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Mineral Waters Across the Channel: Matter Theory and Natural History from Samuel Duclos's Minerallogenesis to Martin Lister's Chymical Magnetism, ca. 1666–1686

1. Introduction

The 1675 *Observations sur les eaux minerales des plusieurs provinces de France* is a study of French mineral waters commissioned by the *Académie royale des sciences* and authored by its chief chymist and one of its most influential founding members, Samuel Cottereau Duclos (1598–1685). Neither its relatively obscure author nor its tedious enumeration of French spring waters, part of the *Académie*'s commitment to collective natural histories, stand out. Yet an examination of the chronicles of its production, transmission, and reception—focusing on the personal and institutional backgrounds of its author and main recipient across the Channel, the English naturalist Martin Lister (1639–1712)—sheds light on the changing attitudes toward chymical knowledge, practice, and scientific communication in both private and public contexts. The full history of the *Observations*, from its inception in Duclos's investigative programme in the 1660s, through its suppression and ultimate publication by the early *Académie* in the 1670s, and to its reception and influence in England in the 1680s, uncovers a rich story that weaves together institutional politics, personal agendas, and the controversial nature of early modern chymical theory and practice.

Chymistry was an essential analytical tool in the hands of seventeenth-century natural philosophers and historians, and as the work of Lawrence Principe and William Newman has shown, it is central to understanding the "long" Scientific Revolution.[1] Scholarly attention has been devoted to understanding the developing norms of openness in the dissemination and presentation of scientific, and particularly chymical knowledge in the late seventeenth century, norms that were at odds with traditions of secrecy about the transmutation of matter and chrysopoeia among individual chymists.[2] Evidenced by early modern "vociferous criticisms" of chymical obscurity, various studies have shown how individual practitioners such as Isaac Newton and Robert Boyle used different strategies for negotiating the emergent boundaries between traditional secrecy and the New Science's espousal of openness.[3] Less well understood are the ways in which *individual* philosophers negotiated these boundaries, especially in relation to *institutional* settings during the formative years of scientific societies in late seventeenth century Europe. Michael Hunter's recent work on the "decline of magic" at the Royal Society has to some extent remedied these omissions. Hunter argues that the Society—as a *corporate* body—disregarded and avoided studies of magical and alchemical subjects in the late seventeenth century.[4] Our examination, while focusing on the contributions of individuals set *within* institutional settings, problematises these distinctions and presents a more complex picture of the role of alchemy and matter theory in the two societies.

The treatment of Duclos's work by the *Académie* shows that it indeed sidelined pursuits associated with alchemy and matter theory, and censored their public dissemination. But while some of this suppression was owing to a more generalized assault on chymical vitalism and Neoplatonism, some of it represented the *Académie*'s ambiguous attitude toward the role of chymistry in natural history. In the case of the study of mineral waters, the *Académie* held the corporate line that chymistry should be used in the service of uncontroversial practices of classification and analysis rather than as a natural philosophical tool meant to provide causal and matter theoretical explanations. On the other hand, we show that the vitalistic dimensions of Duclos's work cropped up in debates on the nature of matter and magnetism at the Royal Society in the early 1680s. By tracing the reception and transmission of the *Observations* within and between the two societies we examine the interplay between secrecy and openness, and between natural historical and natural philosophical programmes in chymistry. This affords insights into the respective epistemological climates of the two scientific institutions.[5] Examining the study of mineral waters, in France and across the Channel, shows that one of the main differences between the *Académie* and the Royal Society during these formative decades lies in their divergent relations to theoretical investigations of natural philosophy. Whereas members of the Royal Society were largely free to focus more on choices between competing theories, including studies of magic and alchemy, the French academicians often had an extra hurdle to clear—having to defend their very pursuit of speculative work.

From an institutional standpoint, our account is *asymmetrical*. Working under the royally funded and closely scrutinized *Académie* Duclos's *Observations* was heavily influenced by institutional politics (sections 2–3). As Fellow of the much less centralized Royal Society, and as independent naturalist, Lister felt freer to pursue causal inquiries and was thus able to develop some of Duclos's most contentious ideas while also departing from them in creative and instructive ways. We thus examine Lister's work on mineral waters, minerallogenesis, and magnetism (section 4) as a foil to explore what Duclos was up to and what he would have liked to accomplish. Lister's reception of Duclos's work reveals therefore not only the staying influence of Duclos's chymical and matter theoretical ideas but also suggests an untaken path that the *Académie* might have embraced. We do not engage in counterfactual history but rather embrace the asymmetry between Duclos's work and its reception by Lister and the Royal Society across the Channel to illuminate in one case the dynamics of knowledge transmission; the differences in intellectual and institutional climates; and the shifting relations between matter theory and natural history at the height of the Scientific Revolution.

Our story goes back to the foundation of the *Académie* in December 1666 and the initial formulation of its programme of investigation of natural philosophy. Earlier that year, one of its founding members, Christiaan Huygens, suggested in a letter to Jean-Baptiste Colbert, the *Académie*'s founder and first protector, that "the most useful occupation for such an assembly would be to work on a natural history project, modelled after Baconian precepts." Such an endeavour should

> consist of experiments and remarks as a supreme way for attaining knowledge of the causes of all that can be seen in nature; for knowing the causes of gravity, heat, cold, magnetic attraction, light, colours, the composition of air, of water, of fire and of all other bodies; that would ascertain animal respiration, the ways metals, stones and plants grow, investigating all things unknown or poorly understood … [one should] divide this history into chapters and collect respective observations and experiments, report rare and difficult experiments as well as those that seem essential for the inquiry, even if common … the collection of all [such instances] will always provide a solid foundation for constructing a natural philosophy, in which it is necessary to proceed from the knowledge of effects to that of causes.[6]

The project, Huygens specified, should focus on "matters judged good, beneficial and useful."[7] In this proposal Huygens linked seamlessly descriptive and causal explanations while addressing controversial issues like the causes of gravity, attraction, and the composition of bodies. Huygens's reference to Bacon implied a systematic collection of data; his injunction to proceed "from effects to causes" implied a combination of natural historical and natural philosophical approaches, including matter theory and chymistry.

Huygens's proposal helped convince Colbert and his advisers to found the *Académie* and was influential in shaping its early investigative agendas. One of the defining features of the early *Académie* was its commitment to collective natural histories. Between 1671 and 1676, the publications resulting from three such projects appeared under the auspices of the *Académie*. The 1671 *Mémoires pour servir à l'histoire naturelle des animaux*, headed by Claude Perrault (1613–1688), and the 1676 *Mémoires pour servir à l'histoire des plantes*, initially directed by Duclos and later by the younger Denis Dodart (1634–1707), are relatively well known and have received scholarly attention.[8]

The third publication was Duclos's *Observations* of 1675, whose title implies a comprehensive natural history of French mineral waters conducted in the early 1670s. Unlike the more ambitious and famous comparative anatomical and botanical natural histories, the overall success of which remains questionable, contemporaries were quick to acknowledge the importance and pioneering nature of the French waters study. It was met with particular interest at the Royal Society in the early 1680s, through the works of Robert Boyle and especially Martin Lister (1639–1712), the author of what can be regarded as the British counterpart to Duclos's *Observations*. Lister's *De fontibus medicatis angliae exercitatio* (*Exercises on the healing springs of England*) came out in 1682. Two years later an anonymous English translation of Duclos's book appeared, entitled *Observations on the Mineral Waters of France*.[9] Circumstantial evidence suggests that Lister was the translator.[10] In 1685 Boyle published his *Short Memoirs for the Natural Experimental History of Mineral Waters*. His account was the last instalment in this wave of interest. The editors of Boyle's *Works* see his *Short Memoirs* as "a clear case of Boyle being impelled into print by the publication of books covering ground that he had already explored but without publishing his findings." These "books" were Lister's *De fontibus* and the English translation of the *Observations*.[11] Shortly thereafter, Lister's ideas about chymistry and mineral and metal formation—which he developed as part of his work on waters—gave rise to debates on the nature of magnetism at the Royal Society, particularly during 1683–1684.

