

Early Modern Experimental Philosophy: a Non-Anglocentric Overview¹

Dmitri Levitin

[This essay has been published in *Experiment, Speculation, and Religion in Early Modern Philosophy*, ed. Peter Anstey and Alberto Vanzo (New York: Routledge, 2019), pp. 229–90. I had always hoped that one of its functions would be as a useful overview for students. But since the volume in which it appears is rather expensive and not always available even in libraries, and since it employs an unusual citation system that makes cross-referencing difficult, I am providing this final draft as a freely available download. However, I would ask that all citations of this essay in academic publications refer to the printed version, including specific page numbers. D.L., April 2019]

It is now thirteen years since Peter Anstey published his important and influential study, ‘Experimental versus speculative natural philosophy’. There, he argued that the distinction between ‘experimental’ and ‘speculative’ natural philosophy was ‘not only... a fundamental distinction in the characterising of natural philosophical method in the latter half of the seventeenth century, but that it is *the* fundamental dichotomy in discussions of natural philosophical methodology during the period’.² Since then, it has been adopted—whether wholesale or in modified form—by several historians of early modern natural philosophy (including me); it has also received some criticism (including, again, from me). Moreover, Anstey’s position has proved to have important, if complex, connections with other developments in the recent historiography of early modern science, not least the wave of new scholarship on Francis Bacon, natural history, and other subjects. It therefore seems a good time to place the arguments developed by Anstey and his collaborators in broader historiographical context. While I will naturally be offering my own interpretation, I also hope that the following can be used as a useful overview of where the field currently stands. I need hardly say that I expect many of my conclusions to be superseded by future research. (I have offered a few suggestions for where such research might bear most fruit.)

I shall proceed by considering the history of both rhetoric and practice from the early sixteenth century onwards. As regards Anstey’s thesis, I will argue that it has very important historiographical merits. But I shall also contend that it is perhaps too neat and schematic in the order it seeks to impose on the evidence. I think this is the case on two fronts in particular: (i) it underestimates the eclecticism of experimental philosophers and the range of sources from which experimental language and action derived; (ii)

¹ This overview is, in effect, a development of the brief comments about Peter Anstey’s seminal work on seventeenth-century experimental natural philosophy that I was able to make in Levitin 2015a, 327–328. I am very grateful to Peter Anstey and Alberto Vanzo for permitting me to develop my ideas on this subject in this forum. I am also indebted to Mordechai Feingold

and Ian Maclean for invaluable comments on a draft version. Readers should be aware from the outset that I have no interest in positing connections between early modern experimental philosophy and the current philosophical movement of that name, and am sceptical that any such connections exist.

² Anstey 2005, 216 (italics in original).

concomitantly, it is too Anglocentric in its focus, and by extrapolating outwards from categories found in English sources it imposes a distorting filter that misrepresents the developments in early modern natural philosophy. Positively, my thesis will be that across Europe, the institutional and intellectual reconfigurations generated by the humanist movement from the fifteenth century onwards initiated a wave of methodological reflection, of which the shift to experiment—in England as elsewhere—was one consequence.

1. ‘Experimental philosophy’: the thesis

To begin, we need to introduce in a little more detail the arguments of Anstey and his collaborators. The rhetorical distinction between experimental and speculative philosophy, they convincingly posit, became current in the very late 1650s and early 1660s, first and foremost in the methodological writings of Robert Boyle.³ They go on to claim that it had its origins in the classic Aristotelian division between ‘speculative’ and ‘operative’ knowledge, especially as that division had been modified by Francis Bacon (although Bacon himself did not directly adumbrate the experimental-speculative distinction).⁴ At its simplest level, the distinction was a polemical one, emphasising that any natural philosophy not founded on observation and experiment was invalid, and especially that ‘hypotheses’ formed without recourse to experience were to be avoided, and lay at the historical origins of natural philosophical error.⁵ In his earlier articles on the subject, Anstey emphasised the weak, imprecise, polemical and contingent nature of the distinction.⁶ To soften its significance further, Anstey and Alberto Vanzo have noted that some of the most important English experimental philosophers, including Boyle himself, also admitted a positive role for speculation.⁷

Here, then, we have a largely uncontentious thesis about the history of scientific rhetoric at one point in late seventeenth-century England. But Anstey and his collaborators also have much more ambitious, precise, and interesting claims to make. First of all, the qualifying comments about the imprecise and rhetorical nature of talk about experimental philosophy are offset with some very strong statements about the philosophical significance of that talk. We have already seen that Anstey has referred to the distinction between experimental and speculative philosophy as ‘*the* fundamental dichotomy in discussions of natural philosophical methodology in the period’. To this we might add even bolder assertions; for example:

The distinction between experimental and speculative natural philosophy provided the terms of reference for virtually all methodological reflection and practice of natural philosophy in England from the late 1650s to the end of the early modern period.⁸

³ Ibid., 218.

⁴ Anstey and Vanzo 2012.

⁵ E.g., Anstey 2005, 224, stating that ‘the core issue was the relation between hypotheses and experience’.

⁶ See the qualifying comments in Anstey 2005, 220–201, 226; likewise Anstey 2014, at 104:

‘We should not expect... that this philosophy of experiment was definitive or even particularly well formed’.

⁷ E.g., Anstey and Vanzo 2012, 518.

⁸ Anstey 2005, 220.

This distinction provided the fundamental terms of reference for the method and practice of natural philosophy from the 1660s until Kant.⁹

It is particularly noteworthy that the second of these quotations drops the reference to England. This is not coincidental, for in a recent piece Anstey and Vanzo have adopted the technique of measuring the extent to which natural philosophers across Europe were or were not ‘experimental philosophers’ in the period 1660–1800. This approach generates some striking and controversial results, such as the claim that there was an ‘absence of an identifiable movement of experimental philosophers in France in the latter decades of the seventeenth century’.¹⁰ I will return to these claims below. For the time being, I should like to note that what we have here is a clear example of reification. For we have moved from the identification of a broad and rather promiscuously applied rhetorical counterpoint in Restoration England, to the positing of a concrete philosophical ‘movement’, to which one could be ‘committed’, and which has clearly identifiable features.

