# Ontological Tensions in 16th and 17th Century Chemistry: Between Mechanism and Vitalism

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## Introduction

The 16th and 17th centuries marked a period of transition between the vitalistic ontology that had dominated Renaissance natural philosophy and the early modern mechanistic paradigm that was endorsed by Cartesian natural philosophers, among others. However, even with the dawning of the 18th century Chemical Revolution, chemistry remained resistant to the mechanical philosophy. What one discovers, when examining the chemical philosophies of the 16th and 17th centuries, is that these transitional philosophies involved quite complex and nuanced ontologies that cannot be easily classified as either strictly vitalistic or strictly mechanistic. In fact, in many of the most important chemical theories of this period, vitalism coexisted quite comfortably with corpuscularian theories of matter. More than this, one also discovers that, to the extent that chemical philosophy resisted subsumption under the mechanical philosophy, it was not the supplanting of vitalism by mechanism that ushered in the Chemical Revolution. Rather, this revolution in chemistry was brought about by a naturalized and physicalistic, although non-mechanistic, interpretation of chemical qualities and operations. This paper will examine these ideas by focusing on a few of the more significant transitional chemical philosophies of the 16th and 17th centuries, in order to show how chemical philosophers at this time adhered to complicated ontologies that only slowly and gradually shifted from a vitalistic point of view to a naturalistic and physicalistic, albeit non-mechanistic, account of chemical qualities and operations. For the sake of brevity, I will restrict my discussion to the chemical philosophies of Sebastien Basso, Jan Bapstista van Helmont, and Robert Boyle. I will also examine the work of Paracelsus, since his chemical philosophy provides the background for the work of Basso, van Helmont, and Boyle. The role played by these chemical philosophies in the shift from vitalism to physicalism is best understood when one focuses on their theories of matter and of vital spirits, and on how the changes in how these notions were conceived ultimately ushered in the Chemical Revolution.

**Vitalism in Paracelsus , van Helmont, and Basso**

Vitalism has been generally regarded as the view which claims that 'vital forces' or 'vital spirits' are causally operative in nature, and that the presence of 'vital force' or 'vital spirit' marks the difference between organic and inorganic matter. Vitalistic descriptions of natural phenomena tend to be qualitative, and vitalistic processes tend to be viewed as holistic and teleological. Most importantly for this essay, vitalism views the causes of motion as inherent within matter and treats all of nature "as if it were intrinsically active and self-organizing."[1] Throughout the history of both speculative and natural philosophy, vitalistic theories have often been overlaid with theological overtones of one sort or another, and the vitalistic theories discussed herein are no exception. Renaissance and early modern natural philosophers believed that they lived in an enchanted universe, that the physical universe did not consist of inert matter but either was itself animate (i.e., it contained a 'world soul' or *anima mundi*) or was inhabited by vital forces and spirits that played a causal role in the occurrence of natural phenomena. For these philosophers, the presence of a world soul or of vital forces and spirits was ultimately attributed either to divine emanation or to divine action. Another characteristic of Renaissance vitalism was that it affirmed a fundamental correspondence between what is above, the macrocosm, and what is below, the microcosm. "The theory of a correspondence between microcosm and macrocosm was at the center of a group of ideas derived from the […] mystical-alchemical tradition crossed with themes common to Neoplatonic mysticism. The vital substances of objects [were] made up of invisible spirits or forces of nature."[2] Natural philosophers, or natural magicians as they were called in the Renaissance, were individuals who not only studied these vital forces and correspondences but also learned how to deploy them for the purpose of controlling or altering natural phenomena. Vitalism dominated natural philosophy during the 15$^{th}$ and 16$^{th}$ centuries as a result of the Neoplatonic and hermetic

[1] *Society & Knowledge: Contemporary Perspectives in the Sociology of Knowledge and Science*, edited by Nico Stehr and Volker Meja (New Brunswick: Transaction Publishers, 2005), p. 77.
[2] Rossi, Paolo, *The Birth of Modern Science*, Translated by Cynthia De Nardi Ipsen (Oxford: Blackwell Publishers, 2001), p. 141.

traditions that informed Renaissance culture. It infused the work of such thinkers as Marsilio Ficino, Tommaso Campanella, Cornelius Agrippa, and Giordano Bruno and continued to dominate natural philosophy well into the 17th century.