2. Conflicting Agendas and the Politics of Matter at the Académie: Louvois and Duclos on the "Diversion of Chemists"

2.1 Louvois's Agenda: Rejections and Suggestions

François-Michel Le Tellier, the Marquis de Louvois (1641–1691), was the second protector of the *Académie*. Unlike his predecessor Jean-Baptiste Colbert, whose protectorate years (1666–1683) were highlighted by his liberal and pluralistic approach, Louvois is chiefly known for his undiscriminating preference of utility over theoretical abstraction.[12] Following a visit to the *Académie* and the Paris Observatory (founded in 1667), the Englishman J. Monroe reported in June 1699 that while Colbert is remembered as a "great man," Louvois "is called still the Scourge of the Sciences," being interested in scientific work insofar as "it could be serviceable to the king to take a town, or gain a Battle." Louvois, Monroe concluded, was "little inclinable to favour Learning."[13] Apart from his lack of interest in theoretical science, Louvois also contributed indirectly to the *Académie*'s recession. The revocation of the Edict of Nantes in 1685, a key part of his political programme, caused two of the most accomplished academicians, Huygens and Olaus Roemer, both foreigners and Protestants, to leave.[14] Suspicious of the independent merits of "learning," Louvois obstructed theoretical investigations into natural philosophy by insisting that academicians participate in governmental engineering projects.

While Colbert's years are associated with tolerance, progressiveness, and economic prosperity, Louvois's decade of the 1680s is marred by religious intolerance, political instability, and war. Three years into his office, Louvois's tendencies had reached a climax in the form of an interventionist declaration issued by Louvois. Chronologically and thematically our story is bound on one end by Huygens's proposal of 1666 and the subsequent establishment of the *Académie*; on the other end, it is bound by Louvois's powerful 1686 memoir and "ministerial interference."[15] The links we show between Louvois's agenda and Duclos's early work, heritage, as well as two-decades-long career at the *Académie* render this late moment a natural entry point into our analysis.

On 30 January 1686, Louvois delivered through his spokesman Henri Bessé de La Chapelle a memoir that epitomizes his conduct and signals the *Académie*'s trying times under his direction.[16]

> Monseigneur Louvois is wondering what could be done in the laboratory. Could you regard this work not as pure but as applied research for a useful end … I call pure research [recherche curieuse], which arises solely from curiosity, a game, and so to speak a diversion of chemists … I understand by useful research [recherche utile] that which might relate to the service of the King and the State; – not the Great Work which also includes the extraction of Mercuries from all sorts of metals, their transmutation or multiplication, which Louvois does not wish to hear spoken of … The other research more suited to this Company and which would be more to the taste of Monseigneur de Louvois concerns everything that could explain Physique and serve Medicine … Nevertheless, if the Company judges it fitting to work on what chiefly concerns Physique, could it not, while carrying out the analyses of plants, observe also their tastes and note if their salts are similar to those of the soil, and incorporate these observations in the great work it has undertaken on plants … if you prefer to concentrate on medicinal chemistry … [please refrain from] disillusioning people about the cures [empirics] have devised or the futile search for the universal remedy like the philosopher's stone. Could you reprint and enlarge the little book on mineral waters of M. du Clos, explaining more fully what they have that is useful or harmful […].[17]

The general message squares well with depictions of Louvois as a pragmatist. But the memoir had a specific target—aspects of chymistry and matter theory—exemplified by Louvois's numerous references to alchemical terms and pursuits he collectively framed as "a game, and so to speak a diversion of chemists." While "useful research" should indeed be beneficial to the Crown, Louvois emphasized what it *should not* be, singling out "the Great Work … the extraction of Mercuries from all sorts of metals, their transmutation or multiplication." In a utilitarian spirit, Louvois regarded proper natural philosophical investigation as "everything that could explain Physique and serve Medicine."[18] Although generally suitable, "medicinal chemistry" had to be carefully separated from any "futile search for the universal remedy like the philosopher's stone." Finally, it was within this very context of medicinal chemistry (iatrochemistry) and natural history, that Louvois recommended the reprinting and enlargement of "the little book on mineral waters of M. du Clos"—Duclos's *Observations*.

Even though by the mid 1680s few academicians practised chymistry and none were overtly preoccupied with its more alchemical facets, Louvois's concern with chymistry clearly had to do with its proximity to alchemy and its shadowy reputation.[19] Louvois's worry over "what could be done in the laboratory" is even more telling. In view of his call for utilitarian and non-speculative investigation, the "laboratory" stood for empirical and potentially "useful research." This is highlighted by allusions to praiseworthy undertakings such as "the great work … on plants" (Diderot's 1676 *histoire des plantes*) or to Duclos's history of mineral waters. And yet, given Louvois's hesitations, these considerations fail to account for his endorsement of Duclos's work. The answer, found in the institutional context of the *Académie*, is indeed related to the laboratory and even to Duclos in particular, but *not* as the author of the 1675 *Observations*. Duclos's tumultuous career as academician, which, as we shall see, directly informed Louvois's concerns—in pretextual and subtextual ways—exemplifies the evolving standing of chymistry, matter theory, and scientific method during the first two decades of the *Académie*'s existence.

2.2 Duclos's Legacy: Conversions and Diversions

We know little about Duclos's pre-academic career. When he joined the *Académie* in 1666 he was already 68 years old. He established and directed its laboratory, located in the King's Library, where he also resided. Unlike other academicians, following his appointment (and until his death in 1685) Duclos conducted all his scientific work within the *Académie*. During the late 1660s and early 1670s he was one of the most influential academicians.[20] His work on mineral waters stands out within his body of work—major parts of which survive in the minutes of the *Académie*, the *procès-verbaux*, and in manuscripts—as the only book he was ever able to publish under the *Académie*'s aegis.

Duclos died only a few months before the 1686 memoir, and the links between his work and Louvois's policies are evocative. One of the most intriguing documents in this context is Duclos's deathbed declaration, recorded by Nicolas Clément, his long-time neighbour at the King's Library. In it Clément described Duclos as an old physician who "disliked attending the sick, and preferred to give his time … to research on the Philosopher's Stone." Yet when asked about this thorny subject and a life dedicated to "research [recherche] on natural causes, particularly those concerning transmutation of metals and on that called the Great Work," Duclos answered that "there was nothing more futile … than holding out the hope of being able to arrive at the transformation of metals."

When asked about his publications, the old chymist "begged [Clément] to bear witness that he had no complete work except a treatise on salts and mixtures that he had put in the hands of M. de la Chapelle," Louvois's assistant and the deliverer of the memoir to the *Académie* in 1686. Duclos added that he

> had meant for a long time to publish this treatise; that M. Colbert and a substantial proportion of the Académie had approved it, but that because of M. du Hamel [Secretary], being always opposed to it … he had not been able to obtain permission to get it printed, which obliged him to give one part to Elsevier who was at the time in Paris, & who printed it in Amsterdam [in 1680]. Regarding the other writings, he stated that he had burned them five or six months before.[21]

While the sincerity of Duclos's recantation might be questionable, his confession has clearly prompted Louvois's references: to alchemy, to the "philosopher's stone," and to the "Great Work."[22]

On his deathbed, his back allegedly turned on his lifelong scientific passion, the aging Duclos wished to make it known that the *Académie* had denied him the right to publish his "treatise on salts and mixtures." Book censorship and book-burnings were not unusual in the France of Louis XIV, not even in the *Académie*.[23] Some time during 1676–77 a committee of four academicians evaluated Duclos's dissertation. Voting three to one in favour of the manuscript, yet failing to reach a required unanimous decision, the book was suppressed. In what appears to be Duclos's private response to the committee's (now lost) report, he complained of the "weak philosophers that could not stomach Platonism."[24] In 1680, Elsevier, the publisher of Van Helmont and Bayle, published Duclos's *Dissertation sur les principes des mixtes naturels, faite en l'an 1677*, which corresponds to the part signalled by Duclos's reference to "mixtures." The other part, a tract on "salts," was never published, but is found in manuscript.[25] The survival of these manuscripts casts further doubt on Duclos's claim that he had destroyed his other writings.[26]

Duclos was one of the most influential yet controversial members of the early *Académie*. During the 1660s and 1670s he participated in debates on matter theory, chymistry, and scientific method. His dispute with Dodart over the merits of chymical analysis weakened his influence on the *Histoire des plantes* project. His chymical philosophy, which featured Hermetic, Paracelsian, and vitalistic precepts, cost him the publication of his dissertation on mixts in France.[27] By the 1680s his institutional standing had declined further still. As Alice Stroup has argued: "for the laboratory, which was central to the *Académie*'s natural historical research, the early years under Louvois were a period of crisis … Duclos was disaffected by Dodart's appropriation of the natural history of plants, his health was failing, and as a Protestant he was out of favour with Louvois, who did not pension him after 1684."[28]

Both Duclos's deathbed declaration and Louvois's memoir touch on institutional censorship and suppression. Contextualizing these sources against one another reveals that Louvois used Duclos and his heritage as academician and chymist in an equivocal manner. Louvois's memoir was of course not addressed directly against Duclos's testimony. Considered against the institutional backdrop, however, Duclos's recently recorded deathbed recantation—referring to the academic censorship affair of a decade earlier—seems to have at least informed the *subtext* of the memoir, while probably comprising its *pretext*. Even after his death, Duclos's name and work conjured up images of divisiveness and institutionally regulated investigation into natural philosophy. As a highly qualified chymist Duclos's work was both "pure" and "applied." By reproaching in a generalized way the former, Louvois condemned an essential part of Duclos's legacy when he warned against the pursuit of alchemical and hermetic practices like metallic transmutations, which had been explicitly, if perhaps disingenuously, denounced by Duclos on his deathbed. At the same time, Louvois indicated that even a chymist of Duclos's stripe could produce useful work, as long as he adhered to a utilitarian and empirical natural historical approach. Late seventeenth-century assaults on chymistry (and vitalism) usually entailed its rejection in favour of or subjection to mechanistic principles, but in this case the directive was to stay away from speculative work altogether. Louvois's utilitarian rhetoric, as he invoked Duclos, was in effect a refashioning of the latter's complex past into an institutionally sanctioned policy that could and should serve as a model for the institution and its individual members.