Anstey and Vanzo are well aware of this, and have delineated with some precision what they take to be the content of this reified experimental philosophy (now no longer necessarily attached to use of the phrase). This, they argue, consisted of a well-defined ‘philosophy of experiment’, articulated most precisely by Bacon, Boyle and Hooke. But it was also prevalent well beyond these three figures, for ‘the methodology of experimental philosophy was developed by the early members of the Royal Society according to the Baconian method of natural history’.¹¹ The philosophy is summarized as follows:

1. One should not firmly commit oneself to any substantive claims or theories on the natural world, unless they are warranted by extensive experiments and observations.
2. In order to make a firm commitment to substantive claims and theories on the natural world, one should follow a two-stage process. During the first stage, one should gather an extensive collection of empirical information by means of experiments and observations. Once this is done, one will be entitled to commit oneself firmly to substantive claims or theories, but only insofar as they are warranted by experiments and observations.
3. Empirical information should be collected by means of first-person experiences, understood as individual, discrete observations or experiments, which have primacy over theories.
4. Empirical information should be organized in experimental natural histories (which differ from ‘traditional’ natural histories in not being limited to biological kinds, in including experiments alongside observations, and in being not a self-standing project, but a preliminary step to the construction of natural philosophy).
5. Natural philosophical theories should be derived from experimental natural histories through a process of induction. Yet, experimental philosophers did not take up Bacon’s elaborate theory of induction, nor did they develop detailed accounts of how theories can be derived from empirical evidence.¹²

Now, already, there are some complications. Where Bacon had offered a precise

⁹ Anstey 2012.

¹⁰ Anstey and Vanzo 2016, 94.

¹¹ Anstey 2014, 108.

¹² This is a mixture of (mostly) direct quotation and some paraphrase of Vanzo 2016, 52–54. See equivalently Anstey 2014, 116.

description of the move from natural history to the establishment of scientific knowledge via inductive logic (what he called *interpretatio naturae*), Boyle and Hooke (as well as other Restoration Englishmen) did not ‘expres[s] any interest in the inductive stage of Bacon’s method’, instead offering a very under-theorised and ambiguous ‘kind of reciprocal feedback loop between experiments and hypotheses’.¹³ But, such discontinuities notwithstanding, it is the Bacon-Boyle-Hooke view of experiment, we are told, that formed the core of an identifiable philosophy of experiment against which European natural philosophy of the post-1660 period can be assessed.

Before I turn to a substantive exploration of this thesis, let me outline what I believe to be its two greatest strengths, in historiographical terms. The first of these has been intentional: the undermining of the application of the distinction between ‘rationalism’ and ‘empiricism’ to early modern philosophy. Of course, Anstey et al. are not the first to make this point.¹⁴ But what they have emphasised—to my mind quite rightly, and more coherently than anyone else—is that it is not simply a relatively trivial point about anachronistic language, but about a whole set of philosophical and conceptual assumptions that are without warrant imported into the study of early modern philosophy. One still hears (albeit less often reads in print) the claim that the rationalist-empiricist distinction is a useful tool, especially in teaching, and that it is not particularly important what terms we use to convey divisions in in the philosophical landscape of early modernity. But this is to ignore the key point: that to do so is to import a whole set of post-Kantian assumptions that simply did not exist in the seventeenth century.¹⁵ The distortions this has caused to the study of early modern intellectual history have been revealed well beyond the field of the history of science.¹⁶ Abandoning our Kantian blinkers reveals a richness and complexity to early modern philosophy that is otherwise obscured.

Another very positive historiographical consequence of the work of Anstey and his collaborators has been more unintentional. For it seems to me that it serves to undermine another approach, one that finds ‘empiricism’ among non-elite practitioners, and then in turn reifies that empiricism into ‘science’, and even ‘modern science’. The recent *locus classicus* for such an approach is Deborah Harkness’ high-profile investigation of putatively ‘scientific’ practitioners in Elizabethan London, *The Jewel House* (2007). This somewhat moralistic search for non-elite ‘empiricists’, is, as Peter Dear has already commented, ‘constructed around the mediating theme of “empiricism”’, where such ‘an undifferentiated empiricism is allowed to stand in for modern science, and hence... to establish as “proto-science” anything older than can be grouped under the “empiricist” label—regardless of differences in character of the activities so grouped’.¹⁷ The sort of precise investigation into the meaning and conceptual implications of various terms clustered around the concept of experience carried out by Anstey, Vanzo and others, and the disintegration of a generalised ‘empiricism’ that emerges, renders the Harkness approach highly dubious. Indeed, when such a precision is applied to the language used

¹³ Anstey 2014, 117–118.

¹⁴ See the historiographical overview in Dobre and Nyden 2013a, esp. 3–8, and the many works cited there.

¹⁵ Vanzo 2014; Vanzo 2012. One other such assumption is that of ‘British Empiricism’, still being deployed (e.g., in Sgarbi 2012).

¹⁶ Hunter 2001.

¹⁷ Dear 2012, 200–201. As well as Harkness, Dear also mentions Smith 2004.

by the ‘lower’ practitioners, it reveals some very interesting things, not least that such practitioners were much more willing to draw on bookish, learned discussions of experience than their modern champions would have us believe.¹⁸

These broad historiographical remarks out of the way, let us now turn to the heart of the issue: the question of the existence and nature of something called ‘experimental philosophy’. Since Anstey has used Bacon, Boyle and Hooke as the landmark figures in the development of the philosophy of experiment, I shall divide my discussions into three chronological groups: (i) before and up to Bacon; (ii) between Bacon and Boyle; (iii) from Boyle to the end of the seventeenth century and beyond. But I do this only for the sake of narrative and structural convenience: as will soon become clear, I am not convinced that these Englishmen were quite as seminal to the development of seventeenth-century experimentalism—or as representative of it—as has been claimed.

