentation and transmutation.

There are some exceptions worth noting. The aerial-niter theory of fertility endured for much longer than the *sal nitrum* alchemical school that provided its theoretical scaffolding in the sixteenth and seventeenth centuries. Richard Bradley, who served as the first botany professor at the University of Cambridge from 1724 until his death in 1732, vehemently defended the aerial-niter theory of fertility against its detractor Jethro Tull, who attacked almost all earlier writers on husbandry as a matter of course. Tull had argued that soil provided nutrients for plants, and while he conceded that air, water, and niter helped to "break up" the soil into digestible particulates, he argued that the plowman could accomplish the same by working the land in the proper way.[15] In this, Tull hoped to crush the "superstitions" of everyday farmers, the alleged "idiocies of plebeian belief," and the duplicity of alchemists.[16] Much like Louis Lemery—but for very different reasons—Tull had hoped to discredit aerial niter, if not in chemistry, then at least in husbandry. In his defense of aerial niter fertility, Bradley had run trials reminiscent of Van Helmont's willow tree experiment to precisely quantify what weight in niter led to what percentage of growth in vegetable mass in order to determine, more importantly, the economic gain one could

[15] On Tull's theories of soil fertility, see Schaffer, "The Earth's Fertility as a Social Fact in Early Modern Britain," 133-9; Fussell, *Crop Nutrition*, 97-99, 100, 102-3, 115, 131, and 135-6; and idem., *Jethro Tull: His Influence on Mechanized Agriculture* (Reading, UK: Osprey Publishing, 1973), 23-5, 29, and 60-1. For a less charitable interpretation of Tull's husbandry, see Peter Mathias, "Who Unbound Prometheus? Science and Technical Change, 1600-1800," in *The Transformation of England: Essays in the Economic and Social History of England in the Eighteenth Century*, edited by Peter Mathias (London: Routledge, 1979), 48.
[16] Jethro Tull, *The New Horse Hoeing Husbandry* (London, 1731), 115 and 124. On this specific language, see Schaffer, "The Earth's Fertility as a Social Fact in Early Modern Britain," 136.

expect from this particular way of fertilizing.[17] This points us to one of the most important shifts in alchemy's relationship with other related fields of study and practice. As those engaged in natural philosophy, natural history, and the chemical sciences jettisoned many of the grandiose, traditional claims of *chrysopoeian* alchemy beginning in the early eighteenth century, and the modern distinction between "alchemy" and "chemistry" began to take shape, the symbolism, language, and concepts of alchemy found homes in other domains, particularly in political economy.

Alchemy continued to be an important part of conceptualizing change and growth in nature. As we have seen, several words and phrases had similar or identical meanings in the contexts of both alchemy and agriculture. Fermentation, putrefaction, and transmutation all held comparable, non-metaphorical meanings when discussing metals in the laboratory or seeds in the soil. Within the context of vegetable philosophy, growth in metals and minerals literally equated to growth in plants and animals. This too changed sometime after the turn of the eighteenth century. For example, as the research of Ted McCormick and Carl Wennerlind has shown, political economists in the late seventeenth and early eighteenth centuries appropriated a great deal of alchemical terminology to explain various financial instruments and monetary concepts in the increasingly complicated imperial, global marketplace, like debt and credit, economic growth, interest on investments, and the circulation of goods and money.[18] The difference is that whereas

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[17] Fussell, *Crop Nutrition*, 98.

[18] See Wennerlind, *Casualties of Credit: The English Financial Revolution, 1620-1720*; idem., "The Alchemical Roots of the Financial Revolution;" idem., "Credit-Money as the Philosophers Stone: Alchemy and the Coinage Problem in Seventeenth-Century England;" McCormick, "Alchemy into Economy: Material Transmutation and the Conceptualisation of Utility in Gabriel Plattes (*c*. 1600–1644) and William Petty (1623–1687);" idem., "Alchemy in the Political Arithmetic of William Petty (1623-1687)," *Studies in the History and Philosophy of Science*, Vol. 37, No. 2 (2006): 290-307; idem., "'A Proportionable Mixture': Sir William Petty, Political Arithmetic, and the Transmutation of the Irish," in *Restoration Ireland: Always Settling, Never Settled*, ed.

the meanings of these terms were often nearly indistinguishable as one moved from laboratory alchemy to agricultural reform to botany, they began to shed their explicitly alchemical meanings beginning in the late seventeenth century and came to be seen as only metaphors, symbols, and representations to describe facets of the expanding capitalist economy.