We can now turn to Duclos's *Observations* and to the intellectual and institutional contexts of its production, from its origins in Duclos's academic heydays of the 1660s to its publication in 1675. Duclos's dissertation on mixts, as we shall see, was not the only case of censorship his work had suffered. The *Observations* too was the product of a decade-long convoluted and politically charged path.

3. Duclos's *Observations* Between Suppression and Publication: Natural History and Matter Theory

The *Observations* is a natural history of French waters, bearing no apparent link to alchemical or otherwise controversial subjects. Its primary goal was closely related to "medicinal chemistry" as it aimed to classify and analyse chymically the waters' medicinal attributes. It was reviewed favourably in the *Philosophical Transactions*, and translations followed in English (1684) and in Latin (1685).[29]

Louvois called for an expansion of the project, to include accounts of the medical virtues of the waters, and to explain their "useful or harmful" effects. Depicting the book's shortcomings, Duclos expressed grave reservations:

> The Matter being subordinate to Physical Speculation, the Royal Academy of the Sciences have determined to employ themselves in the Enquiry of the Qualities of those [waters] in this Kingdom … The Resolution to proceed herein has not been taken without much consideration; the Reasons from the advantage of these Waters for the restoring Health in many Diseases, being counterbalanced by those of the Difficulties in knowing the Causes of their Properties, which depend particularly upon the Mixtures of Certain Substances which meet together in their Passages in the Earth, or in the Cavities and Interstices of Rocks, which are various and many, as Vapours, Juices, Salts, Earths, etc.[30]

Nature's complexity notwithstanding, the greatest problem was not the *extent* of the investigation of waters but the distinctly descriptive natural historical *method* employed. Lacking causal explanations, the book was an exemplar of "applied [chymical] research for a useful [medical] end," to use Louvois's words. The main problem, as Duclos saw it, was the incompleteness of a study precluding matter theoretical consideration, something that could not be remedied by broadening the project's scope. The nature of "Exhalations and Vapours," for instance, is difficult to know because "the Diversity of their Principles is very great." "All these Diversities of Mineral Salts," Duclos noted, "render the Judgment of the Proprieties of Waters partaking of them very difficult and uncertain."[31] The *Observations'* main limitation, then, was its (purposefully induced) silence on issues like the generation of minerals and the way they influenced the waters "in their Passages in the Earth."

The book's title points to work carried out in 1670–1671 but Duclos's interest in the subject goes further back to a larger chymical project that began as soon as the *Académie* was founded, devised to "determine rigorously the 'true principles of mixts [compounds]' by analyzing such bodies and by generating them and observing their properties."[32] The project, which was Duclos's brainchild, resulted in his censored and partly published "treatise on salts and mixtures."

During 1667 Duclos delivered a number of lectures at the *Académie* on mineral waters and seawater, two matters he considered as closely related due to the importance he ascribed to the "diversities of Mineral Salts" they contained.[33] These investigations laid the foundations of the *Observations*, not least Duclos's formulation of twenty-four parameters of analysis and classification of mineral waters.[34] Yet the evolutionary itinerary, from these early discussions to the 1675 *Observations*, was far from linear. The causal-theoretical explanations, which had been purged from the published work—where they are in effect replaced by Duclos's qualifications and sceptical remarks—are found in the early lectures. Towards the end of "continued examination …" memoir Duclos argued that "it is highly likely that the different properties of mineral waters owe to the diversity of the salts with which they are imprinted:"

> […] we find salts capable of producing nearly all the effects we observe in the usage of these waters … If it is true, as I think, that the salt is the primary natural mixt, resulting from the first union of pure elements, namely the igneous spirit with the body of water [l'esprit ignée avec le corp de l'eau] … chymistry has shown that in the resolution of all mixts, salt is found; that their parts, whether mercurial or sulphurous, are reduced to salt, and that the salt is their primary being. This is what Paracelsus claimed in the tenth book of his Archidoxes, that the sea is the mother of all minerals. That is, that all the minerals originate in a salt. Van Helmont proposed his alkahest as a solvent capable of reducing all the mixt bodies into salt without any residues, earthy or otherwise.[35]

Tracing the evolution of the *Observations* reveals its striking itinerary and the dynamic nature of natural philosophical investigation. Put simply, in 1667 Duclos began at the *Académie* a series of examinations of mineral waters, some of which included alchemical considerations. Eight years later, a book drawing on this investigative programme was published, referring to analyses done during 1670–71. Duclos attributed the delay in publication—the lag between 1671 and 1675—to "all these Difficulties [that] have hindered, these four years … what the Naturalists of the Academy have been able to observe on Waters … which they have examined according to the opportunities which they have had."[36] Since the *Académie*'s minutes and records for 1670–74 are missing, it is difficult to establish the nature of these "difficulties." In any case, the published result was a sanitized account, devoid of Duclos's theoretical accounts of matter, which he considered central. Finally, about a decade later when Duclos died, the *Observations* was portrayed in Louvois's memoir as an archetype for "useful research."

Considering Duclos's complex work, career, and legacy bears out the *Académie*'s struggle to balance politics and science as well as individual and corporate interests, while seeking to control theoretical debates. Much like the Royal Society, one of the main strategies the *Académie* had explicitly adopted from its inception was an overt commitment to natural historical and experimental work. Even as late as 1686, by which time all the overly ambitious natural historical projects were completed, the importance of Baconian agendas was still being forcefully reiterated. Yet Louvois's version was highly restrictive compared to Huygens's proposal of two decades earlier, in which the Dutchman promoted "Baconian precepts … as a supreme way for attaining knowledge of the causes of all that can be seen in nature." Louvois's inhibited decree for "useful research" undoubtedly steered academicians away from topics like "magnetism … the composition of all other … bodies … [or] the ways metals, stones and plants grow," to use some of Huygens's examples.

Yet during the same time members of the Royal Society were debating vigorously these exact subjects. Questions about the genesis of minerals and metals led to discussions about the nature of matter and the role of chymical explanations, which led to disputes over the merits of the "magnetic philosophy," pitting vitalist-chymical explanations against mechanistic ones.[37] As we demonstrate, the fact that what had been suppressed at the early *Académie* was being pursued actively at the Royal Society in the 1680s is more than a coincidence. Duclos's natural philosophy and chymical cosmology inspired these developments in England, both directly and indirectly. His ideas first crossed the Channel through Lister's work on mineral waters, followed by the English translation of the *Observations*. Interestingly, Lister not only drew substantially on Duclos's ideas and methods but also employed ideas similar to those found in Duclos's early blueprints, to which he may have been exposed. At the same time, working within a different institutional and political milieu, Lister expanded these views, which were then subjected to active debate. When examined in their respective contexts, Duclos's and Lister's work in natural philosophy highlights the commonalities and differences between the two scientific societies and intellectual climates.

4. French Waters Across the Channel: The *Observations* and Lister's *De fontibus*

4.1 From Mineral Waters Back to Mineral Formation: Lister's **De fontibus***, Pyrites, and Vital Salts*

As the contemporary institutional embodiment of empiricist agendas, the Royal Society took interest in the French natural histories of plants and of waters, both of which relied on chymical analysis. As Hunter has shown, the Royal Society displayed an "early concern for systematic data-collecting," based in particular on Baconian methodology.[38] Despite Duclos's reservations, and despite its origins, the *Observations* was a high instance of such inductive empiricism, in which Bacon's "Articles of Inquiry" included topics like: "From what Place they came"; "Whether being put to Distillation by an Alembic … there rose and distill'd first of all some Liquor more subtil than the rest"; etc.[39] Forced to limit his theoretical explanations, Duclos deployed chymical testing and analysis as classificatory markers.