2. Before Bacon

Anstey and Vanzo have offered a pre-history of the experimental-speculative distinction, which can be summarised in the following manner. Before Bacon, ‘nearly all’ natural philosophical authors—working within the Aristotelian paradigm—agreed that ‘natural philosophy was a speculative, theoretical or contemplative discipline, rather than a practical, operative or productive discipline’. Bacon, however, divided natural philosophy into speculative and operative parts (the former consisting of metaphysics and physics, the latter of mechanics and natural magic; natural history straddles both parts). There is thus a fundamental discontinuity between the Aristotelian position and that of the English Restoration, and it seems that ‘this fundamental Baconian shift was an important factor in the emergence of the experimental/speculative distinction in England in the 1660s’.¹⁹ Anstey and Vanzo do not speculate too much on how the Baconian schema morphed into the one of the 1660s, except to offer some comments on Dutch medical debates of the 1640s–1660s, where some physicians ‘contrasted the speculative conclusions of the Cartesians, derived by way of reasoning (*ratiocinatio*) from mechanistic principles, with Harvey’s “real and sensual disquisitions” (*disquisitiones reales & sensuales*), that is, experiments and observations’.²⁰

Of course, no one doubts that the majority of mainstream Aristotelian philosophy was classified as a contemplative or speculative *scientia*, because it was concerned with knowledge of causes. Moreover, the story just narrated ties in well with recent literature on Francis Bacon, which has attempted to reassert his seminal novelty in this regard, sometimes in near-hagiographic terms. But it seems to me that that story is a textbook example of how reification leads to historical confusion. For even if we assume, for the time being, that the experimental-speculative distinction *was* central in the post-1660 period, why do we then need to assume that its ‘origins’ lie in a similar linguistic distinction? Might it not have been the case that reality was rather less neat—that is, that there had long been a growing emphasis on the value of knowledge derived from the senses over that derived from reason, and which had emerged well before Bacon or the

¹⁸ Levitin 2015b.

¹⁹ Anstey and Vanzo 2012, 505–506, 512. See further Kusukawa 1996; Anstey 2012.

²⁰ Anstey and Vanzo 2012, 517–518. The references are to van Hogelande 1646, 195–196; Sylvius 1681 [1661], 26.

Dutch medical debates? I should like to suggest that this is precisely what had happened in many different fields of intellectual activity broadly connected to natural philosophy. The sixteenth-century expansion of higher education, the rediscovery and publication of ancient medical and philosophical texts, and the subsequent debates between ‘lower’ and ‘learned’ practitioners over who was the true inheritor of ancient traditions all led to the emergence of an institutional debate about the nature of, and relationship between, various natural philosophical disciplines, and a concomitant emphasis that natural knowledge should be derived from experience rather than apriorist reasoning.

We can already see this development at the most general level, in Aristotelian natural philosophy. It was in the sixteenth rather than the seventeenth century that natural philosophy underwent its most important ‘emancipation’ from metaphysics, and was thus infused with a new emphasis on sensory information. This went hand-in-hand with a self-conscious repudiation of the supposed ‘metaphysical’ corruption of Aristotelian natural philosophy, a theme that was also picked up by almost all of the humanist anti-Aristotelians.²¹ Generalising greatly, we can say that up to the fifteenth century, institutionalised Aristotelian natural philosophy had prioritised the ‘metaphysical’ approach to the subject offered in the *Physics*, which considered *ens mobile* from the first principles of matter, form and potency. But, especially under the influence of the rediscovered Greek commentators, above all Alexander of Aphrodisias, there was a shift to the ‘naturalistic’ approach of the *De generatione et corruptione* and Book IV of the *Meteorology*, with the subject matter conceived as *corpus potentia sensibile* and its principles—the four elements and the sensible qualities.²² Among figures like Pietro Pomponazzi and Simon Portius, this led to a strong emphasis on sense perception as the source of natural philosophical knowledge. Pomponazzi, for example, in a chapter ‘On the method of proceeding in natural matters’, ‘makes it quite clear that knowledge of nature and natural objects can be attained only by sense-perception and arguments derived immediately from it, and that whenever reason seems to contradict sense-perception, the former has to give way to the latter’.²³

This move had profound consequences. It led to a widespread shift in the teaching of Aristotelian natural philosophy, with far more attention devoted to the ‘naturalistic’ parts, and even a conscious division between those parts and the ‘metaphysical’ parts of physics.²⁴ At the intellectual level, it led to the denial (e.g., in the hands of Portius) of the necessity of such central scholastic Aristotelian concepts as substantial form, with sensible qualities determining the nature of things, and thus being open to empirical investigation from effects to causes.²⁵

Pomponazzi, we should note, even performed experiments to correct previous Aristotelians.²⁶ Of course, he was no systematic experimenter. But then again, neither was Bacon.²⁷ What is crucial to our story is that the next generation of Aristotelians—especially those who combined their natural philosophical interests with medical practice

²¹ Reiner 1955; Wilmott 1984, 286–288. For Bacon’s adaptation of the theme, see *Advancement of Learning* (1605), OFB 4: 86.

²² Keßler 2001; also Keßler 1995; Lohr 1988.

²³ Keßler 2001, 85, quoting Pomponazzi 1525, fol. 30^v.

²⁴ Blum 1988.

²⁵ Keßler 2001, 90–95.

²⁶ Perfetti 2000, 55–58.

²⁷ Before I am jumped on by a horde of Baconians, I should point out that I am perfectly aware that Bacon did perform *some* experiments: see Rees 1981.

or ideas—pushed even further this emphasis on sense experience. One thinks here of Girolamo Fracastoro, Gerolamo Cardano and Bernardino Telesio, the last of whom began his great treatise on nature, *De rerum natura*, by promising that he would ‘not deal with metaphysical principles of nature, which are the result of mere theoretical speculations, but that his philosophy of nature will be based on what is obvious to sense-perception or can be derived immediately from it’, and by declaring unambiguously that knowledge of the natural world should be derived not ‘from reason, as it has been done by men in former times, but should be perceived by sense, and obtained from things themselves’.²⁸

That Bacon had some admiration for Telesio is well known, as is the fact that he criticised the Italian’s philosophy for ignoring the role of human artifice and the mechanical arts.²⁹ But for the time being this is not our concern; rather, I am only seeking to show that a rhetorical contrast between sense-based (good) and rationally-derived (bad) philosophical knowledge was becoming commonplace in the sixteenth century. In this respect, it is no coincidence that the Aristotelians just mentioned had medical interests. As a set of seminal studies have recently shown, sixteenth-century medicine underwent a crucial transformation. More and more, it valorised observational and sense-derived knowledge, often insisting on the superiority of such knowledge to that derived from non-observational philosophy, while, crucially, insisting that such knowledge was still at least in some sense *philosophical*.³⁰

At the most fundamental level, this occurred because of the immense expansion of medical provision in this period, analogous to the similarly vast expansion of university education. This led to frequent turf wars, and thus polemics, between non-university-trained practitioners, such as surgeons and apothecaries, and learned physicians, conducted primarily with reference to the ancient medical sects: Rationalists, Empirics and Methodics. Since the learned physicians accused the practitioners of being base Empirics, the latter sought to turn the accusation into a positive by elevating the status of experiential knowledge. They did so through recourse to the many new texts humanist medicine had made available, above all the Hippocratic corpus, as well as Dioscorides. In turn, the learned physicians responded by emphasising that it was *their* brand of medicine that was truly observational, and even that they disdained pointless philosophising without experience. Soon, they institutionalised these ideas in the burgeoning universities, establishing chairs in medicinal simples or botany, and making practical knowledge a prerequisite for qualification as a learned physician.³¹

Since medicine was the higher discipline with the closest relationship to natural philosophy, these changes had profound significance. What is essential to emphasise here is that what all sides insisted on was not the importance of bare experience, but that experience was imperative to a more complex system of therapeutic or even philosophical

²⁸ Keßler 2001, 97–98; Telesio 1586, 1. For Fracastoro on the value of evidence derived from the senses rather than reason, see Rossi 1954, and now Hoffmann 2003. Ernst Cassirer considered him a direct predecessor of the so-called ‘British Empiricists’: Cassirer 1922–1923, 1: 236.