Why did these changes take place? One answer lies in the substantial modifications to the English economic system following the Glorious Revolution of 1688 and the series of financial crises that shook the English economy in the 1690s. The twelve years between the Glorious Revolution and the turn of the eighteenth century witnessed a veritable upending of the financial order in England. The new king, William III, brought Dutch economic and financial innovations to England, including the establishment of a national debt (1693), the centralized, Bank of England to assume such debt (1694), and publicly traded, joint-stock companies. England entered the continent-spanning Nine Year's War (1688-1697) against France, funded by a combination of heavy taxation and national debt. A near collapse of the monetary system due, in part, to a chronic shortage of gold and silver bullion and a debasement of existing coins led to a reminting of the entire currency (the "Great Recoinage" of 1696-99). And the London Mint, with Isaac Newton at its helm starting in 1699, assured that the courts prosecuted counterfeiters more harshly than ever before.[19] In

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Coleman Dennehy (Aldershot: Ashgate Press, 2008), 123-39; and Vera Keller and Ted McCormick, "Towards a History of Projects," *Early Science and Medicine*, Vol. 21, No. 5 (2016): 423-444.

[19] On these innovations in general, and particularly the role of credit in their development, see R.G.M. Dickson, *The Financial Revolution in England: A Study in the Development of Public Credit, 1688-1756* (London, 1967); Natasha Glaisyer, "'A Due Circulation in the Veins of the Public': Imagining Credit in Late Seventeenth- and Early Eighteenth-Century England," *The Eighteenth Century*, Vol. 46, No. 3 (2005): 277-97; Wennerlind, *Casualties of Credit*, esp. 1-82; and John Levin, "The Meanings of Gold: Alchemy and Economy in Seventeenth-Century England," (Unpublished Paper, University of North London, 2010), 7, last 15 June 2013, http://anterotesis.com/wordpress/wp-content/uploads/2010/03/Levin_Alchemy_and_Economy.pdf. On Newton's career at the Mint and his harsh stance on counterfeiting, see Thomas Levenson, *Newton and the*

this new financial order, the Bank of England would assume all national debts and issue government bonds with promised interest payments from the state. This new credit-money was securely backed by an asset—in the case of private individuals, usually land or other valuable property, and in the case of the state, future tax revenues or returns on state investments.[20] While the plan was limited in its scope, it worked well enough to keep the economy afloat and fund the war against France. According to Wennerlind, it may also have accounted for the rapid decline in patronage, projects, and other funding of alchemical pursuits in Europe from about 1690 onward.[21]

Conceptually, alchemy provided many fruitful metaphors to describe the function of a circulating, credit-based money and wealth as something that could be created and grow. The Hartlib Circle and later Restoration alchemists and political economists had each understood transmutational alchemy and the interest eventually returned from borrowing on credit as equivalent solutions to the scarcity of money, and thus, they used similar language to describe these solutions. One such metaphor was that of the "spirit" of the economy, which echoed earlier alchemical notions of a "universal spirit" enlivening inert matter and uniting it with the rest of the cosmos, or the "Spirit of Nature," which had the power to affect matter from a distance without physical contact.[22] Henry More, Isaac Newton's mentor during his early years at Cambridge, wrote of the "Spirit of Nature" as an active force that explained this type of action at a distance, describing it as a "great

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Counterfeiter: The Unknown Detective Career of the World's Greatest Scientist (Boston: Houghton Mifflin Harcourt, 2009).

[20] Wennerlind, "Credit Money as the Philosopher's Stone," 236-7. Wennerlind mentions that these were different from an early financial instrument known as "bills of exchange," which served only as a means of exchange, whereby debts and credits could be passed from one person to the next. Credit-money was a means of payment and could circulate much more widely.

[21] Ibid., 237-8.