Boyle's own work on the subject—the *Short Memoirs for the Natural Experimental History of Mineral Waters* (1684/5)—which was published in reaction to Duclos's work, provided an even more conspicuous illustration of this methodology. Although he praised the "little Tract of the

French Mineral Waters … publish'd by the Virtuosi of the famous Royal Academy of Science at *Paris*," Boyle promised the reader a work "far beyond any thing that has been publish'd in this kind."[40] Whereas Duclos stressed the shortcomings of adhering too closely to a natural historical approach, Boyle extolled its merits emphatically as the only fit method. As if echoing Louvois, Boyle stated, "I am apt to look upon the difficulty, of *Securely* determining the Effects of Mineral Waters *a priori*, as little, if at all, less than insuperable to Humane Understandings." Boyle's *Short Memoirs* was thus an empirical natural history intentionally devoid of speculative or "a priori" considerations. Boyle sought to produce a genuine "Historical account of a Mineral Water," which would offer a "Sett of heads" alongside a "variety of Methods or ways, to make Tryals fit for investigating the Nature, or examining the Qualities of the Propos'd Water." Likewise, he stressed the utilitarian dimension of the book, the aim being "much more to assist practical Physicians to find the vertues and effects of Mineral Waters, than to inform Speculative Naturalists of their causes and manner of being generated."[41] A similar competitive nationalistic spirit can be detected in the English edition of Duclos's *Observations*, which "has been thought not unworthy to speak the *English* Tongue," the anonymous translator explained, since "It may be hop'd, that Our Nation … may hence be excited by a Generous Emulation, to a like, if not greater Performance in this kind."[42]

In 1682, another work on mineral waters, *De fontibus medicatis Angliae exercitatio* was published, to which Boyle referred as the "late ingenious exercitations, of the Learned Doctor [Martin] *Lister*."[43] On 12 April 1683, Fellow of the College of Physicians Tancred Robinson assured Lister in a letter that Boyle "is as proud of your good opinion, as you can possibly bee of his; hee hath try'd most of the experiments of your last book [*De fontibus*] … hee shew'd mee this day the severall crystallisations of those salts, which you have describ'd and figur'd; and hee says hee is very fearfull to propound anything to a person of your piercing sagacity."[44] Lister, for his part, collected several of his contributions to the *Philosophical Transactions* and compiled them into his *Letters and divers other Mixt Discourses in Natural Philosophy* (1683), which he dedicated to "the most noble and truly vertuous Robert Boile, Esq."[45]

Lister was educated at Cambridge and studied medicine at Montpellier (1664–1666), a post-Reformation stronghold of Protestantism, chemical philosophy, and vitalism.[46] Elected a Royal Society Fellow in 1670/1, he followed various studies including botany and mineralogy, contributing over fifty papers to the *Philosophical Transactions*.[47] As vice-president of the Royal Society, he often chaired meetings when the President, Samuel Pepys, was called away on business. During 1683–1684 Lister advanced his vitalist theory on the origins of minerals and metals, which included the foundation for his chymical theory of magnetism.[48] Both theories originated in his medical interests in the healing properties of English mineral waters, which relied on Duclos's work on the subject. Lister published *De fontibus* privately in 1682. A second edition appeared in 1684, and the English edition of Duclos's *Observations* (1684), advertised it as "confirming the Experiments of our French virtuosi."[49] Like Duclos, Lister surveyed English mineral waters, "comparing the several salts of medicinal waters, their similitudes, and contrarieties."[50] A careful reading of *De fontibus*, however, shows that Lister's account, while supporting and "confirming" Duclos's findings, advanced in a sense the matter theoretical explanations that were missing from Duclos's *Observations*. Experimentally, Lister's findings can be seen as supporting Duclos's; theoretically, however, we find continuities alongside distinctions.

Like Duclos, Lister recognized the impact of "Vapours" and "Salts" on waters. Unlike the chymically minded Duclos, Lister's mineralogical approach was prominent, as he paid meticulous attention to shapes and forms of salt crystals. Lister's was a common practice among late seventeenth-century chemists who considered the macroscopic and microscopic examination of crystalline structures important, as their regularity seemed to suggest their innate formative power in chemical transformation. Lister concluded from isolation by dehydration that in "the mineral springs of England … only two kinds of salt have been found, that is nitre of lime [salt of lime] and common salt."[51] This accorded with Duclos's findings that "the Salts which have been Condensed after Distillation, or slow Evaporation" of mineral waters were of either "the Nitre of the Ancients, which is a Sulphurous-Mineral Salt" or "Common Salt."[52] Lister explained the presence of sea salt in English springs by the runoff of seawater inland but "Niter of lime" was a different case. "Where there is nitre of lime, there is always limestone to be found," Lister explained, "salts, when dug-up, grow into crystals. But there exists a second way in which these develop … [which] occurs slowly and in stages, on the analogy of the method by which plants germinate."[53] This observation helps us understand Lister's interests and reasoning.

An understanding of Lister's work on salt crystals is best attained by placing him in the intellectual context of the seventeenth-century chemical debate about the formation of minerals. Some chemists, such as Joseph Duchesne (1544-1609), Johann Glauber (1604-70), and Nicaise La Febvre (1610-1669) claimed there was a "hermaphroditical" or formative salt believed to be responsible for the minerallogenesis.[54] As Emerton stated, "As the instrument of the form, as embodiment of the generative seed and spirit, and as the transmitter of mineral qualities including crystallinity, salt became the formative principle par excellence, the formal cause of minerals."[55]

There were several contenders for the identity of this formative salt principle including niter, sal ammoniac, and marine or common salt, but many early modern chemists, Lister most thoroughly, postulated that the vitriolic salt produced by iron pyrites or fools' gold was the true "universal salt" responsible for generating minerals.[56] Indeed, Vitriol itself was "sometimes identified" by seventeenth-century physicians and natural philosophers analyzing spa waters with an "Essurine Acid Salt," a "universal salt which could take on different forms according to the minerals with which it came into contact. "[57] Vitriol had the advantage of being "conveniently assimilable" to some of the principles of what were thought to be the fundamental principles of matter, the Paracelsian *tria prima* of salt, sulfur, mercury: vitriol was a salt, and the vitriolic liquid or spirit of vitriol (sulphuric acid) called 'gur' or 'bur' was believed by Glauber and other early modern mining authors to be a sign of the presence of mineral ores, "with which sulfurous exhalations were also associated."[58]

Indeed, roughly the first third of the *De fontibus* is dedicated to two subjects: "Descriptions of the four better known fossil salts"—vitriol, alum, saltpetre, sea salt—and a lengthy discussion on "Veins of Iron" and pyrites, also known as "fool's gold."[59] Whereas the latter is the subject of the second and longest chapter in the book, mineral waters are first discussed only in the fourth chapter. Lister had a longstanding interest in pyrites, going back to 1670s and to an unpublished manuscript, in which he described pyrites as "ironstone marcasites," which were "nothing else but a body of iron disguised under a vitriolic varnish."[60] The exploration of pyrites in a book on "Healing Springs" can be understood only in reference to Lister's cosmology, in which pyrites and related chymical processes had key explanatory roles.

Lister asserted that salts form or "grow into crystals" either quickly through dehydration or in a slower way, a process he likened to the germination of plants. His vitalist reasoning was based on an analogy between pyrites and limestone: "A ferrous vein is of course the parent of green vitriol, and limestone of salt of lime."[61] By "ferrous vein" Lister meant pyrites.[62] While vitriol develops from pyrites, salt of lime (nitre of lime) grows out of limestone. Upon exposure to moist air, pyrites (iron sulphide – FeS_2) undergo a spectacular change, turning into "green vitriol" ($FeSO_4$ – iron II sulphate),[63] a green salt widely used in ink manufacture and wool dying since the Middle Ages.