²⁹ *De principiis atque originibus* [c.1612?], OFB 6: 250–251. For Bacon and Telesio, see Rees’ ‘Introduction’ and Commentary in OFB 6: xxix, xxxvii–xlii, xlix, liii, 422–426, 428–431; Pousseur 1990.

³⁰ For the complex relationship between medicine and natural philosophy in this period, see Schmitt 1985; Maclean 2002, 70–76; Mikkeli 1992, 135–147.

³¹ This paragraph offers an over-simplified summary of a wealth of literature: e.g., Riddle 1980; Visentini 1984; Minelli 1995; Garbari, Tongiorgi Tomasi and Tosi 1991; Reeds 1991; Nutton 1985; Nutton 1997; Bylebyl 1979; Findlen 2006a.

knowledge. This led to conceptual innovations of lasting significance, and of direct relevance to our subject. Perhaps most important was the huge rise in talk of *observatio*, and the introduction of the term *phaenomena* to refer to the objects being observed. As Gianna Pomata has shown, this development ‘first emerged in neo-Hippocratic medical circles with the recovery of the ancient Empiric/Skeptical philosophical vocabulary’. And as she demonstrates with a wealth of examples, ‘the combined purport of these terms, in their ancient Empiric/Skeptical acceptance, was an emphasis on the distinction between direct experience (*autopsia*) and indirect experience, the insistence on focused and repeated observation (*tērēsis*) as the foundation of empirical knowledge, and the urge to keep to the phenomena (*phainomena*), or things as they appear, avoiding useless and contentious theorization’.³² In medicine, this manifested itself in the second half of the sixteenth century in a vastly increased focus on case histories, many inspired by an attempt to emulate those of books 1 and 3 of the Hippocratic *Epidemics*.³³ New readings of Galen (and of Rationalist medicine more generally) also now stressed that he prioritized direct experience more than some of his followers, and even that he had taken much from the Empiric sect.³⁴ The result was a ‘Rational Empiricism’—that is to say, an ever growing focus on the empirical component of learned medicine which nonetheless insisted that that component was never reducible to ‘*nuda experimenta*’, but was methodically organised and rationally interpreted.³⁵ Such claims had become so commonplace by the late sixteenth century that they were even standardly deployed in the vernacular.³⁶

Because medicine and natural philosophy had such an intimate relationship, not least in the universities, *observatio* and *phaenomena* soon found their way into broader natural philosophical discourse.³⁷ This is not just a matter of linguistic curiosity. Rather, what is important is that:

observatio was actually quite different from the old category of *experientia*. Even when co-opted into mainstream philosophical terminology, *observatio* kept a strong flavour of the Empiric/Skeptical source from which it had originated. It invariably indicated... authored observation—not just the generic, anonymous experience of the Aristotelian *empeiria* or of the Plinian *observationes*. *Observatio*, moreover, kept its ancient antagonism to hypothesis, doctrine, or theoretical speculation. A suspicion of theory... was at the very core of the concept of *observatio* as it gained ascendancy in early modern philosophical language. (Pomata 2011a, 67)

This new emphasis on observation in medicine thus effected both a ‘philosophisation’ of experiential medicine, and a ‘experienciation’ of natural philosophy. Many examples could be provided. One is the philosophization of natural

³² This is the summary from Pomata 2011a; for the evidence, see there, *passim*, and Pomata 2011b.

³³ Pomata 2011a, 58–59; Pomata 2010; Maclean 2002, 201–204; Nutton 1988, 123–124; Nutton 1989; Lonie 1985.

³⁴ See, e.g., the examples collected in Siraisi 1987, 66, 70, 73–75; Siraisi 1997, 27–29; Siraisi 2012, esp. 85–86; Siraisi 1990, 174; Maclean 2002, 20–21, 339–340. Vesalius’ famous preface to his *De humani corporis fabrica* (1543) is only

one manifestation of this move, which stemmed from the publication of the Greek Aldine edition of Galen (1525): see O’Malley 1964, 317–318.

³⁵ Pomata 2005, 136–137, quoting Martin Ruland’s *Curationes empiricae et historicae* (1578–1596).

³⁶ Muratori 2017.

³⁷ See above all Baroncini 1992, esp. 39–62, 116–123. Pomata 2011a, 66–67 suggests a particularly prominent role for the works of Petrus Ramus in this regard.

history that one finds in Andrea Cesalpino, who insisted that taxonomizing the results of botanical collection on the basis of plants' reproductive function provided the discipline with a philosophical status—here his work was moving in the same direction as that of physicians like Leonhart Fuchs, Guillaume Rondolet and Ulisse Aldrovandi.³⁸ Perhaps even more significant was the so-called 'Aristotle project' of sixteenth-century Padua, which culminated in Fabricius ab Aquapendente's claim that a broadly-conceived philosophical anatomy should form the basis for the whole of medicine.³⁹

Here again we encounter some very clear statements of a preference for experiential knowledge—newly accorded a higher, 'philosophical' status—over knowledge derived from reasoning. Gabriele de Zerbi, for example, already insisted in the early sixteenth century that anatomy 'should be studied as the principal basis of medical art' because 'the manual operation directed by the senses of sight and touch would lead to knowledge without much reasoning, because singular things are nearest the senses and therefore easiest for us to know'.⁴⁰ This experiential component was always present in learned medicine, since, unlike Aristotelian natural philosophy, it could hardly be conceived of as a pure demonstrative *scientia* (even in theory). Renaissance doctors dealt with this issue above all by recourse to the complex sub-discipline of semiotic—the study of indicative signs perceived by the senses to infer the cause of disease—considered one of the three theoretical of the five parts of medicine (although it was sometimes also said to overlap with the practical parts).⁴¹ In the sixteenth century, humanist learned physicians effected very significant developments in semiotics, including even the development of a 'proto-quantified version of probability'.⁴²