[22] Michael White, *Isaac Newton: The Last Sorcerer* (New York: Basic Books, 1999), 206.

influence and activity in the *nascency* as I may so call it, & *coalescency* of things."[23] Newton scholar Richard S. Westfall has argued that these metaphors gave Newton the conceptual tools necessary to visualize gravity, writing that his lifetime of involvement with alchemy was a "stimulus" to thinking "beyond the bare ontology of mechanical philosophy."[24] Nature provided abundant examples of birth and growth without direct physical intervention, so why should the political economy, it was argued, be any different? Monetary circulation, interest, and credit, like gravity or the *spiritus vitalis*, required "action at a distance."

Spirit remained a potent metaphor. In 1696, the first year of the Great Recoinage, the merchant John Cary wrote a treatise on the benefits of credit where he imagined it as a "spirit" of the economy. He wrote that "the Wealth and Greatness of the Kingdom of England" existed in its surfeit of trade, the foundation of which was "carry'd on by its Credit." To Cary, credit became the lifeblood of the economy, circulating just as blood did in the human body; and the spirit illuminated the life of the nation. If credit failed, so too would the economy, since credit was as "necessary to a Trading Nation, as Spirits are to the Circulation of the Blood in the Body natural; when those Springs…Decay, and grow Weak, the Body languishes, the Blood Stagnates, and Symptoms of Death soon appear."[25] Similarly, overreliance on one source for this line of credit was viewed as dangerous, and the Bank of England was often anonymously attacked because its monopoly constrained the circulation of credit and hampered private financiers from making money and

[23] Henry More, *The Immortality of the Soul, So farre forth as is demonstrabl for the Knowledge of Nature and the Light of Reason* (London, 1659), 467-8, quoted in Michael White, *Isaac Newton*, 206. Emphasis in original.
[24] Richard S. Westfall, "Newton and Alchemy," in *Occult and Scientific Mentalities in the Renaissance*, ed. Brian Vickers (Cambridge: Cambridge University Press, 1984), 330.
[25] John Cary, *An Essay towards the Setlement of a National Credit, in the Kingdom of England, Humbly Presented to the Two Honourable Houses of Parliament* (London, 1696), 1.

promoting economic growth. One anonymous writer extended the spirit and blood metaphor, writing that "of all Monopolies, a wise State should constantly discourage a Monopoly of Cash and Credit, they being to Trade what Blood and Spirit are to the Body."[26] While a credit-based currency had numerous advantages, many also recognized its dangers. In any case, terminology like growth, spirit, circulation, and transmutation, though drawn directly from alchemy (and in some cases, described by practicing alchemists) took on distinct new meanings in this incipient financial regime.

Gold also became differently understood outside of its alchemical contexts. Where once it was seen as the pinnacle of physical matter and the completion of the gradual, unfolding natural transmutation of God's creation perfected on earth, it became an economic object denuded of its metaphysical significance. Economic historian John Levin has shown that the substance of gold was treated differently in alchemical and economic contexts during the later seventeenth century, at which point the direct monetization of precious metals into a standard, circulating currency "brought [gold] down from the heavens to earth, made [it] commonplace and tarnished," and suggested its behavior within the English economy was subject to definable, natural laws that looked very different from those described by alchemy.[27]

Subsequently, the meanings of transmutation shifted as well. As more and more natural philosophers and political economists renounced alchemy and it came to be regarded as, at best, a form of counterfeiting, the language of transmutation came to

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[26] Anonymous, *A Short View of the Apparent Dangers and Mischiefs from the Bank of England* (London, 1707), 10, quoted in Glaisyer, "'A Due Circulation in the Veins of the Publick': Imagining Credit in Late Seventeenth- and Early Eighteenth-Century England," 291.