Extending the analogy, Lister perceived the visibly striking transformation of pyrites into green vitriol, and of limestone into nitre of lime, as comparable processes, which he associated with the way "plants germinate," gradually maturing and turning green in the presence of air. Like vitriol, limestone salt could only result from the exposure of limestone to air: "nitre of lime is produced in one and the same way as vitriol." He derived this assumption analogically and empirically. Nitre of lime was produced by the exposure of limestone to air since "where there is nitre of lime, there is always limestone to be found."[64] Lister was likely observing the formation of saltpetre on walls that had been whitened by limestone.[65]

Based on what he considered as a pioneering analogical explanation (by analogy to pyrites), Lister thought he was "the first … to give the shape and description of this lesser known salt [of limestone]."[66] He specified that the salt would not form when limestone was steeped in water. Thus limestone salt—like vitriol and plants—developed *only* in the presence of air through a slow and gradual maturation process. The explanation was modelled on the chymical behaviour of pyrites:

> The creation of vitriol makes the whole matter clear. Its first eruption from pyrites is exceedingly premature, if it occurs in contact with air; but, as time proceeds, it becomes a little more mature. And yet fully formed vitriol is not produced from any ferrous stone until after its due maturity which it finally reaches after a continuous period of development … If however [a pyrite] is kept perpetually under water I am not yet convinced that it will be productive of any salt. Certainly no vitriol whatever will be generated.[67]

As we have seen, in the *Observations* Duclos reported having obtained limestone salt from mineral waters only by dehydration, which Lister would refer to as the "premature" way. Tellingly, Duclos mentioned what Lister called the "second way in which these [salts] develop"—through the process that "occurs slowly and in stages" and it is akin to vital chymical processes of transmutation. Duclos found no vitriol in the waters, which corroborated Lister's view that the salt could only be formed through contact with air. "It is not stated that mature vitriol can be drawn from any of our mineral springs as far as I know," Lister clarified, and "The Philosophers of Paris quite rightly marvel at this after a careful examination of about one hundred mineral springs in France."[68] Duclos kept theoretical (let alone vitalist) considerations out of the *Observations*, merely noting that "vitriol, which shooteth forth by the humid air on Sulfurous Marchasites [pyrites] hath likewise a Succulent art, Condensable only by a total evaporation of its Aqueous Humidity."[69] Tracing the origins of this remark back to the 1660s and to the early drafts of the *Observations* provides the missing theoretical background.

In 1667, between the April memoir on "observations on two different salts which are found in seawater" and the July memoir on the "continued examination of diverse mineral waters" Duclos lectured before the assembly only once, on 14 May.[70] His topic was "the action of air on some clay earths and on their marcasites":

> I have observed that these marcasites [pyrites] … before having been repeatedly imprinted by the air, and filled with vitriolic salts, yield nothing but iron. But after a substantial period of time … having been repeatedly imprinted by the air and filled up with vitriolic salts, in which [the salts] mature, and become perfected, various metals are successively obtained, according to their degree of maturation: first copper, then silver, and finally a bit of gold … the clays [earths] in which these marcasites are found, also ferment in the air, assuming various dispositions … the nitrous earths, when exposed to air, are filled with saltpetre as if the air caused the nitrous seed they contain to vegetate, nourishing it or at least carrying [nourishment] along with it. These seeds or ferments therefore determine [inform] the air or what it carries with it to produce the nitre in nitrous earths or the vitriol in vitriolic earths.[71]

The "seeds or ferments" carried by the air are agents of transmutation, attained by the imprinting of baser metals with "vitriolic salts." Such mineral salts, Duclos clarified in the *Observations*, originate in dried up or solidified "mineral vapours or exhalations [that] do mix with common waters" to determine their qualities. The "first Beings or Embryo's of Mineral Salts are nothing else but Vapours or Juices unconcrete, whereof some may be Condensed … or be disengag'd from their matrixes, and rendered capable of Concretion by the means of the Air."[72] Before having had a chance to "ferment" and be "imprinted by the air" the pyrites yielded only iron; following a prolonged exposure to air, they transmuted into other metals like silver and gold.

Both Duclos and Lister have assigned a key role to air, using vitalist metaphors. While Lister referred to mineralogical parents, germination, and growth, Duclos spoke of seeds, maturation, fermentation, nourishment, and vegetation. Lister advanced these interpretations in his *De fontibus* whereas Duclos's similar speculations were omitted from the *Observations*. Lister's numerous references to the work on waters of the *Académie* clarify his reliance on Duclos's chymical ideas. Yet Lister was not only familiar with the *Observations*, but seems to have also been exposed to some of its unpublished and suppressed parts.[73]

In the preface to *De fontibus* he declared his interest and familiarity with the deliberations of the *Académie* on mineral waters: "in order to object to an assertion made by P. Guirius … I am not unduly impressed by his salt of Alumen, about which he forcefully argues, after making a careful investigation of what D. Closeus [Duclos] had to say about the same waters before the Philosophers of Paris."[74] Lister may be read here as referring to the *Observations*, but the reference is perhaps to a lengthy (again, unpublished) memoir Duclos had presented to the *Académie* on 12 March 1667, in which he critiqued the then newly published *Le Secret des Eaux Minérales Acides* of one Pierre Le Givre.[75] Le Givre's name, however, is nowhere mentioned in the *Observations*. Moreover, this 1667 critique centres on the role of the "salt of Alumen" (mentioned by Lister) in "ferruginous" waters and their role in the formation of iron.[76] The lack of mention in the *Observations* of Duclos's critical evaluation of Le Givre—an examination of waters, matter theory, and minerallogenesis—squares well with the patterns of suppression we have described.

This further suggests that Lister had access—either personally during one of his visits to France or through correspondence—to Duclos's early drafts and ideas.[77] Moreover, Lister's reference here had more to do with his interest in the nature of pyrites and iron than with a mere wish to appeal to Duclos's authority. In particular, he sought to refute what he considered to be Le Givre's "ill-considered claim" that "green vitriol … is not produced" from pyrites "although absolutely no other kind is produced naturally from Pyrites and Pyrites itself is nothing other than iron in its pure metallic form."[78] Lister indeed found support in Duclos, who claimed that the only cause underlying the qualities of the "ferruginous" waters was "the primary being of iron or its embryonic and soft vein."[79]

Like Lister, Duclos sought to advance causal and theoretical explanations concerning mineral formation as a key to understanding the virtues of mineral waters. Despite his reservations, Duclos decided to publish his findings, most likely because he saw value in offering a classification of waters based on their salt contents and other chymical attributes. Compared to Duclos's 'sanitized' *Observations*, Lister's *De fontibus* evinces its author's independence as natural philosopher and chymist, delineating both his reliance as well as his departures from Duclos's work.

4.2. Lister's Departure: From Mineral Formation to Magnetism

Duclos, we will recall, held that "salt is the primary natural mixt, resulting from the first union of pure elements, namely the igneous spirit with the body of water … salt is their primary being … the sea is the mother of all minerals … [and] all the minerals originate in a salt." This view embeds Paracelsian, Helmontian, and Neoplatonic precepts. Paracelsus first suggested "the *Water* or *Sea*, the true Element, as being the true Mother of all Metals."[80] Van Helmont later developed this idea into a vitalist chymical cosmology in which water was the primary element and universal material substratum, while fermentation was the fundamental process governing material change. For Duclos, all salts ultimately originated from water through its activation by the universal "igneous spirit." In his most substantial departure from Duclos, Lister objected to this metaphysical precept, rejecting "Helmontius' explanation of the generation of vitriol … that salt is formed naturally in water itself."[81] Lister also rejected Duclos's metaphysical view of salt more generally, stating that "sea salt differs completely from the salt of inland springs in kind, and a clear distinction must be drawn in every respect between seawater and fresh water."[82]

Duclos and Lister agreed that air played a central role in the formation of salts, minerals, and metals. Duclos, who thought that all matter originated ultimately from water, maintained that the "first Beings or Embryo's of Mineral Salts are nothing else but Vapours, or Juices unconcrete … disengag'd from their matrixes, and rendered capable of Concretion by the means of Air."[83] He maintained that "mineral vapours or exhalations" had a crucial role in shaping the constitution of the waters, but he refrained from discussing their nature or mechanisms of action. Adamant "that pyrites can by no means produce its own vitriol from its own waters," Lister provided an intriguing explanation.[84] To turn into vitriol, pyrites had to come in contact with air, even underground where the mineral waters are formed and where air is not commonly found. Hence "pyrites and limestone … dissolve, as it were, entirely in springs of this kind because of an exceedingly subtle current of air."[85] Although vitriol will not result from pyrites found under water or underground, "the same stone, or if you will, metallic ore, when immersed into water, is as it were dissolved into spirit, or a sulphurous exhalation … That is to say, it becomes spirit in its whole nature."[86] Pyrites are activated and volatilized when immersed in water, emitting a "sulphurous exhalation," a property unique only to pyrites and limestone, the only substances Lister thought capable of giving off "a vaporous breath."[87]

According to Lister, these "sulphurous exhalation[s]" emanating from pyrites were closely linked to the production of magnetic qualities, since "in no mine whatever in England is sulphur to be found unless pyrites is present to the same extent … in order to know why and to what extent some mined substance contains pyrites, employ a magnet … and you will never be deceived by the experiment.[88] William Gilbert, the most influential English magnetic philosopher, argued that subterranean "exhalations are the remote cause of the generation of metals." Expressing ideas that clearly influenced Lister, Gilbert asserted that

> these exhalations and the fluids produced from them enter bodies often and change them into marchasites [crystallised form of iron pyrites] and they pass into veins … and in time there results a vein of iron, or loadstone is produced, which is nothing but a noble iron ore; and for this reason and also on account of its matter being quite peculiar and distinct from that of all other metals, nature very seldom or never mingles with iron any other metal.[89]

Combining Gilbert's and Duclos's ideas on minerallogenesis and metallogenesis, Lister argued that pyrites, iron, and loadstones constituted a separate species of metal; iron was the source of magnetism, and pyrites the source of its creation. And the same sulphurous exhalations from the volatile salts of pyrites that heated hot springs, when ignited, resulted in thunder and lightning which were also magnetic in nature.[90] This explains in part why the word "magnet" appears well over thirty times in a work on English mineral waters.