One discipline within the Renaissance tradition of natural magic that was especially receptive to the vitalistic ontology of Neoplatonism was alchemy and, even during the transition from alchemy to modern chemistry, lingering elements of the vitalistic standpoint continued to resonate within chemical philosophy. As well, to the extent that chemical philosophy impacted on developments in iatrochemistry (i.e., pharmaceutical chemistry) and medicine, vitalism continued to also impact these disciplines throughout the 17th and part of the 18th century. However, one of the misconceptions that informs much of the literature on this subject is that vitalism ended with the advent of corpuscular philosophy and atomism. At the heart of this misconception is the belief that corpuscularism implies mechanism and that, therefore, the advent of the corpuscular philosophy is responsible for sealing the lid on the casket of vitalistic theories. However, this is indeed a misconception. The historical process whereby ancient corpuscularism and atomism were revived in the 16th century is, in fact, quite complex. Although the atomism of Democritus and Leucippus was physicalistic and mechanistic, what made it possible for particulate matter theory to be resurrected after millennia was the survival, through late antiquity, the Middle Ages, and the Renaissance, of the ancient notions of *minima naturalia* and of non-physical *semina rerum*. Several medieval and Renaissance theories employed the notion of *minima naturalia* as the smallest possible particles in nature, not further reducible to other particles. By interpreting the notion of *minima naturalia* as minimum-sized particles of reagents, many Medieval and Renaissance alchemists developed their own type of corpuscularism or particulate matter theory, called 'alchemical atomism', as a qualitative version of atomism. The Neoplatonic notion of *semina rerum* also played a significant role in the revival of atomism in the 16th century for, although the *semina* were interpreted in the Plotinian and Augustian traditions as spiritual archetypes in nature, *semina* were understood by corpuscularians of the late 17th century in much more physicalistic terms. Although"[m]ost historians [and philosophers] of science have considered early seventeenth-century atomism as preparatory to the mechanical theory of matter"[3], there is strong evidence to show that, for much of the 17th century, chemical philosophers adopted a view of matter that was both corpuscular and vitalistic. In other words, these chemical philosophers adhered to a particulate matter theory while also embracing the idea that chemical qualities and operations were non-mechanistic and involved the action of vital spirits and ferments. As Antonio Clericuzio tells us,

> [t]he doctrine of spirit played a substantial part in seventeenth-century natural philosophy and medicine. The Neoplatonic spirit of the world [*anima mundi*] was widely adopted by chemical philosophers as a principle of motion and life. In a hierarchically organised universe it was deemed to be a substance originating in the stars and therefore superior to the four elements. This notion became central to chemistry and medicine thanks to [Marsilio] Ficino's *De vita Philosophicae* (1571). As William Harvey noted in his *Exercitationes duae*, it [the doctrine of spirits] was often employed as a *factotum*, in both natural philosophy and medicine.[4]

In order to understand the complex ontologies that informed the chemical philosophy of the 16th and 17th centuries, one must understand that chemical philosophy had been involved in a process of self-definition and development since it was first articulated as such in the work of the controversial alchemist Paracelsus. Thus, a clarification of the context in which 16th and 17th century chemistry evolved is in order. Chemistry, as a discipline, does not enjoy the same kind of long historical tradition that is enjoyed by astronomy, mechanics, mathematics, and physics. In fact, up to the 16th century, chemistry "had no organized structure whatsoever, no theories of change and reactions, and no clearly defined tradition. Like geology and magnetism, chemistry became a science between the seventeenth and eighteenth centuries. Unlike mathematics, mechanics, and astronomy, it was itself a product of the Scientific Revolution."[5] As Paolo Rossi tells us, in *The Birth of Modern Science*, "[t]here is no figure like a Euclid, Archimedes, or Ptolemy in the history of chemistry. Instead, modern chemists find themselves in the somewhat disconcerting company of alchemists, druggists, iatrochemists, sorcerers, astrologers, and other sundry figures."[6] One of the reasons why chemistry was long considered to be the red-headed stepchild in the family of science is that, for much of its history up to the 16th century, it was

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[3] Clericuzio, Antonio, *Elements, Principles and Corpuscles: A Study of Atomism and Chemistry in the Seventeenth Century* (Dordrecht: Kluwer Academic Publishers, 2000), p. 37.
[4] *Ibid*.
[5] Rossi, p. 137.
[6] *Ibid*, p. 139.

primarily a practical enterprise that did not seem to be anchored upon a solid theoretical and philosophical foundation. The scientific status of chemistry was, therefore, dependent upon the development of a chemical philosophy and, as surprising as it may seem, the person responsible for developing the first genuine chemical philosophy is the infamous alchemist knownw as Paracelsus.

Despite his legendary fame as a bombastic alchemist and occultist, Theophrastus von Hohenheim, a.k.a. Paracelsus, (ca. 1493-1531) was a seminal figure of early chemistry. Most importantly, Paracelsus helped to transform 16th century alchemy by giving it an essentially medical identity, and he made this the basis for the development of an alchemical epistemology.[7] Paracelsus made significant advances in medicine by arguing against the Galenic and Scholastic view that disease was caused by an imbalance of the four bodily humors, which might be cured by bleeding or herbal remedies, and by claiming instead that disease was caused by the presence of external agents attacking the body and this could be cured through 'chemical' remedies. He identified the characteristics of many illnesses, such as goiter and syphilis, and treated them with sulphur and mercury compounds. He was, therefore, "the first to introduce the medicinal use of mineral substances to the practice of medicine. Chemistry, or the spagyric art, became the cornerstone of medicine."[8] By all accounts, however, the characterization of Paracelsus as an alchemist and mystic is not a mistaken one. He fits very well within the Renaissance tradition of natural philosophy and natural magic to the extent that the theoretical framework upon which his work relies is staunchly vitalistic and not only posits the existence of vital forces and spirits but also fully affirms the theory of correspondence between microcosm and macrocosm. Paracelsus's vitalism is, not surprisingly, theological and it shapes his chemical interpretation of Genesis, in which creation is understood as a separation of the elements by God. For Paracelsus, "[s]ince the divine creation [is] best understood as a chemical process, then nature must continue to operate in chemical terms. Chemistry [is] the key to nature – all created nature."[9]