[27] Levin, "The Meanings of Gold," 10. Levin seems to be indebted to William Letwin for these connections. See William Letwin, *The Origins of Scientific Economics: English Economic Thought, 1660-1776* (London: Methuen, 1963).

describe, for example, the process by which land could be converted into money through establishing national banks that would issue credit-money backed by real estate as a security.[28] William Potter described this process as a type of transmutation of land into money and argued that because a credit-based currency could conceivably create wealth indefinitely provided that the collateral land continued to be productive, "its capacity of inriching the Nation is in a sort infinite."[29] Just as alchemy promised multiplication, this "bank of lands," as Potter called it, was itself a form of "improvement." The circulation of goods and money accounted for transmutation as well. As the German alchemist and economic theorist Johann Joachim Becher noted, "credit, banknotes, and hard cash [gold] are transmuted into each other every hour."[30] Similarly, it was the capacity for automatic, independent growth that led economic theorists like former Hartlib Circle member Henry Robinson to directly compare alchemy and credit money as "capable of multiplying the stock of the nation, for as much concerns trading…[ad] infinitum" and to declare triumphantly that a credit-based currency was the equivalent of "the Elixir or the Philosopher's Stone."[31]

These notions also applied to the social sphere. In one particularly odious example, William Petty, who hovered on the outskirts of the Hartlib Circle as a young man, described

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[28] Ibid.

[29] For examples of this in seventeenth-century texts, see William Potter, *A Bank of Lands; or, an Improvement of Lands, never thought of in former Ages: Begun to be presented upon most rationable and demonstrable grounds* (London, ?1653), 290; idem., *The Key to Wealth: Or, a New Way for Improving Trade* (London, 1650); and Hartlib, *His Legacy of Husbandry*, 194.

[30] "Dr Becher's *Special-Relationen*, wegen *Anticipation*, einer Million Reichsthaler vor Ihro Käyserl. Majest.." *Politischer Discurs* (1671): 703, quoted in Smith, *The Business of Alchemy,* 133. ["*Credit, Banck/ und baar Geld lassen sich in Holland alle Stund ineinander verwandlen*."] The translation is Smith's.

[31] Henry Robinson, *Certain Proposals in Order to the People's Freedom and Accomodation in some Particulars with the Advancement of Trade and Navigation of this Commonwealth in General* (London: M. Simmons, 1652), 19.

his proto-eugenic scheme to pacify the Irish as a form of "transmutation."[32] In his attempt to socially engineer the Irish population, he suggested the forcible removal of Irish women from Ireland—they were to be placed in service roles or married off to poor English bachelors—followed by the migration of English women to Ireland, where they would marry and raise children who were English in language, culture, and blood. He described these activities as a form of "improvement" and the generational transformation of the populace as "transmutation," and though this project thankfully never became a reality, it ultimately formed the basis of the "political arithmetic" that defined his later career.[33]

Unlike alchemy, of course, vitalism remained a powerful force in the sciences, waxing and waning in popularity throughout the eighteenth, nineteenth, and early twentieth centuries, and purporting to explain why living beings were fundamentally different from non-living beings or possessed some non-physical or non-chemical essence that animated life. This more recent vitalism—from Franz Mesmer's *magnétisme animal* to Henri Bergson's *élan vital*—was, in effect, the reverse of the seventeenth-century alchemical variety, which had attempted to find a vital spirit in inanimate matter via chymical methods. This shift occurred just as agricultural reformers were ending their relationship with alchemy.

It is perhaps fitting that Georg Ernst Stahl, the same chemical theorist who first described the historical "three famous schools of alchemy"—the mercury school, the vitriol school, and the *sal nitrum* school—also marks a transition point for vitalist alchemy. Stahl had originally considered himself a vitalist after studying the works of Johan Joachim

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[32] McCormick, "Alchemy into Economy," 349-51. On Petty's interest in alchemy, see William Petty, "History of Dy[e]ing," in Thomas Sprat, *History of the Royal Society,* 284-306; BL, MS Add. 72897, f. 1-37; Petty to Hartlib, c. early 1649, HP 7/123/1B-2A; and Hartlib, *Ephemeris*, Part 2, April – August 1649, HP 28/1/14B.
[33] McCormick, "Alchemy into Economy," 350-1.

Becher while a medical student at the University of Jena in the early 1680s. However, beginning in the late 1710s, Stahl became critical of *chrysopoeia* and redefined chemistry and alchemy as separate domains, the former a rational science of material change, the latter mere chicanery.[34] He denied celestial influences on terrestrial matter; disputed the growth of minerals and metals as analogous to biological growth; rejected seeds, *semina*, and *sperma* as the origins of minerals; and argued against the possibility of transmuting base metals into gold.[35] The crux of the cosmology that made vitalist alchemy possible was a union of celestial and terrestrial worlds and of animate and inanimate matter, bound together in a living cosmos. Stahl drew distinct boundaries between the material and spiritual, the ethereal and the terrestrial, life and non-living matter.