At the Royal Society, Lister's chymical theory posed a direct challenge to Boyle's mechanistic accounts of magnetism, designed in part to refute the threat of Gilbertian animism and other vitalist theories. In 1676, Boyle published a series of experiments on the subject, based on the assumption that "magnetical operations may much depend upon Mechanical Principles."[91] He noted that touching or rubbing objects against a loadstone conferred magnetism upon them. Boyle's view of magnetism, which involved direct and mechanical particle contact—what he called "atomic effluvium in constant circulation"—rather than action at a distance, was adopted by other prominent Fellows, such as Thomas Brown, Henry Power, and Robert Hooke.[92] To address the challenge of Lister's chymical theory of magnetism, while bolstering Boyle's previous inquiries, a series of experiments took place during 1683–1684 at the Royal Society under the direction of Hooke, centring on the heating, drilling, hammering, and breaking of magnets.[93] Although Hooke demonstrated before the Society that magnetism was induced in an iron drill bit by the mechanical action of drilling, his experiment failed to account for Lister's observation that lightning had reversed the polarity of a compass. According to Hooke, "by striking a needle with a brass hammer the pole might be changed from north to south. To which it was answered by Dr. Wallis that there was nothing of hammering mentioned in this relation [of the lightning flash] but with more probability a new touch of a magnet."[94] The experiment was ultimately impracticable because if the compass had been hit, it would have been badly damaged.[95]

Out of some exasperation, at the next meeting, Lister submitted a paper relating experiments he had performed, in which he concluded that magnetic bodies "can affect no change upon a magnetically touched drill." "Much less can we expect," he added "that glass or flint, or hard wood should do it: which I recommend again to farther trial, because Mr. Hooke owned he could not make them succeed in private trial, accusing the too soft temper of the drill."[96] Hooke subsequently performed a series of failed experiments in which he had drilled marble, copper, and brass with steel shafts, yet no magnetic effects were detected.[97] Thereafter Lister's magnetic theories went silent, and his point about lightning and the compass reversal would not be determined until nearly a century later, when the oscillatory nature of the electric discharge of lightning was discovered.[98] Opposing the mechanistic ideas of Fellows like Power, Boyle, and Hooke, Lister played an important role in what Stephen Pumfrey called "the final resurgence of interest in magnetic philosophy" in England, with its roots in Gilbertian vitalism.[99] Hooke and other mechanical philosophers at the Royal Society seem to have felt about Lister much like Louvois did about "pure research" in general, which he identified with the "diversion of chemists."

5. Conclusion

Reconstructing the fate of the *Observations* thus reveals a wide canvass across which we can appreciate how natural philosophical ideas and practices shaped and have been shaped by intellectual, institutional, and national factors between the two leading scientific societies of the late seventeenth century. Our analysis also illuminates the shifting relations between matter theory and chymical methods during a most formative period in the history of their evolution, and provides a case study of the dynamics of knowledge transmission between early modern French and English natural philosophers and their respective scientific affiliations. The *Académie* under Louvois's administration sought to put chymistry in the service of benign classification and analysis practices, whether for natural historical empirical descriptions or for practical medical ends. Discussions of matter theory, particularly any involving vitalism, had been institutionally banned. As the *Académie* attempted to distance itself from such natural philosophical concerns, Duclos's investigations had been suppressed—his work censored and speculative chymical work actively hindered. Duclos's sanitized and empirically (re)oriented *Observations* was well-received across the Channel, as it squared closely with the Royal Society's tendencies toward Baconian empiricism and classificatory natural history. However, Lister knew Duclos's work in a rather different light, in close alignment with its more alchemical and vitalistic dimensions, which he combined with Gilbert's work to create a unique vitalist theory of minerallogenesis and magnetism that challenged the Society's espousal of mechanistic doctrines. When as vice-president of the Society in the 1680s Lister attempted to prove his ideas experimentally, Hooke and other fellow mechanists discredited and rejected his efforts. Yet his ideas were not ignored. Theories involving alchemy and vitalism may have met with personal and institutional disapproval in both scientific societies, but they were not overlooked or set aside in the Royal Society. Rather, they were publicly debated, indicating an institutional asymmetry in theory and practice between Duclos's work and its reception by Lister across the Channel.

Notes

[1] Use of the term "chymistry" is guided by Lawrence Principe and William Newman, "Alchemy vs Chemistry: The Etymological Origins of a Historiographic Mistake," *Early Science and Medicine* 3, 32–65

(1998). For studies of chymistry, natural history, and the Scientific Revolution see Lawrence Principe, ed. *Chymists and Chymistry: Studies in the History of Alchemy and Early Modern Chemistry* (Sagamore Beach, MA, 2007).

[2] States of secrecy in early modern science have recently served as the theme of the June 2012 issue of the *British Journal for the History of Science*, edited by Koen Vermeir and Dániel Margócsy.

[3] Lawrence Principe, "Robert Boyle's Alchemical Secrecy," *Ambix* 39 (July 1992): 63–74, on 63. See Principe, *The Aspiring Adept: Robert Boyle and His Alchemical Quest* (Princeton, N.J., 1998); William Newman, *Gehennical Fire: The Lives of George Starkey, an American Alchemist in the Scientific Revolution* (Cambridge, Mass., 1994); Principe, "Alchemy Restored," *Isis* 102 (2011), 305–312; Principe, "Reflections on Newton's Alchemy in Light of the New Historiography of Alchemy," pp. 205–19 in *Newton and Newtonianism: New Studies*, eds. James E. Force and Sarah Hutton, (Dordrecht, 2004). William R. Newman, *Atoms and Alchemy: Chymistry and the Experimental Origins of the Scientific Revolution* (Chicago: University of Chicago Press, 2006).

[4] Michael Hunter, "The Royal Society and the Decline of Magic," *Notes and Records of the Royal Society* 65, 2 (2011) 103-119.

[5] For a recent evaluation of scientific connections and knowledge exchange between Britain and France see Robert Fox and Bernard Joly (eds), *Franco-British Interactions in Science Since the Seventeenth Century* (Milton Keynes, UK: College Publications, 2010), esp. 1–43.

[6] Christiaan Huygens, *Oeuvres Complètes* (The Hague: Martinus Nijhoff, 1888–1950), vol. 6, 95–96 (letter undated). The phrase Huygens used was "dessein de Verulaminus." [Boantza's translation].

[7] Ibid.

[8] See, for instance, Anita Guerrini, "Buffon and the Natural History of Animals," *Notes and Records of the Royal Society* 66, 393–409 (2012); Victor Boantza, "Alkahest and Fire: Debating Matter, Chymistry, and Natural History at the Early Parisian Academy of Sciences," in O. Gal and C. Wolfe (eds), *The Body as Object and Instrument of Knowledge: Embodied Empiricism in Early Modern Science* (Dordrecht: Springer, 2010), 75–92.

[9] Samuel Duclos, *Observations on Mineral Waters of France Made in the Royal Academy of the Sciences* (London: Henry Faithorne and John Kersey, 1684).

[10] Anna Marie Roos, *The Salt of the Earth: Natural Philosophy, Medicine, and Chymistry in England, 1650–1750* (Leiden: Brill, 2007), 74.

[11] Michael Hunter and Edward B. Davis (eds), *The Works of Robert Boyle* (London: Pickering and Chatto, 1999-2000), vol. 10, xxix.

[12] Although Louvois's ministerial conduct was not the sole cause of the *Académie*'s decline during the 1680s, his administration had a detrimental effect on its overall function. See G. G. Meynell, *The French Academy of Sciences, 1666-91: A reassessment of the French Académie royale des sciences under Colbert (1666-83) and Louvois (1683-91)* (Dover: n.p., 2002). John. M. Hirschfield, *The Académie Royale des Sciences (1666-83): Inauguration and Initial Problems of Method* (New York: Arno Press, 1981). Adrian Mallon, "Science and Government in France, 1661–1699: Changing Patterns of Scientific Research and Development" (Queen's University Belfast: Unpublished PhD thesis, 1983). Mallon builds on R. Hahn, *The Anatomy of a Scientific Institution: The Paris Academy of Sciences, 1666–1803* (Berkeley: University of California Press, 1971).