[7] *Alchemy and Chemistry in the 16th and 17th Centuries*, edited by Piyo Rattansi and Antonio Clericuzio, International Archives of the History of Ideas No. 140 (Dordrecht: Kluwer Academic Publishers, 1994).
[8] Rossi, p. 142.
[9] Debus, Allen G., *The Chemical Philosophy: Paracelsian Science and Medicine in the Sixteenth and Seventeenth Centuries* (New York: Dover Publications, 2002), p. 86.

Paracelsus's chemical philosophy was based upon three fundamental principles: His theory of prime matter, his theory of elements, and his theory of principles. His theory of prime matter, as previously stated, was based upon his chemical interpretation of Genesis in which God is a divine chemist who spontaneously created the world *ex nihilo*.[10] Paracelsus's theory of the elements included prime matter (i.e., water) and fire, earth, and air, which were also considered matrices. "Plants, minerals, metals, and animals were the *fruit* of the four elements."[11] Although Paracelsus inherits his theories of prime matter and of the elements from ancient sources, it is with his theory of principles that he makes a truly original contribution to alchemy and to chemical philosophy. The principles of chemical reaction, according to Paracelsus, are salt, sulfur, and mercury, what he calls the *tria prima*. "This *tria prima* also consist[s] of spiritual substances and correspond[s] to the Body, Soul, and the Spirit. Salt makes bodies solid, Mercury makes them fluid, and Sulfur makes them inflammable."[12]

Although the theory of the *tria prima* was a modification of earlier sulfur-mercury theories of metals, it has a special significance in the rise of modern science because it represents a broadening of these theories "to provide an explanation for all nature."[13] For Paracelsus and for later Paracelsians, vital spirit is essential for both the organic and the inorganic worlds. "Spirits were conceived as the active agents, upon which all the principal operations in nature and in the human body depended."[14] In his *De Natura Rerum* (1537), Paracelsus states that "[t]he life of things is none other than a spiritual essence, an invisible and impalpable thing, a spirit and a spiritual thing. On this account there is nothing corporeal, but has latent within itself a spirit and life, which, as just now said, is none other than a spiritual thing."[15]

Paracelsus's chemical philosophy, however, was not merely mystical but also contained the fundamental elements of what would later become modern chemistry and modern scientific method. Paracelsus's approach, for example, was solidly empirical. According to Paracelsus, "to attain true knowledge one must abandon the surface of bodies, penetrate their inner nature and

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[10] Rossi, p. 141.
[11] *Ibid*.
[12] *Ibid*.
[13] Debus, Allen G. (2002), pp. 78-79.
[14] Clericuzio, Antonio, "The Internal Laboratory. The Chemical Reinterpretation of Medical Spirits in England (1650-1680)", in Rattansi and Clericuzio (1994), p. 52.
[15] Paracelsus, *De Natura Rerum*, as quoted in *Ibid*.

break them up into their constituent parts until each of these is accessible to sight and touch."[16] To make the constituent parts of bodies accessible to the alchemist, Parcelsus emphasized analysis. However, he "and his followers laid the foundations for viewing analysis as only half of the equation – as a necessary preliminary to resynthesis."[17] Paracelsus and his followers thus changed the practice of alchemy by emphasizing the twin processes of analysis and synthesis (*spagyria*), to allow them to penetrate the true inner nature of bodies. When discussing the inner nature of bodies, Paracelsus was influenced by Ficino and "placed special emphasis on *semina* [or *semina rerum*], which he considered as invisible spiritual forces and as archetypes."[18] There are clearly echoes here of the Augustinian doctrine of seminal reasons in Paracelsus's conception of *semina*. "[*S*]*emina*, which originate in the Word [or *Logos*] are contained in the *Yliaster* [the universal matrix of the cosmos] and are prior to chemical principles and to elements. Nature as a whole is a *panspermia*"[19], that is, the seeds of life imbue the entire universe. The notion that *semina* are responsible for the generation of natural bodies, including metals in the bowels of the earth, continued to influence Paracelsian chemical philosophers throughout the 16th and much of the 17th century. Paracelsus's contemporary, Girolamo Fracastoro, took this Neoplatonic notion of *semina rerum* a step further by combining it with Lucretian atomism and reinterpreting it "in terms of invisible units of matter"[20] and arguing that *semina* are also the causes of communicable diseases, when they propagate through the atmosphere and penetrate a host organism. In this way, both Fracastoro and Paracelsus greatly advanced the medical theory of disease by moving away from a strictly Galenic theory of humoral imbalance and toward the ontological theory of pathology and contagion.