After Stahl, Enlightenment philosophers of biology still often discussed the innate forces that produced vital action and transformed inert raw materials into living creatures, but they did so using very different terminology divorced from chemistry and alchemy. The French materialist philosopher Julien Offray de la Mettrie called it "irritability" (*irritabilité*); *encyclopédiste* Denis Diderot called it "sensibility" (*sensibilité*).[36] This smuggling of vitalistic ideas back into mechanistic and materialistic interpretations of life and matter was

[34] Chang, "Alchemy as a Study of Life and Matter," 327; and Newman and Principe, "Alchemy versus Chemistry: The Etymological Origins of a Historiographical Mistake," 39.

[35] Ibid. Chang has done a great deal of work on Stahl, the turn away from a vitalistic cosmos, and the shift from the (al)chemical philosophy of the seventeenth century and the phlogiston theory of the eighteenth. See also, Chang, "From Vitalistic Cosmos to Materialistic World: The Lineage of Johann Joachim Becher and Georg Ernst Stahl and the Shift of Early Modern Cosmology," in *Chymists and Chymistry: Studies in the History of Alchemy and Early Modern Chemistry,* ed. Lawrence Principe (Sagamore Beach, MA: Science History Publications, 2007), 220-21; idem., "Georg Ernst Stahl's Alchemical Publications: Anachronism, Reading Market, and a Scientific Lineage Redefined," in *New Narratives in Eighteenth Century Chemistry*, ed. Lawrence Principe, (Dordrecht: Springer, 2007), 23-43; and idem., "Fermentation, Phlogiston, and Matter Theory: Chemistry and Natural Philosophy in Georg Ernst Stahl's *Zymotechnia Fundamentalis*," *Early Science and Medicine* 7 (2002): 31-64.

[36] See Kathleen Wellman, *La Mettrie: Medicine, Philosophy, and Enlightenment* (Durham, NC: Duke University Press, 1992), 160; Elizabeth L. Haigh, "The Vital Principle of Paul Joseph Barthez: The Clash between Monism and Dualism," *Medical History* 21 (1977): 1–14, esp. 7–8; and Chang, "Alchemy as a Study of Life and Matter," 328.

common throughout the eighteenth century. Though it is possible that everyday, anonymous farmers maintained such an animistic, vitalist interpretation of the cosmos and the earth into the eighteenth century, it did not lead to the kind of agricultural reform seen during the seventeenth century.[37] From the early eighteenth century to the early twentieth century, vitalism was more concerned with understanding what makes living things tick than with the potential of animating the non-living.[38]

What of the future of "chymistry" in agriculture and botany? Again, as we saw in chapter three, seed steeps and fructifying waters became more chemically complex during the eighteenth century but further research into fungal maladies and smut diseases eventually eliminated many ingredients which proved to be superfluous. Steeping seeds in these chemical concoctions seems to have died out around the middle of the nineteenth century.[39] Historians of agriculture often begin studies of modern chemical agriculture, the science of plant nutrition, and the development of the artificial fertilizer industry in the 1830s and 1840s with the German chemists Justus von Liebig and Friedrich Wöhler, who

[37] For astrology, at least, there is some evidence that in English North America, common farmers craved what was familiar, and thus almanacs included various aspects of the occult such as astrometeorological weather predictions and astrological medicine. For this so-called "folklorization thesis," see Jon Butler, "Magic, Astrology, and the Early American Religious Heritage, 1600-1760," *American Historical Review*, Vol. 84, No. 2 (1979): 317-46.