[13] Elmo S. Saunders, "The Decline and Reform of the Académie des Sciences à Paris, 1676–1699" (Ohio State University: Unpublished PhD Thesis, 1980), 11.

[14] Joseph Bertrand, *L'Académie des sciences et les académiciens de 1666 à 1793* (Paris: J. Hetzel, 1869), 43–44.

[15] See Alice Stroup, *A Company of Scientists: Botany, Patronage, and Community at the Seventeeth-Century Parisian Academy of Science* (Berkeley: University of California Press, 1990), 51–56, 107.

[16] David Sturdy, *Science and Social Status: The Members of the Academie des Sciences: 1666–1750* (Woodbridge: Boydell Press, 1995), 215.

[17] Académie Royale des Sciences, Procès-Verbal de séance, tome 11: 157r–158r (hereafter: AdS, PV);

also in Meynell, *op. cit.* (note 12). We are aware that the word 'research' has a modern ring but Louvois refers to "recherche" (curieuse and utile or speculative and useful respectively), which could be translated as (re)search, study, or investigation.

[18] On the Academy and utility see Robin Briggs, "The Académie Royale des Sciences and the pursuit of utility," *Past and Present* 131, 38–88 (1991).

[19] Mi Gyung Kim, *Affinity, That Elusive Dream: A Genealogy of the Chemical Revolution* (Cambridge, MA: MIT Press, 2003), 17–110.

[20] Sturdy, *op. cit.* (note 16), 108.

[21] Duclos's deathbed declaration is recorded in *Nouvelles de la république des lettres*, October 1685, 1139–43; also in Meynell, *op. cit.* (note 12).

[22] On the political and institutional background to this declaration, as well as the circumstances of Duclos's election to the *Académie*, see Victor Boantza, *Matter and Method in the Long Chemical Revolution: Laws of Another Order* (Burlington: Ashgate, 2013), 17–21.

[23] Jonathan Israel, *Radical Enlightenment: Philosophy and the Making of Modernity 1650–1750* (New York: Oxford University Press, 2001), 97–104. Pierre Bayle's first work was censored in 1681.

[24] MS. fr. 1333. S. Duclos, 'Dissertations physiques … faites en l'an 1677 and Remarques sur les Essais physiologiques de Boyle,' July 1688, from f. 238. This is the original version of Duclos's Dissertations physiques sur les principes des mixtes naturels, as submitted to the *Académie* in his application to publish the book. The negative report of four academicians – Blondel, Du Hamel, Perrault, and Mariotte – appears on fols. 42v–44r.

[25] MS. fr. 12309 (MF. 15775). 'Dissertations sur les sels contenue en plusieurs lettres dans a un physicien d l'academie royale des sciences par un autre physicien de la mesme academie en l'an 1677.' This is an epistolary manuscript consisting of 29 unsigned letters, arranged along four themes: 'Du sel en général', 'Des sels primitifs nitreux' and 'Du sel commun resoult & circulé'. For details see R. Franckowiak, Le développement des théories du Sel dans la chimie française de la fin du XVIe à celle du XVIIIe siècle (Université Charles de Gaulle, Lille III: Unpublished PhD Thesis, 2003), 137–149.

[26] This is further supported by the existence of yet another (explicitly alchemical) manuscript in La bibliothèque de l'Arsenal in Paris. S. C. Duclos, MS 2517, 'Abregé de La transmutation projective des Métaux. Recueil de Mr Duclos sur la Transmutation des Métaux'.

[27] See Boantza, *op. cit.* (note 22), 17–26; Alice Stroup, "Censure ou querelles scientifiques: l'affaire Duclos (1675–1685)," in Christine Demeulenaere-Douyère and Eric Brian (eds), *Règlement, usages et science dans la France de l'absolutisme* (Paris: tec et doc, 2002).

[28] Stroup, *op. cit.* (note 15), 54–55

[29] "An Accompt of Some Books," *Philosophical Transactions*, 11, 611–622 (1676) on 612–621. S. Du Clos, *Observationes super acquis mineralibus diversarum provinciarum Galliae* … (Leiden: Peter Van Der As, 1685). See Roos, *op. cit.* (note 10), 74. Interestingly, the Latin edition, which appeared in Leiden in 1685, also included a Latin translation of his dissertation on mixts—*Dissertatio super principiis mixtorum naturalium*—first published in French by Elsevier five years earlier.

[30] Duclos, *op. cit.* (note 9), 2–3.

[31] *Ibid.*, 4, 6, 10, 12.

[32] Frederic L. Holmes, "Analysis by fire and solvent extractions: The metamorphosis of a tradition," *Isis*, 62, 130–48 (1971) on 133. In the inaugural meeting of the *Académie*, held on the last day of 1666, Duclos presented a comprehensive "Project d'exercitations physique," at the heart of which was the "recherche des principes des mixtes naturels." The latter became the blueprint of his 1680 *Dissertations sur les principes des mixtes naturels*. In this lengthy memoir, Duclos set out the foundations of his matter theory and experimental views. Resembling his research framework for the study of mineral waters, he identified twenty-three parameters for the examination of natural mixts. AdS, 1: 2-13.

[33] "Observations de deux sels différentes, qui se trouvent en l'eau de la mer" (30 April) AdS, PV, 1: 121–129; "Examen de l'eau minérale de Passy" (July 30) AdS, PV, 1: 135–140; "Examen continué de diverses eaux minerals" AdS, PV, 1: 141–170. The latter discussed "de l'Eau de Ste. Reyne … de Forges … de Vic le

Comte … de St. Myon … de St. Pardoux … de Vichy … de Nery" and many others, all of which featured in the 1675 book. Duclos, *op. cit.* (note 9), 18–24.

[34] AdS, PV, 1: 143–45; Duclos, *op. cit.* (note 9), 13–16.

[35] *Ibid.*, 168–67.

[36] Duclos, *op. cit.* (note 9), 12.

[37] Stephen Pumfrey, "Mechanizing Magnetism in Restoration England: The Decline of Magnetic Philosophy," *Annals of Science* 44 (1987), 1-21.

[38] M. Hunter, "Robert Boyle and the Early Royal Society: A Reciprocal Exchange in the Making of Baconian Science," *British Journal for the History of Science* 40, 1-23 (2007), on 1.

[39] In Bacon's natural histories we usually find, "In each Title, after an Introduction or Preface, Particular Topics or Articles of Inquiry are immediately proposed, as well to give light in the present, as to stimulate further inquiry." Bacon, as cited in *op. cit.* (note 38), 6; Duclos, *op. cit.* (note 9), 13–16.

[40] Robert Boyle, *Short Memoirs for the Natural Experimental History of Mineral Waters* in Hunter and Davis, op. cit. (note 11), Advertisement, A2 (recto and verso).

[41] *Ibid.* 4–5, 7.

[42] Duclos, *op. cit.* (note 9), preface (not paginated).

[43] Boyle, *op. cit.* (note 40), fol. A3 verso. Martin Lister, *De fontibus medicates Angliae* (London, 1682); or "Exercises on the healing springs of England."

[44] Oxford, Bodelian Library, Lister MS 34, fol. 34r.

[45] Martin Lister, *Letters and Divers Other Mixt Discourses in Natural Philosophy* (York: J. White for the author, 1683). The text is in two editions. The first edition of *Mixt Discourses* is in the Huntington Library, in San Marino California. It does not appear in J. F. Fulton, *A Bibliography of the Honorable Robert Boyle, Fellow of the Royal Society*, 2nd ed. (Oxford: Clarendon Press, 1961).

[46] See Anna Marie Roos, *Web of Nature: Martin Lister (1639–1712), the First Arachnologist* (Leiden: Brill, 2011); Allen G. Debus, *The French Paracelsians: The Chemical Challenge to Medical and Scientific Tradition in Early Modern France* (Cambridge: Cambridge University Press, 1991). In the eighteenth century, Montpellier became a centre of medical and chymical vitalism.

[47] For Lister's investigations in natural history and his role as the founder of conchology and arachnology see R. W. Unwin, "A Provincial Man of Science at Work: Martin Lister, F.R.S., and His Illustrators 1670–1683," *Notes and records of the Royal Society of London* 49, 209–30 (1995). For a recent analysis of Lister's cabinets of curiosities see P. Fontes da Costa, "The Culture of Curiosity at the Royal Society in the First Half of the Eighteenth Century," *Notes and records of the Royal Society of London* 56, 147–66 (2002).