The notion of *semina rerum* continued to influence many 16th and 17th century Paracelsians who embraced both a vitalistic ontology and a corpuscular and, more specifically, atomistic conception of matter. One of the 17th century Paracelsians whose work is particularly intriguing is Sebastien Basso (also known as Basson or Bassonus). Basso's Paracelsian chemical philosophy,

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[16] Bianchi, Massimo Luigi, "The Visible and the Invisible. From Alchemy to Paracelsus", in Rattansi and Clericuzio (1994), p. 18.
[17] Newman, William R. and Lawrence M. Principe, "Alchemy and the Changing Significance of Analysis", in *Wrong for the Right Reasons*, edited by J.Z. Buchwald and A. Franklin (Dordrecht: Springer, 2005), p. 79.
[18] Clericuzio (2000), p. 18.
[19] *Ibid*.
[20] *Ibid*, p. 17.

which he developed in his *Philosophia Naturalis* (1621), "stands out as one of the earliest and most articulate expositions of the corpuscular theory of matter."[21] In fact, along with Isaac Beeckman, Sebastien Basso is considered to be one of the inventors of molecular theory. Yet, Basso's work also stands out as a prime example of Neoplatonic vitalism. By motion, for example, Basso is referring to sympathy and antipathy, that is, to attraction and repulsion, and he attributes the motions of atoms not to external and mechanistic laws but to the actions of the world soul and, ultimately, of God. We, thus, find in Basso a strong affirmation that all natural phenomena are caused by the motions and rearrangements of atoms and, in that regard, he has much in common with later mechanistic atomists. But what distinguishes his views from those of later atomists and materialist corpuscularians is that, for him, this motion must be attributed to vital spirit, and vital spirit is to be understood in non-material and non-mechanistic terms. Although Basso's movement toward a corpuscularian theory of matter is a significant contribution to the eventual development of modern chemistry, other Paracelsians, such as Petrus Severinus, took even further steps towards the development of a theory of vital spirits that would, ultimately, lead to the late 17th century reinterpretation of these spirits in physicalist terms.

We, therefore, find that, at the end of the 16th and the beginning of the 17th century, the chemical interpretation of vital spirit becomes unambiguously chemical, while still retaining a strong Neoplatonic tone. For example, the work of Duschesne and Croll develops the view "that medical spirits and spirits extracted by chemists [have] the same source, namely, the spirit of the world. On this basis they stated that the only active remedies [are] those prepared by using spirits extracted by distillation." [22] Such an unambiguous chemical interpretation of vital spirit is even more evident in the chemical philosophy of Jan Baptista van Helmont (1579-1644). For van Helmont, vital spirit (*Archeus*) is conceived as an alkaline volatile salt that moves through the body. Van Helmont states that "[t]he spirit of life receives in the left ventricle of the heart a 'divine illumination', by which it is enabled to preserve and to sustain life […] within the left ventricle of the heart, vital spirit is generated from the volatile salt contained in *cruor* [blood without spirit] and by means of a local ferment."[23] Van Helmont theory of spirit, however, still

[21] *Ibid*, p. 39.
[22] Clericuzio (1994), p. 53.
[23] *Ibid*.

retains a strong Neoplatonic tone, although he rejects certain aspects of Neoplatonic thought such as, for example, the traditional analogy between microcosm and macrocosm.

We find that van Helmon develops an interesting hybrid theory that combines corpuscular and quasi-physicalistic explanations of many chemical phenomena with aspects of Paracelsian vitalism. Unlike other natural philosophers before him who had embraced either a notion of *minima naturalia* or of *semina rerum*, van Helmont's chemical philosophy embraces both of these notions. However, unlike Frascastoro, van Helmont follows Paracelsus in interpreting *semina rerum* as "the main agents in nature [and as] spiritual, non-corporeal entities."[24] For van Helmont, the *minima naturalia* are interpreted in strictly physical terms as corpuscles. In fact, "Helmontian atoms are identical with the *minima naturalia*, i.e., the smallest particles into which a substance may be divided. There is little doubt that for van Helmont *minima naturalia* are actual physical units. [However] [i]t is also apparent that they have qualitative determinations, not mechanical properties."[25] Non-mechanical properties are accounted for by the *semina rerum*, which work with the *minima naturalia* to bring about changes in nature by providing the spiritual force of action that brings about qualitative chemical alterations. Van Helmont claims that, in order to provide a mechanical explanation for chemical alterations such as, for example, the mixture of substances, one would have to restrict oneself to explaining this phenomenon by considering only the mechanical properties of shape, size, and motion. Therefore, under such a mechanistic model, a mixture of substances would have to be explained as the juxtaposition of physical parts. However, according to van Helmont, a "purely mechanical juxtaposition of [physical] parts does not bring about a real mixture [of substances]."[26] It does not bring about a true synthesis. This is why mechanical principles cannot explain chemical reactions. Instead, van Helmont claims that chemical reactions, mixtures of substances, and transmutations depend upon ferments that are contained in *semina rerum*, which are the formative principles from which all natural bodies originate. These ferments are themselves formative spiritual agents and, although analysis and

[24] Clericuzio (2000), p. 56.
[25] *Ibid*, p. 56.
[26] *Ibid*, pp. 58-59.