This tendency to raise the status of experiential knowledge while deriding 'theoretical' is also evident in the case of less mainstream medical traditions. The best example here is that of Petrus Severinus' 'philosophisation' of Paracelsianism, which had always insisted on the importance of knowledge acquired via the senses, telling a story of the corruption of such knowledge from a Hippocratic high point, through to the destructive philosophical abstractions introduced by Plato and Aristotle, and then by Galen.⁴³ Likewise idolizing the time of Hippocrates as a putative golden age of empirical collection and collaboration, Severinus nonetheless insisted on the philosophical and learned status of an ideal Paracelsian medicine; in this sense his case is analogous to that of the 'Rational Empiricism' discussed above.⁴⁴ According to Severinus, Hippocratic medicine had been corrupted by hypothesizing and reduction to first principles, in particular that of Galen. This anti-hypotheticalist language was accompanied by the strongest emphasis on direct experience, only recourse to which could allow one to be a genuine 'interpreter of nature'.⁴⁵

Here we have another feature of Baconian language previously considered unique to the Englishman: that of the 'interpretation of nature'.⁴⁶ It is thus not surprising to find

³⁸ The fullest discussion is Jensen 2001, esp. 204–205; see also Perfetti 2000, 231; Maclean 2002, 141–143; Savoia 2006.

³⁹ Cunningham 1985; Cunningham 1997, 167–190; and for the longer-term story in Padua, see Mikkeli 1992, 148–159.

⁴⁰ Mikkeli 1992, 150.

⁴¹ Maclean 2002, 276–332.

⁴² Maclean 2011, 295.

⁴³ Webster 1982, 52; Pagel 1982, 58–59; Halleux 1980.

⁴⁴ Shackelford 2002, esp. 143–208.

⁴⁵ Severinus 1571, 2, 73–74.

⁴⁶ The key discussion for Bacon is now Serjeantson 2014. Severinus is discussed at p. 690, but his use of 'naturae interpretes' is not noted (see also Severinus 1571, sig. β2^r, 104–105). Despite this, I remain convinced by the

Bacon admiring Severinus, approving of his method but also condemning his acceptance of the doctrinal details of Paracelsianism.⁴⁷ My point is not that Severinus, Fabricius, or anyone else directly anticipated Bacon. Rather, what I am trying to show is that a strong emphasis on the value of sense experience, coupled with a disdain for non-sensory knowledge, and—perhaps most importantly—the elevation of sensory knowledge to ‘philosophical’ status, was already prevalent across Europe in the second half of the sixteenth century. These developments may have occurred within a broadly Aristotelian framework that continued to insist that natural philosophy should be a contemplative or speculative science—although it should be noted that there was often debate on that score too, again especially in medicine⁴⁸—but they seem to me a much more important source for the development of European experimental philosophy than niche figures like John Dee, highlighted solely because he offers a linguistic foreshadowing of the experimental-speculative distinction.⁴⁹

But all this being said, some Bacon scholars might object that the identification of such a rhetoric before Bacon does not detract from the novelty of Bacon’s project. Above all, they would point to a major Baconian innovation: the experimental natural histories which were to form the foundation for the new natural philosophy, and which, as we have noted, also play a central role in Anstey’s philosophy of experiment. And indeed, it is one of the great achievements of recent Bacon scholarship to destroy the old myth of Baconian natural histories as more or less theory-free random accumulations of facts, in favour of a view of them as ‘research-oriented, experimental and exploratory investigations of nature... shar[ing] elements of methodology, theoretical and epistemological presuppositions, as well as norms and values’.⁵⁰ But as important as this work has been, it seems to me that, in its attempt to destroy the caricature of a ‘fact-gatherer’ Bacon, it threatens to return to another caricature, that of Bacon the father of modern science, where it is the case that ‘if “science” emerged in the late seventeenth century, it emerged very much on the grand design of Francis Bacon’s natural and experimental history’.⁵¹

Much of the impetus for this move comes from the brilliant new edition of Bacon’s writings published by Oxford University Press, and especially the seminal work of the late Graham Rees. According to Rees’ introductions to Bacon’s natural historical writings, when considered ‘against the background of his predecessors’ assumptions and practices’, Bacon’s project as adumbrated in the *Novum organum* (1620) was one of ‘stunning originality’.⁵² This view has been accepted by many, including Anstey.⁵³ But I think that Rees may have accepted Bacon’s claim that none of his ancient or modern

case made in this article for Bacon’s idiosyncrasy and importation of legalistic terms into natural philosophy.

⁴⁷ The evidence is collected in Shackelford 2002, 257–264. Even in his criticism (*Temporis partus masculus*, in Bacon 1857–61, III, 533) Bacon was probably being semi-dishonest, given his seeming debts to Paracelsian philosophical doctrine. For this, the pivotal analysis remains Rees 1975 (esp. 83–84, 101, 173 for Severinus).

⁴⁸ Mikelli 1992, 135–147, esp. 142–143, 146, 147.

⁴⁹ As in Anstey and Vanzo 2012, 507–508.

⁵⁰ This scholarship is large, and culminates in the very full treatment in Jalobeanu 2015—for

extensive further literature, see the historiographical overview there, at 17–48 (quotation from 43). One might note, however, that the older literature was not quite as blind to the complexities of Bacon’s experimental method as the revisionists make out: see, e.g., Jardine 1974, 143–149; Eamon 1994, 285–291.

⁵¹ Jalobeanu 2015, 201.

⁵² See Rees, ‘Introduction’, in OFB 11: xlv. But even Rees noted that it would be ‘egregiously outmoded’ to call Bacon ‘the Father of the Experimental Philosophy’, *ibid.*, lxxxiv).

⁵³ See, e.g., Anstey 2015, 116; Anstey 2012, 12; Anstey 2014, 110.

predecessors ‘have set themselves the goal of which we speak for natural history’⁵⁴ a bit too uncritically.