[38] Ibid., 328. On post-Stahlian vitalism, see Peter Hans Reill, *Vitalizing Nature in the Enlightenment* (Berkeley: University of California Press, 2005), 75-83 and 125-39. For a more recent investigation of the former preoccupation of latter-day vitalists, see Jessica Riskin, *The Restless Clock: A History of the Centuries-Long Argument over What Makes Living Things Tick* (Chicago: University of Chicago Press, 2016). Though not strictly vitalistic, many twentieth- and twenty-first-century attempts to define the boundaries between life and non-life or replicate life artificially have bucked this trend. See, for instance, Natalie Wolchover, "A New Physics Theory of Life," *Quanta Magazine*, 22 January 2014, https://www.quantamagazine.org/ 20140122-a-new-physics-theory-of-life/; Stanley L. Miller, "The Production of Amino Acids under Possible Primitive Earth Conditions," *Science* 117 (1953): 528-9; A. Lazcano and J.L. Bada, "The 1953 Stanley L. Miller Experiment: Fifty Years of Prebiotic Organic Chemistry," *Origins of Life and Evolution of Biospheres*, Vol. 33, No. 3 (2004): 235-242.; E.P. Rybicki, "The Classification of Organisms at the Edge of Life, or Problems with Virus Systematics," *South African Journal of Science* 86 (1990): 182-186. On recent attempts to create a synthetic cell with viable DNA, see Robert Lee Holtz, "Scientists Create First Synthetic Cell," *Wall Street Journal*, 21 May 2010, http://www.wsj.com/articles/ SB10001424 052748703559004575256470152341984.

[39] Smith and Secoy, "A Compendium of Inorganic Substances Used in European Pest Control before 1850," 1180-1191.

together discovered isomers and radical compounds, and managed to artificially produce organic materials, including urea, in the laboratory, which in the post-alchemical era was thought to be impossible.[40] Yet, as we have seen, farmers had been incorporating chemical substances into fertilizers for centuries. Ironically, Liebig's work on plant nutrition demonstrated that the nourishing material of plants was inorganic, and he described this discovery in a way that, but for its modern chemical terminology, could have been written by a seventeenth-century agricultural reformer:

> Plants live upon carbonic acid, sulphuric acid, and silicic acid, lime, potash, and iron; many of them also require common salt…Dung, etc., did not act through direct assimilation of its organic elements, but through products of decomposition and putrefactive processes, i.e., by transference of carbon into carbonic acid and its nitrogen into ammonia or nitric acid. Organic manure, which consists of portions of debris of plants and animals may be replaced by the inorganic compounds into which it breaks up in the ground.[41]

Though he denied any vitalistic force concealed in fertilizers and discovered the purely physical, chemical processes involved in crop nutrition, Liebig, nevertheless, had arguably isolated the chemical substances that a throng of vitalist alchemists, agricultural reformers, and common farmers had sought for centuries. A more complete history of agricultural chemistry must take these earlier lineages into account.

Similarly, botany shed many of the concepts that had united it with mineralogy and metallurgy under a cohesive vegetable philosophy. Nehemiah Grew made an early attempt at disuniting plant growth from a broader, cosmic vital context in his *Anatomy of Plants* (1682). Drawing from the ancient atomistic notions of Lucretius and Epicurus and their contemporary boosters Descartes and Gassendi, Grew hoped that by conducting a

[40] See for instance, William H. Brock, *Justus von Liebig: The Chemical Gatekeeper* (Cambridge: Cambridge University Press, 1997).
[41] Liebig, quoted in Fussell, *Crop Nutrition*, 191-2. Carbonic acid refers to carbon dioxide dissolved in water (H_2CO_3).

thorough, rational investigation of the parts of plants under a microscope, he could unravel the mystery of botanical growth. Grew eventually described growth in semi-atomistic terms that combined a mechanical understanding of germination, phototropism, and the movement of sugars and liquids through the vascular tissues of plants with an alchemical interpretation of the "fermentation" of seeds. While he maintained "there is a Vital World which God hath made" and a "vital substance in nature," his vitalism was almost entirely spiritual, and he formed a dual interpretation, not unlike Cartesian dualism, but applied to living bodies and all other matter.[42] Likewise, in his landmark work *Vegetable Staticks* (1727)—which contributed to the field of pneumatic chemistry and attempted to explain plant transpiration, respiration, and vascular motion—Stephen Hales described the reversible processes by which plants released "aerial fluids" and "fixed" air within the solid or liquid parts of their bodies. He called this "fermentation," which by the 1720s referred to any process that released gases from solids or liquids, and claimed that this demonstrated the repulsive forces between air particles. Plants used this to draw in nutrients from air, soil, and water, and to expel wastes.[43] What all of these examples—from the financial revolution and "political arithmetic" to botany and chemical agriculture—have in common is an inheritance of alchemical influence even if the theory and practice of alchemy no longer endured.