"reduction of bodies into their *minimae partes* is a 'pre-condition' for transmutation – [it] is ultimately a spiritual process."[27]

Van Helmont explains many physical changes in this manner, changes such as the production of a gas for example, and interprets these as changes in "the disposition of the *tria prima* within the corpuscles of water […] The purely material change, that is the attenuation of water parts into atoms, is preliminary to a process that is qualitative, not mechanical."[28] Therefore, physical change takes place in the *minima naturalia*, but the process of chemical change that ensues is the action of *semina rerum*. With this nuanced ontology, van Helmont makes significant contributions to the development of modern corpucularian theory such as, for example, his explanation of certain chemical reactions, such as the "transmutation" of iron into copper and the production of glass, in corpuscular terms.[29] "Both [chemical reactions] are explained in terms of addition and subtraction of particles. The notion of atoms is also employed in van Helmont's theory of mixture and of generation […] [But] [t]hese corpuscular views by no means presuppose a mechanical theory of matter […] [Van Helmont] imposed severe restrictions on the corpuscular theory of matter. *Semina rerum* and ferments are the active principles on which all natural phenomena ultimately depend."[30]

**Cartesian Mechanism and the 'Chymistry' of Robert Boyle**

In order to understand the reasons why many chemical philosophers of the 16$^{th}$ and 17$^{th}$ centuries rejected mechanical explanations of chemical phenomena, one must first understand what the mechanical philosophy implied. 'Mechanism', or the mechanical philosophy, is the view "according to which matter is inert and all interactions in nature are produced by the impact of particles."[31] In this sense, Cartesian mechanism is also reductionistic, that is, all qualities (including chemical qualities and reactions) are thought to be reducible to the mechanical and quantitative properties of shape, size, and motion. For reductionists, all higher-level phenomena and properties are entirely deducible from lower-level properties. In this view,

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[27] *Ibid*, p. 60.
[28] *Ibid*, pp. 57-58.
[29] *Ibid*, p. 56.
[30] *Ibid*, p. 58-61.
[31] *Ibid*, p. 7.

> the physical world is represented by particles of matter in motion and can be interpreted by the laws of motion determined by statistics […] dynamics [and] mechanics […] Natural phenomena such as air resistance, friction, the different behaviors of individual bodies, the qualitative features of the physical world were now considered irrelevant to the discourse of natural philosophy or viewed as *disturbing circumstances* which were not […] to be taken into account in an explanation of the physical world.[32]

For Cartesian mechanists, "any explanation of natural events requires the building of a mechanical model as a 'substitute' for the actual phenomena being studied."[33] Mechanical philosophy is, therefore, anti-vitalistic and anti-teleological, since it assumes that "nature is not the manifestation of a living principle but is a system of matter in motion that follows [mathematically precise] laws […] the explanation of natural phenomena excludes all reference to *vital forces* or *final causes*."[34] For the mechanical philosophy, both inorganic and organic material bodies are governed by deterministic and mechanistic laws of motion that are external to matter itself. "[A]ll interactions in nature are produced by the impact of particles"[35] in accordance with mechanical principles. For mechanists, matter is not intrinsically active or self-organizing and its motions are not self-determined. Instead, its motions are entirely determined by mechanistic causal chains and external laws of motion. For dualistic mechanists like Descartes, although matter itself is not active or self-determined, self-determination exists in the world to the extent that minds exist and are active and self-determined. For materialist mechanists like La Mettrie, on the other hand, since only inert matter exists, there is no such thing as self-organization or self-determination in the world.

This view, however, was not dominant in the context of 17th century chemistry, physiology, and medicine. In fact, for many chemists and physiologists, organization and spirit were inherent in matter, although in this period of transition, spirit was interpreted in chemical terms. "[F]rom the 1650s the notions of spirit (and of fermentation) became central issues […] [many English chemists and physiologists] shared the view that matter was endowed with an internal principle of organization, life and sensibility, namely, the spirit, which they described in terms of

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[32] Rossi, p. 122.
[33] *Ibid*, p. 125.
[34] *Ibid*.
[35] Clericuzio (2000), p. 7.

particles having specific chemical properties."[36] This explains why "the distillation of spirits became an important component of seventeenth-century chemistry and medicine […] [for the purpose of] identifying and manipulating the spiritual essences extracted from natural bodies by means of distillation […] [ and for] 'capturing' the spirit of the world, which Paracelsians conceived as the celestial vital substance contained in the air."[37]