According to Rees, Bacon’s was a ‘post-humanist conception of natural history’ that differed fundamentally from that of predecessors such as Rudolphus Agricola, Conrad Gesner, or Aldrovandi.⁵⁵ This view depends on a misrepresentation of sixteenth-century natural history and methodological discourse. The idea that Bacon’s view of natural history as a ‘cooperative undertaking’ was ‘transformat[ive]’ is not only a factual error—ironically, Bacon’s model may well have been humanist erudition⁵⁶—but also belies practical reality. Gesner’s, for example, was both conceived of and performed as a deeply collaborative enterprise.⁵⁷ Nor is there much truth to the claim that sixteenth-century natural history was fundamentally about ‘erudition’, ‘post-prandial chat’, and ‘savouring of authorities’.⁵⁸ Rather, humanist natural historians repeatedly extolled the value of direct experience, often at the expense of more abstract knowledge, once again prefiguring the experimental philosophers of the late seventeenth century. Luigi Anguillara, for example, wrote in 1561 that the ideal naturalist was one ‘who possessed theory as well as practice, and has experienced many things’. Moreover, this explicitly led to conceptions of philosophy as an experiential discipline, in ways that contradicted the traditional Aristotelian definition: ‘One delights in *practical natural philosophy*, which one learns from ocular testimony’, wrote Gabriele Falloppio in 1560. Previous natural histories were not (as Bacon self-servingly claimed) designed as curiosities, but conceived as the foundation of natural philosophy: ‘I call this sensory [philosophy] the mother of universal philosophy, from which it derived its origins’, wrote Aldrovandi, who would become known as ‘a true sensory Philosopher’. By the early seventeenth century, such rhetoric had developed into a fully-fledged belief that ‘one ought to believe more in the observation of natural things than in... [pre]suppositions’, independent of any Baconian influence.⁵⁹ At this point, university botanists had for several decades been conducting interventionist investigations of nature.⁶⁰

Renaissance natural history thus offered many of the rhetorical features of late-seventeenth-century English experimental philosophy (although obviously not the systematic emphasis on ‘experiment’, to which we will return). But again, what seems more important than rhetoric is that conceptually, Bacon’s vision of natural history as preparative to—and part of—a full natural philosophy, was only the culmination of a long trend. In 1476, in the preface to his new translation of Aristotle’s animal books, Theodorus Gaza had insisted that Aristotle had first composed the *Historia animalium*, and only then the *De partibus animalium* and the *De generatione animalium*, precisely because the two later books deal with causes, building on the historical knowledge of the

⁵⁴ *Parasceve ad historiam naturaelm* (1620), OFB 11: 455–457.

⁵⁵ Rees, ‘Introduction’, in OFB 12: xxxii–xxxiii, and xxvii for a particularly hagiographic version.

⁵⁶ Grafton 2009a.

⁵⁷ See Findlen, 2006b, 458, drawing on Heller and Meyer 1983, at 67. And for the separation of philological and observational modes of natural inquiry in Gesner (and for his preference for the

latter), see now Leu 2016; Leu and Ruoss 2016; Grafton 2018, esp. 45–46.

⁵⁸ Rees, ‘Introduction’, in OFB 12: xxvii, and *passim*.

⁵⁹ Findlen 1994, 202–203 (quoting Anguillara’s *Simplici* 1561, 14–15), 207 (quoting Fabio Colonna’s *La Sambuca lincea* (1618)); 205 (quoting Falloppio from di Pietro 1970, 53 (my emphasis)); 206; see also the quotation from Aldrovandi at 211.

⁶⁰ Egmond 2017.

thing itself delivered in the first.⁶¹ Gaza's edition became utterly dominant in sixteenth-century natural philosophy.⁶² It is impossible to overestimate the importance of this move, which resonated not only among natural historians but also such heavyweights of sixteenth-century natural philosophy as Agostino Nifo and Zabarella. 'The shift from Scholastic Aristotelianism to Renaissance Aristotelianism implied a shift from *historia* as knowledge without causes to *historia* as knowledge preparatory to the investigation of causes'.⁶³ Gradually, this view was elaborated in sophisticated ways, so as to explain how the initial 'historia' stage 'can be made to yield up demonstrative syllogisms'.⁶⁴ This new focus on the value of purely historical knowledge of accidents was justified—as it would be in the seventeenth century—by reference to epistemic modesty; Daniel Furlanus and Nicolaus Taurellus both argued, for example, that 'because it is not always given to man to know the essences of things, he may have to be content with accidental differences'.⁶⁵ But this modesty was also combined with a confidence that the new emphasis on *historia* would sweep away the errors of scholastic natural philosophy and medicine—this was the case as early as Alessandro Benedetti's *Historia anatomica* of 1502.⁶⁶ By the late sixteenth century, Fabricius was adopting the Aristotelian scheme that began with *historia* as the basis for his whole physiological research programme.⁶⁷

Indeed, the similarities with Bacon go beyond the emphasis on *historia* as propaedeutic to natural philosophy. One of the most important, but least noted, characteristics of the Baconian natural history programme—as summarised in the catalogue of 130 natural histories that should make up the mother history required for natural philosophising—is that it follows very closely the structure of traditional scholastic natural philosophy.⁶⁸ This kind of expansion of *historia* to serve as a preparative to a wider range of the traditional subjects of Aristotelian natural philosophy is precisely what Fabricius offered in his project to re-philosophize anatomy in the true Aristotelian manner.⁶⁹ We will recall that Bacon, for all his anti-Aristotelianism, admitted that Aristotle's natural historical project was very worthwhile (he was particularly envious of its scale, which he thought had been facilitated by sponsorship from Alexander the Great, a humanist trope that remained a source of inspiration for the collection of observational data well into the seventeenth century).⁷⁰ According to Bacon, the problem lay not in Aristotle's method but in his practice, specifically his corruption of his natural historical data through presuppositions imported from his logic—like the accusation of corruption via the importation of metaphysics, this was by then an anti-Aristotelian commonplace.⁷¹ Just like the sixteenth-century Aristotelians, then, Bacon was expanding

⁶¹ Gaza 1549 [1476], sig. aa3^r.

⁶² Monfasani 1999, 205: 'Gaza reigned supreme over the *De animalibus* until the nineteenth century', also 212; Perfetti 1995.

⁶³ Pomata 2005, 111. For Nifo, see also Perfetti 1999, 311–312.

⁶⁴ This quotation is from Maclean 2005, 156–157, which offers many important examples—the quotation refers to Cristoforo Guarinoni.

⁶⁵ *Ibid.*, 158.

⁶⁶ Pomata 2005, 114–115.