I began this work by asking whether or not alchemy could be considered a life science in the seventeenth century. As we have seen, alchemy was many things to many

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[42] Nehemiah Grew, *Cosmologia Sacra: Or, a Discourse of the Universe as it is the Creature and Kingdom of God* (London, 1701), 18 and 31. See also, Brian Garrett, "Vitalism and Teleology in the Natural Philosophy of Nehemiah Grew (1641-1712)," *British Journal for the History of Science* Vol. 36, No. 1 (2003): 63-81; and Scott, *Secret Nature of Seeds,* 146-57, esp. 154.

[43] Jan Golinski, "Chemistry," *The Cambridge History of Science*, Vol. 4, *Eighteenth-Century Science*, ed. by Roy Porter (Cambridge: Cambridge University Press, 2003), 383.

people during this time, and a study of how matter comes alive was among the most common, important, and disputed. Embedded within the worldview that made such an interpretation of nature possible was the idea of the inherent elasticity and changeability of physical materials. As early moderns wrestled with the implications of their newfound knowledge of power over the natural world—following the lead of experimenters like Palissy, Plat, and most of all Bacon—the question became how to put this knowledge to use. For members of the Hartlib Circle interested in agricultural reform, its utility lay in public welfare, food security, national defense, financial profit, spiritual fulfillment, a systematic understanding of biological growth, and the recreation of Eden on earth. These were all truly vital matters.

In its religious context, unresolved tensions remained over whether to envision nature as a practically infinite, exploitable resource under humanity's dominion or as a fragile, finite territory in need of stewardship and conservancy. Modern interpretations of post-Baconian science, wedded to early modern capitalism and imperialism, have often been unkind to sixteenth- and seventeenth-century figures on this account. Although there is sufficient evidence to indicate that many early moderns showed remarkable sensitivity to the ecologically destructive nature of certain scientific investigations, Baconians and Hartlibians of the seventeenth century are quite often portrayed as entirely indifferent to concerns of resource exhaustion, the mismanagement of land use, and the plight of anyone in the way of development. After all, why would anyone care about these things if alchemy promised to deliver near infinite returns on the manipulation of nature, and nature complied? As we have seen, a partial answer comes from their attitude toward the artificial and the natural. On numerous occasions, champions of alchemy from Paracelsus and

Plattes to Hartlib and Beale had asserted that nature would not simply bend to the will of the alchemist or agricultural reformer. Only by emulating natural processes, moving with the rhythms of nature, or even removing oneself from the equation altogether could the secrets of nature be unlocked and its power harnessed. While Bacon had written that "human power and knowledge meet in one," he also admonished natural philosophers that "where a cause is unknown an effect cannot be produced…to be commanded, nature must first be obeyed."[44] Even as they sought utopian political ends and cornucopian economic gain, the Hartlibian alchemists and agricultural reformers largely hoped to work with nature, not against it.

Moreover, those doing this work were some of the unsung protagonists of early modern science. The figures that populate this work range from the well known or the wealthy, like Isaac Newton and Robert Boyle, to the often entirely anonymous people who dug saltpeter, plowed fields, mixed fructifying waters, bought and sold seeds, smelted metals, and traveled to exotic locales for plant specimens. Most were somewhere in between. They were people of moderate means who saw enough potential in the technical operations of alchemy and the theories of vegetable philosophy to engage in a variety of projects and experiments intended to reform husbandry. Experiment was the great equalizer, at least in the sense that all of the seventeenth-century agriculturists, alchemists, and botanists that I have examined in detail accepted its authority, especially to resolve disputes between themselves and their sources—both ancient and contemporary. In the broader vitalist tradition, alchemy was something that was happening in nature *everywhere* one observed physical change; thus, experiment need not be confined to the lab. It could be

[44] Bacon, *Novum Organum*, I.3

freed to transpire wherever the intrepid alchemist dared to go. Many historians have described alchemists as creatures of the library, the princely court, the university, and the laboratory. Let us not forget that many were also creatures of the farm, fen, field, kitchen, orchard, and garden.

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