This celestial vital substance, or *anima mundi*, had been identified by Paracelsus as the aerial nitre, also called saltpeter or potassium nitrate. His reason for identifying the vital spirit with saltpeter is that potassium nitrate gives off life-sustaining oxygen when heated. Paracelsus had already reflected on what he considered to be the unique properties of saltpeter and had claimed that "no other salt in the world is like [saltpeter] […] The part played by Saltpeter in gunpowder is one reason why it is different from all other salts, and Paracelsus repeatedly explained thunder and lightning in terms of an aerial, windy, or aetherial nitre and sulphur."[38] Paracelsians later contended that, in addition to salt, there were two volatile parts in saltpeter, sulphur and mercury, which were respectively the soul and the spirit of the aerial nitre. Based upon Paracelsus's own investigations into the nature of the aerial nitre and upon the Neoplatonic belief in the microcosm/macrocosm analogy, the Paracelsians developed the theory that the vital spirit originates in the celestial sphere and is carried in the air. It is then inhaled by human beings and reaches the heart, from which it is "carried around the body in a circular motion, imitating the divine circularity [of the celestial bodies]. This motion impressed on the blood relates not only to the spirit of the blood in the heart but to all of the spirit of the blood in the body."[39] There is, therefore, throughout the work of the Paracelsians, a persistent interest in the blood and its relation to the vital spirit. Like van Helmont's identification of vital spirit with volatile alkaline salt, the Paracelsians' identification of *anima mundi* with saltpeter and their identification of aerial nitre as something that penetrated the body through the blood were important steps toward the late 17th century naturalization of the notion of vital spirit and the reinterpretation of this notion in physicalist terms.

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[36] Clericuzio (1994), p. 59.
[37] *Ibid*, pp. 53-54.
[38] Debus, Allen G., "The Paracelsian Aerial Nitre", *Isis*, Vol. 55, No. 179 (1964), p. 47.
[39] Debus, Allen G., *The Chemical Philosophy: Paracelsian Science and Medicine in the Sixteenth and Seventeenth Centuries* (New York: Dover Publications, Inc., 2002), p. 235.

It is with this context in mind that I now turn to the work of another transitional figure in chemical philosophy, Robert Boyle (1627-1691). Boyle has generally been regarded by most historians of science as one of the principal champions of mechanism in the 17th century and as a key figure in advancing the Cartesian mechanical philosophy. Historians of science point to the many writings in which Boyle extolled the virtues of the mechanical philosophy and to his work, *The Sceptical Chymist*, in which Boyle responds to and critiques aspects of spagyrical and alchemical philosophy. Although it is widely known that he was himself a practicing alchemist who believed in the possibility of the 'transmutation' of metals, it is also the case that Boyle attempted to understand transmutation in a way compatible with the mechanical philosophy. Aside from Boyle's own claims in favor of the mechanical philosophy, historians of science also point to his corpuscular conception of matter as further evidence of his commitment to mechanism.

This interpretation of Boyle's corpuscular philosophy as purely mechanistic was reinforced in Thomas Kuhn's essay "Robert Boyle and Structural Chemistry", in which Kuhn writes that "Boyle's faith in the corpuscular principles of the 'Mechanical Philosophy' is the major source of his new emphasis in chemistry upon structure, configuration and motion, as well as a cause of his rejection of explanations in terms of inherent characteristics of the ultimate corpuscles."[40] Boyle does, indeed, make some very clear statements in favor of mechanism, in his work *The Excellency and Grounds of the Corpuscular or Mechanical Philosophy* (1674). Indeed, the title of this work itself conflates the notion of corpuscularianism with the notion of mechanism, as though these notions implied each other.

However, despite the received view among many historians of science, Robert Boyle's own ontology cannot be easily categorized as purely mechanistic. A close examination of Boyle's chemical writings, both published and unpublished, shows that "he was far from subordinating chemistry to mechanical philosophy, since he did not explain chemical phenomena by immediate and direct recourse to the mechanical affections of particles. As a matter of fact, he regarded chemistry as a discipline independent from mechanics. He explained chemical phenomena in terms of corpuscles endowed with chemical, rather than mechanical, properties. Accordingly, his

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[40] Kuhn, Thomas, "Robert Boyle and Structural Chemistry", *Isis* 43 (1952), p. 19.

chemical philosophy can be described as corpuscular, not as mechanical."[41] "One of Boyle's chief scientific pursuits was to explain chemical phenomena in corpuscular terms and to establish chemical foundations for corpuscular philosophy […] unlike [many of] his predecessors, Boyle's combination of chemistry and corpuscular philosophy was based on an articulate theory of matter and was supported by a substantial amount of experimental evidence […] [Boyle's theory of matter is commonly described as purely mechanical."[42] However,

> [a]lthough Boyle often repeated that the mechanical properties of corpuscles were to be regarded as the most general notions of natural philosophy, a closer analysis of his natural philosophy reveals a number of agents not operating according to the principles of mechanical philosophy. These agents are seminal principles, spirits, and ferments – which Boyle conceived as corpuscles endowed with the power of fashioning other parts of matter. The notion of *semina* is of special importance to the understanding of Boyle's theory of matter, as it was adopted to link his corpuscular philosophy to his theological view of nature […] [Boyle was acquainted with the work of Paracelsus, Basso, Sennert, and van Helmont. In fact] [t]he notions of spirit and ferment, which he used in *The Usefulnesse of Experimental Philosophy* [and in the *History of Blood*] […] testify to Boyle's debts to the Helmontian iatrochemistry. The notion of ferment occurs also in Boyle's alchemy. He described the elixir as ferment, a substance which has the power of transmutting a huge quantity of matter, many times its weight.[43]