⁶⁷ Cunningham 1997, 175–176.

⁶⁸ The 'Catalogus historiarum particularum' is at OFB 12: 474–485. This *is* noted by Garber 2014, 96.

⁶⁹ Cunningham, 1997, 173–175.

⁷⁰ Levitin 2015a, 312.

⁷¹ *Advancement of Learning* (1605), OFB 4: 91; *De augmentis scientiarum* (1623), SEH 1: 562; *Novum organum* (1620), OFB 11: 88, 98–100, 156. For the corruption through logic idea in humanist anti-Aristotelianism, see Wilmott 1984, 286–288; Levitin 2015a, 245–250. Likewise, Bacon's claim that Aristotle's logical philosophy had corrupted previous attempts to 'dissect' or 'penetrate' nature, especially those of Democritus (e.g., OFB 11: 88), was by then widely available: see Lüthy 2000; also Rees 1980.

the scope of *historia* to render it preparative to the full scope of subjects of an Aristotelian natural philosophy stripped of logical and metaphysical impurities.

It is somewhat remarkable to note that for all the immense historiographical labour that has gone into Bacon studies, there has been no concerted study of Bacon in relation to the medical tradition. And yet, perhaps the most famous methodological statement Bacon ever made—the parable of the ants, spiders and bees in Book One, aphorism 95 of the *Novum organum* (1620)—was couched in the terms of late Renaissance justification of medical observation, Bacon presenting his ideal as a middle-way between Empiricism and Rationalism.⁷² Like many late-sixteenth century naturalists, Bacon perceived the alliance between Hippocrates and Democritus as the ideal of natural investigation, when nature was ‘dissected’ rather than ‘abstracted’, as it would be by Plato and Aristotle.⁷³

Of course, not everything Bacon claimed about the novelty of his natural historical programme was a fabrication. For example, his focus on material and efficient causes (and abandonment of final causes) obviously differed him from the Aristotelian tradition, and permitted a greater emphasis on the study of accidents and particulars.⁷⁴ But even this move was perfectly possible within mainstream learning, and was performed to justify his spectacular experimental results by Fabricius’ student William Harvey.⁷⁵ Moreover, the fact that Bacon’s *Sylva Sylvarum* (1627) *did* seem more like an ‘undigested heap of particulars’, as its contemporary editor William Rawley put it, made it possible for self-proclaimed ‘Baconians’ to operate in the fact-gatherer mode popular in the older historiography. (Indeed, this may well have reflected the fact that the book was never intended by Bacon for publication in its current form.)⁷⁶

One other innovative feature in particular was emphasised by Bacon, and has been picked up in the recent literature. This is his insistence that this would be a history not just of natural kinds but also of ‘the experiments of the mechanical arts’,⁷⁷ and thus that this was experimental natural history.⁷⁸ In turn, this led to generically unusual natural histories, such as those of qualities. We shall see below that this conception of natural history was perhaps not quite as influential as has been claimed. For the time being we should only note that, as far the best of the recent scholarship has been able to discern, it was not the function of a brilliant new methodological insight, but of Bacon’s own idiosyncratic vitalist matter theory. The division of natural history into that of generations, pretergenerations and of the arts (the last of which, Bacon says, he had ‘also got used to calling *Mechanical* and *Experimental*’), was designed to showcase the full range of matter’s vitalist, appetitive actions—the last division (history of arts) was favoured because it revealed the actions of bodies ‘while they are still operating’, rather than after they ‘have finished off what they are doing’, which is all that a traditional history of natural kinds could reveal.⁷⁹ It was this process that constituted Bacon’s science of

⁷² *Novum organum*, OFB 11: 152–153.

⁷³ *Advancement of Learning*, OFB 4: 99; *De principiis atque originibus* [c.1612?], OFB 6: 196–199, 204–207; *Novum organum*, OFB 11: 88–89; 342–345; *Historia vitae et mortis* (1623), OFB 12: 214–217; although see also the attack on Hippocrates as relying *too much* on experience in *Temporis partus masculus* [c.1603?], SEH 3: 535; also Rees 1980, 567–570.

⁷⁴ Maclean 2005, 168.

⁷⁵ French 1994, 277, 301, 313–17, 346–350, although see now the challenge in Goldberg 2016, esp. 319–321.

⁷⁶ As has been recently argued in Rusu and Lüthy 2017. The very interesting claims of this paper will no doubt be hotly contested by other Bacon scholars.

⁷⁷ *Novum organum*, OFB 11: 157.

⁷⁸ Anstey (2012) in particular has insisted on the radical novelty of these two components.

⁷⁹ *Novum organum*, OFB 11: 157, 359.

magic.⁸⁰ Bacon's valorisation of experimentalism was thus less an attempt to build a full-scale 'experimental philosophy', and more a means of philosophizing the tradition of natural magic that culminated in the works of Giambattista Della Porta. In this respect, it was analogous to Fabricius' philosophization of anatomy, or Severinus' philosophization of Paracelsianism.⁸¹

3. From Bacon to Boyle

Of course, notwithstanding everything that has just been said, it may still be the case that the way Bacon was *received* does justify the reification of something called 'experimental philosophy', or of a Bacon-Boyle-Hooke philosophy of experiment that should be considered archetypal of late seventeenth-century experimentalism. The only way to assess this is to examine the status of experiment in natural philosophical discourse between *c.* 1620 and 1660. Such an investigation reveals that calls for a philosophy based on experiment derived from many more sources than anything that can even loosely be labelled Baconianism. Natural philosophical *novatores*—indeed, all natural philosophers—of this period were by training eclectic in their approach.⁸² There are very good reasons for thinking that this broad eclecticism was central to the crystallisation of experiment as a methodological shibboleth.

One such source was, once again, learned medicine. Across Europe, the first half of the seventeenth century saw the development of what can viably be called experimental research. In Italy, we may point to work of Gaspare Aselli (based at the University of Pavia) whose discovery of the lacteal vessels of the lymphatic system was celebrated as a major scientific event through to the end of the century and beyond.⁸³ Drawing on Fabricius' legacy, Aselli insisted that a comprehensive anatomical *historia* must lie at the root of all medical-philosophical knowledge. But 'compared with Fabricius, [he] vastly expands the place of *historia* in his account' precisely because he thought it the best means to convey the novelty of his discovery (thus he offered a very detailed 'history of the discovery' [*inventionis historia*]).⁸⁴ In the Dutch Republic, we find in the famous medical faculty of the University of Leiden a full programme of experimental anatomy present by the 1630s, stimulated in part by Harvey's discovery of circulation, but also by continuing adherence to Aristotelian methodological ideas (such as Zabarella's version

⁸⁰ There is now a large literature on Bacon's matter theory and its connection to his methodology. The best discussion seems to me to be that of Weeks 2007a, 151–202, and Weeks 2007b, esp. 136. The seminal earlier discussion is Rees 1980; see also the overview in Manzo 2001. Anstey (2012, 25–26), by contrast, attempts to disconnect Baconian natural history from natural magic.