[48] See Anna Marie Roos, "Loadstones and Gallstones: The Magnetic Iatrochemistry of Martin Lister (1639–1712)," *History of Science* 44, 343–64 (2008).

[49] As Lister was fluent in French, it is possible that he was the translator of Duclos's *Observations*. He was likely exposed to the work of Duclos during his medical studies, and he was a member of a Montpellier salon of natural philosophy, which included members like Nicolas Steno. Lister visited Paris to tour the *Jardin des Plantes* and consult its *materia medica*, on which occasion he may have been exposed to Duclos' project analyzing mineral waters. Oxford, Bodelian Library, Lister MS 5, fols. 215–27. See also Rob Iliffe, "Foreign Bodies: Travel, Empire and the Early Royal Society of London," *Canadian Journal of History* 33, 357–85 (1998). For the importance and reception of *De fontibus* by contemporaries see Roos, *op. cit.* (note 10), 69.

[50] Review of M. Lister, "De fontibus medicatus angliae," in *Weekly Memorials for the Ingenious* 50, 376–82 (1683) on 377.

[51]Martin Lister, *De fontibus medicates Angliae*, 33. All our quotations are taken from Anna Marie Roos's English translation found in Roos, *op. cit.* (note 10), 207–67. The original pagination, which we use, is kept in the translation.

[52] Duclos, *Observations on Mineral Waters*, 17-18. What Duclos called here "Nitre of the Ancients" is niter of lime (or nitrum calcarium). See, for instance, John Rutty, *A Methodical Synopsis of Mineral Waters . . .* (London: William Johnston, 1757), 420–21.

[53] Martin Lister, *De fontibus*, 49–50.

[54] This paragraph is adapted from: Anna Marie Roos, "Martin Lister and Fool's Gold," *Ambix* LI, 1 (March 2004), 26. Duchesne was a physician to the Duke d'Anjou, and his best known work delineating his ideas about salts was: *The Practice of Chymicall and Hermitcall Physicke*. Trans. Thomas Timme (London, 1605). Le Febvre was Royal Professor of Chemistry at the court of Charles II of England, and a fellow of the Royal Historical Society, and his work on salts was the *Tracté de la chymie* (Paris, 1660). The English translation was entitled *A Compleat Body of Chemistry* (London, 1664); Lister refers to Johannes Glauber's *A Description of Philosophical Furnaces* (London, 1651).
[55] Norma Emerton, *The Scientific Interpretation of Form* (Ithaca: Cornell University Press, 1984), p. 214.
[56] The historiography of the universal salt is discussed by Emerton in *The Scientific Interpretation of Form* pp. 209-232, *passim*. For a discussion of the importance of niter as a formative salt, see Allen Debus, "The Paracelsian Aerial Niter," *Isis* 55 (1964): 43-61.
[57] Noel G. Coley, "Cures without Care: Chymical physicians and mineral waters in seventeenth-century English medicine," *Medical History* 23, 2 (April 1979), 191-214, on 197; For example, Coley notes that physician Samuel Derham stated in his *Hydrologia philosophica* (1685), "As water impregnate with this Acid runneth through the subterraneal Channels and meeteth with a glebe of Alum, Nitre, Marcasites of Iron or of Copper [Pyrites], etc., so it is determined to this or that Specifick Salt, whether Alum, Nitre . . . Vitriol of Iron or Copper." Some chemists even postulated vitriol was the philosopher's stone; common until the eighteenth century was the "vitriol acrostic": *Visita Interiora Terrae Rectificando Invenies Occultum Lapidem* (visit the interior of the earth; by rectifying you will find the hidden stone." See Emerton, *Scientific Reinterpretation*, p. 210, footnote 2.
[58] Emerton, *Scientific Reinterpretation,* p. 217.
[59] Lister, *De fontibus*, 1, 10; see also Anna Marie Roos, "All that Glitters: Fool's Gold in the Early-Modern Era," *Endeavour* 32, 147–51 (2008).
[60] Lister, "Method for the History of Iron," 18; see Roos, *op. cit.* (note 10), 66–67, esp. footnote 79.
[61] Lister, *De fontibus*, 10.
[62] *Ibid.*, 25.
[63] *Ibid.*, 50–51. In modern chemical notation: $2FeS_2 + 7O_2 + 2H_2O \rightarrow 2FeSO_4 + 2H_2SO_4$.
[64] *Ibid.*, 51.
[65] *Ibid.*, 8; this is similar to the formation of nitre crystals in limestone saltpetre caves.
[66] *Ibid.*, 8.
[67] *Ibid.*, 51, 53.
[68] *Ibid.*, 65.
[69] Duclos, *op. cit.* (note 9), 7.
[70] Earlier in April Duclos had read a memoir in which he attacked some of Boyle's mechanistic explanations of the qualities of salts found in his *Origin of Forms and Qualities*, this installment foreshadowed Duclos's five months long systematic critique of Boyle's (September 1667 through February 1668). See Boantza, *op. cit.* (note 22), chapter 1.
[71] AdS, PV, 1: 131–32.
[72] Duclos, *op. cit.* (note 9), 4, 8.
[73] We know that Lister owned and read a copy of Duclos's *Observations*, which he donated to the Bodleian Library (as part of 1200 other books); he left notes in the back of his copy. Lister MS A 261, Bodleian. He also donated a compendium of tracts on mineral waters that contained his work *De Fontibus* as well as the 1685 Latin edition of Duclos's work, which included both the *Observationes super aquis mineralibus* and the *Dissertation super principiis mixtorum* (MS Lister A 268, Bodleian).
[74] Lister, *De fontibus*, preface iii; see also Stroup, *op. cit.* (note 15), chapter 15, note 96.
[75] The reference is to Pierre Le Givre, *Le Secret des eaux minérales acides* . . . (Paris: Jean Ribou, 1667).
[76] AdS, PV, 1: 57–70. Probably potassium alum or the hydrated form of potassium aluminum sulfate $KAl(SO_4)_2 \cdot 12H_2O$, which has caustic qualities.
[77] Beside his stay in Montpellier, from January 1664 to April 1666, Lister also visited France in the summer of 1681; a passport was given to him in Whitehall on 14 July 1681, allowing travel in France (MS Lister 3, fol 1, Bodleian Library).

[78] Lister, *De fontibus*, preface iii.
[79] AdS, PV, 1: 66.
[80] Paracelsus, *His Archidoxes: Comprised in Ten Books, Disclosing the Genuine Way of Making Quintessences, Arcanums, Magisteries, Elixirs, &c., Trans. I. H.* (London, 1661), 146.
[81] Lister, *De fontibus*, 57.
[82] *Ibid*, 6.
[83] Duclos, *op. cit.* (note 9), 8.
[84] Lister, *De fontibus*, 58,
[85] *Ibid*, 74.
[86] *Ibid*, 65.
[87] *Ibid*, 80.
[88] *Ibid*, 77–78.
[89] William Gilbert, *De magnete*, book 1, chapter 7, 36–37. Pumfrey, *op cit* (note 39), 10 noted that Lister read and quoted from Gilbert. This connection was also noted by H.H. Ricker III "Magnetism during the seventeenth century," *General Science Journal* (January 5, 2011), http://www.gsjournal.net/Science-Journals/Essays/View/3239 [Accessed 5 November 2014].
[90] Lister, *De fontibus*, 78.
[91] Robert Boyle, *Experiments and Notes about the Mechanical Production of Magnetism* (London: E. Flesher, 1676), 16.
[92] A. R. T. Jonkers, *Earth's Magnetism in the Age of Sail* (Baltimore: Johns Hopkins University Press, 2003), 83.
[93] Pumfrey, *op. cit.* (note 37), esp. 9–15.
[94] Thomas Birch, *The History of the Royal Society of London for Improving of Natural Knowledge from Its First Rise*, vol. 4, 251–52; see also Pumfrey, *op. cit.* (note 39), 12. Wallis referred to these observations of polarity changes in compasses due to lightning strikes as significant to the study of magnetism many years later, in "A second letter of Dr Wallis to the publisher, relating to Mr Somner's Treatise of Chartham News. And some magnetick affairs," *Philosophical Transactions* 276, 1022–38 (1701). Our thanks to Philip Beeley for alerting us to this source.
[95] Ricker, *op cit* (note 89).
[96] Birch, *op. cit.* (note 94), 262.
[97] *Ibid.*, 265–66.
[98] In a letter to Peter Collinson of 17 July 1750, Benjamin Franklin explained the effect of lightning on the needles of compasses. See Jared Sparks, ed. *The Works of Benjamin Franklin* (Boston, 1840), vol. 5, 223. See also Ricker, *op cit* (note 89).
[99] Pumfrey *op. cit.* (note 37), 9.