From what has already been established, it is clear that Boyle was not unique in both embracing a corpuscularian theory of matter and rejecting strictly mechanical explanations of chemical qualities. As has been stated, corpuscularism does not entail mechanism and, especially in the 16$^{th}$ and 17$^{th}$ centuries, "the acceptance of a particulate theory of matter very rarely involved the idea that *all natural phenomena* could be accounted for by means of particles endowed only with mechanical properties."[44] In fact, Boyle concurs with Paracelsian and other vitalists regarding the notion that chemical qualities and operations cannot be accounted for by reducing them to the mechanical properties of shape, size, and motion of particles. Although he was critical of the Paracelsian doctrine of the theory of principles and qualities, "his criticism did not entail that all chemical properties were reducible to […] mechanical attributes.[45] "[Boyle's] aim was to reject the notion that sensible qualities were reducible to this or that ingredient of a

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[41] Clericuzio, Antonio, "A Redefinition of Boyle's Chemistry and Corpuscular Philosophy", *Annals of Science*, Vol. 47, No. 6 (1990), p 563.
[42] Clericuzio (2000), p. 103.
[43] *Ibid*, pp. 106-107.
[44] *Ibid*, pp. 563-564.
[45] *Ibid*, p. 564.

mixed body. He [presented] the idea that a quality had relative character, namely, that it was generated from the constant interactions of different corpuscles, which themselves might not bear the quality in question [and] [h]e himself developed new and more sophisticated ways of detecting the chemical qualities of bodies."[46] This suggests that Boyle saw chemical qualities as 'emergent' properties that could not be merely reduced to shape, size, and motion and "refrained from establishing a direct relationship between a given quality and a set of mechanical properties of the simplest corpuscles."[47] Boyle is, in fact, openly critical of the Epicureans and Cartesians who "pretend to explicate every particular Phaenomenon by deducing it from the Mechanicall affections of Atomes or insensible particles."[48]

The question, therefore, is this: How is Boyle able to reconcile his openly professed commitment to mechanical philosophy with his resistance to mechanical explanations of chemical qualities and operations? The answer lies in the particulate theory of matter that Boyle develops while conducting his early chemical studies. It is through this complex particulate theory that he is able to argue both for the mechanical philosophy and for non-mechanical explanations of chemical phenomena. In his manuscript "Of ye Atomicall Philosophy" (1651-1653), Boyle equates atoms with *minima naturalia*, particles that are not further divisible, although there is a definite distinction between Boyle's conception and the Scholastic understanding of *minima naturalia*, in that "Boyle rules out the Aristotelian notion of form."[49] He states, "by Atoms […] I understand not indivisible Mathematicall points […] but *minima naturalia* […] because tho they may be further divided by Imagination yet they cannot by Nature."[50] For Boyle, the primary properties of *minima naturalia* are understood as mechanical, that is, as shape, size, and motion.

However, in addition to adopting the notion of *minima naturalia*, Boyle also embraces a version of the notion of seminal powers to explain chemical qualities, although for him seminal powers are not spiritual but corpuscular in nature. In order to explain the existence of corpuscular seminal powers, while at the same time maintaining a mechanistic notion of primary properties, Boyle classifies corpuscles into first-order and second-order. First-order corpuscles

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[46] *Ibid*.
[47] Clericuzio (2000), p. 108.
[48] Boyle, Robert, *Royal Society Boyle Papers*, VIII, Folio 166r.
[49] Clericuzio (2000), p. 116.
[50] Boyle, *RSBP*, XXVI, Folio 163r.

(*minima naturalia*) are described in terms of the mechanistic properties of shape, size, and motion. However, second-order corpuscles are compounded corpuscles that are endowed by God with seminal powers, that is, with specific "faculties or powers to fashion other parts of matter."[51] Thus, although Boyle is not a vitalist and any inherent internal faculty of motion to first order corpuscles, he does posits second order corpuscles with the special power of generation. [52] There is an indication that, for Boyle, the corpuscular seminal powers are emergent properties of second-order corpuscles, that is, of compound corpuscles. In fact, "Boyle maintained that chemical qualities depended […] on the way in which the corpuscles that composed a given body were disposed to act, or to be acted on by, those of other bodies […] [and that they] emerged from the constant interactions of corpuscles passing from one body to the other […] he [thus] denied that they directly originated from the mechanical properties of their primary particles [first-order corpuscles]."[53]

It is, therefore, clear from this discussion that Robert Boyle, who has been widely regarded as embracing a purely mechanistic corpuscular chemical philosophy, in fact holds a very complex ontology that is clearly neither vitalistic in the sense of Paracelsus, Basso, or even van Helmont nor entirely mechanistic in the manner of Cartesian mechanism. As a chemist, he is strongly committed to explaining chemical phenomena in ways that account for the qualitative changes that occur in chemical reactions and 'transmutations' and he is, therefore, not satisfied with reducing atoms and corpuscles to merely primary and entirely quantitative properties. Mechanistic explanations, for Boyle, just cannot satisfactorily account for chemical phenomena. However, although Boyle embraces the notions of vital spirits and ferments, he does not interpret these in Neoplatonic terms. Instead, he is instrumental in providing an analysis of vital spirits in chemical and physicalistic terms, while avoiding a strictly mechanistic account. Boyle's theory about the general nature and classification of spirits was, in part, developed during his studies of the spirit of blood. Here, Boyle

> argued that this spirit was not homogeneous, but a compound substance, of whose chemical properties he was keen to give a more detailed account […] In the *Memoirs for*

[51] Clericuzio (1990), p. 583, footnote 107.
[52] *Ibid*.
[53] *Ibid*, p. 588.

> *the History of Human Blood* he recorded that from the distillation of blood he had obtained, besides oily and phlegmatic parts, a clear liquor which, though probably it contained some phlegm, might be called spirit, because 'it is fully satiated with saline and spirituous parts' […] Boyle's researches on the spirit of blood – carried out in the 1670s – marked an important stage of the development in the chemical study of spirits, since they were specifically aimed at finding out the chemical components of vital spirits. Accordingly, they brought about the abandonment of the belief that spirit as such – a homogeneous and vaguely defined [non-physical substance] – had to be regarded as the origin of vital spirit.[54]

As Clericuzio has argued, "a transformation of the notion of spirit by seventeenth century English chemical physiologists permitted them to view vitality as resulting from the chemical activity of substances rather than arising from a homogeneous spirit or soul."[55] It is precisely when vitality begins to be no longer viewed in theological or supernatural terms and to be viewed, instead, in naturalistic, albeit not mechanistic, terms that the stage is set for the advent of the Lavoisier's Chemical Revolution.

**Conclusion**

As can be seen from the above, the shift from a vitalistic to a non-vitalistic theory of mater was not sudden and radical but, rather, followed a subtle, nuanced, and gradual path, from the 16th to the 18th century. Furthermore, the paradigm that ultimately supplanted vitalism in chemistry does not seem to have been mechanism but, rather, physicalism, that is, it was a shift from a dualistic ontology of matter and spirit to an ontology in which the only causally efficacious factors involved in natural phenomena were thought to be entirely physical and empirical factors. In this shift, the world soul itself was reduced from a spiritual to a physical ontological status and was, ultimately, identified with potassium nitrate or aerial niter. But, this physicalistic and naturalistic approach to the articulation of vital spirit and chemical qualities did not entail an entirely mechanistic approach. In fact, for chemical philosophy, physicalism and naturalism remained, in many regards, non-mechanistic.

Although mechanical philosophy did advance 18th century chemistry to some extent and made important contributions such as, for example, the tables of affinity that were "based on displacement reactions and were supposed to show the relative strengths of the attractive forces

[54] Clericuzio (1994), p. 64.
[55] *Ibid*.

between atoms"[56], the mechanical philosophy never quite succeeded in explaining "chemical properties such as acidity, alkalinity, metallicity, salinity, and the chemical operations of combustion, fermentation, and distillation."[57] "[Although] Newton [for example] had hoped to reduce chemistry to a science describing the mechanical interactions between atoms […] that hope was not fulfilled […] The Chemical Revolution came about not by any triumph of the mechanical philosophy but by a rationalization of these traditional chemical qualities and operations."[58] I would argue that this rationalization most definitely occurred with the demise of vitalism. However, this demise did not so much result in the victory of mechanism but, rather, in the victory of physicalistic and naturalistic articulation of chemical qualities.

> [I]f the revolution chemistry was not mechanical, it was definitely physical […] [and resulted from [Lavoisier and his associates] bringing the physical theory of gaseous states into chemistry […] The three Aristotelian elements that represented the three physical states of matter [air, water, and earth] [were] demolished by the Chemical Revolution […] Lavoisier's elements were those simple substances that could be analyzed no further […] [and] they were known by chemical […] characteristics […] The final elimination of fire as a substance [would have] to wait for thermodynamics and the kinetic theory of the nineteenth century.[59]

With this dissolution of the traditional theory of the elements and with a physicalistic, albeit not mechanistic, understanding of chemical properties and operations, 18th century chemistry ultimately shed its vitalistic cloak. But this development was less the outcome of the dominance of mechanism than it was the result of a two-century long process, involving alchemists, chemists, and chemical philosophers, that slowly transformed and naturalized *minima naturalia*, *semina rerum*, and vital spirits. Put briefly, when the world soul became potassium nitrate, the 'disenchantment of the world' had begun.

[56] Hankins, Thomas L., *Science and the Enlightenment* (Cambridge: Cambridge University Press, 1985), p. 84.
[57] *Ibid*.
[58] *Ibid*.
[59] *Ibid*, p. 112.