⁸¹ As with Severinus, such 'philosophisation' involved dismissing those elements of the discipline whose status was more disreputable. For a conclusion that bears some resemblance to mine, see Dear 2012, 200; also the broader overview in Henry 2008, esp. 18–28. The most up-to-date account of Bacon's debts to Della

Porta, again with a conclusion that bears some resemblance to that offered here, is Rusu 2017; see further the works cited there.

⁸² Raphael 2016.

⁸³ Guerrini 2013 offers a very interesting discussion with much data directly relevant to us; also Orland 2012, esp. 470–474. For an example of the reception of Aselli's discovery as a landmark in experimental anatomical research, see Lambert 2013, 271; for English examples, see Boyle, *Certain Physiological Essays* (1661), B 2: 65; Patrick 1662, 21; Wittie 1669, 246; Stubbe 1670, 115; Glanvill 1676, III, 4; Goodall 1676, 46.

⁸⁴ Pomata 2005, 118–121 (quotations from 118).

of the *regressus*), and by reference to chymical experimentation.⁸⁵ And as Evan Ragland has demonstrated, the generation of the 1630s–1650s—above all Franciscus Sylvius, Johannes Walaeus, Thomas Bartholin and Johannes Van Horne—developed a post-Harveian experimental programme which they directly contrasted with what they presented as the non-experimental, apriorist physiology of Descartes; Sylvius, for example, praised ‘sensible philosophers’, and complained of the ‘fabrications’ of Cartesian mechanical anatomy. Here was a clearly articulated rhetorical distinction between experimental and apriorist philosophy, independent of any obvious Baconian influence and clearly indebted to the long experiential tradition in Renaissance learned medicine.⁸⁶ This emphasis on experiment had soon migrated even to basic philosophy teaching, and now even included use of Bacon, incorporated into a traditional Aristotelian framework.⁸⁷

In England, the emphasis on both experience and experiment is also to be found in the works of the ‘Oxford physiologists’ of the 1650s. Largely due to a brilliant book by Robert Frank Jr, these figures have been characterized as followers of William Harvey. But as Frank himself well knew, they were eclectic in their methods, and Harvey offered them more in the way of a set of problems. Harvey had developed both the Zabarellan legacy in natural philosophy and the ideas of his old medical teacher, Fabricius, to justify the experimental programme that led to his discovery of the circulation of the blood.⁸⁸ Despite his well-known antipathy for Bacon, Harvey, working from within the Aristotelian tradition, considered a thorough *historia* an essential propaedeutic to philosophical explanation (at least as he presented his methodology in the *Exercitationes de generatione animalium* (1651)).⁸⁹ Moreover, he explicitly contrasted the knowledge he had gained from the senses with that which others might claim to possess from ratiocination.⁹⁰ As Frank showed in his unsurpassed account, the subsequent research programme shaped the practice of experiment in England in the 1650s and in the first decades of the Royal Society.⁹¹ It thus seems the case that when Walter Charleton stated in 1657 that in the College of Physicians ‘you may behold Solomon’s House in reality’, we should read this not as evidence of the influence of Baconianism, but of precisely the opposite: that is to say, of the easy way in which mainstream institutional research could claim to have achieved the Baconian ideal.⁹² This was possible because influential medical pedagogues such as Francis Glisson and William Petty were teaching that the physician *should* incorporate new sensory data into his knowledge (partly through their use of the theory of indicative signs), and that this was not a concession to Empiricism,

⁸⁵ See the chapters by Lusingh Scheurleer, Lindeboom, Luyendijk-Elshout and de Pater in Scheurleer and Posthumus Meyjes 1975. For *regressus* and experiment, see the classic study Schmitt 1969.

⁸⁶ Ragland 2015, at 193, 195 for the examples, and 202 for the important conclusion. Also Ragland 2017a, esp. 359–360 for Leiden medicine preceding physics in its experimental turn, and Ragland 2017b for a fantastic pan-European overview. The broader framework for the Dutch Republic is established in Cook 2007; only further comparative work can reveal the extent of its singularity.

⁸⁷ Dibon 1954, 206; Van Miert 2009, 252, 256, 265–268, 274, 290.

⁸⁸ Schmitt, 1984; Wear 1983.

⁸⁹ Lennox 2006, 33–37.

⁹⁰ For several examples, and an account of the epistemology behind them, see Wear 1983, 238–241; Ragland 2015, 178–179.

⁹¹ Frank 1980. It is a great shame that much of the evidence discovered by Frank has never been considered since.

⁹² Charleton 1657, 34. In this I side with Webster 1967 who limits the direct influence of Bacon to Gerald Boate’s *Ireland’s Natural History* (1652) (at 410), and Frank 1979, at 84–92, rather than with Jalobeanu 2015, 167–168.

but an example of the kind of true ‘Rational Empiricism’ we met being developed throughout Europe in the sixteenth century. Men like Nathaniel Highmore, a friend of Boyle, justified their experimentalism and anti-Aristotelianism by using the probabilist account of medical knowledge we have likewise encountered among Renaissance physicians.⁹³ Mid-century English experimentalism, in other words, was much more a part of pan-European developments than is usually recognized.

It thus seems strange to assert that the Oxford physiologists were not ‘members’ of the experimental philosophy ‘movement’.⁹⁴ Indeed, such a claim again looks like an example of how the reification of methodological discourse leads to the positing of historical realities that conflict with the evidence at hand.⁹⁵ After all, members of the Oxford group came to play a central role in the early Royal Society (see below). The sources for the methodological and rhetorical preference for experiment and for its opposition to philosophy derived from non-sensory ratiocination were far too multifarious for the modern interpreter to be able to reduce it to anything like a coherent movement or philosophy.

The Oxford natural philosophers did not only draw on European medical traditions; they also found inspiration in mechanical and experimental modes of experimentation. Indeed, the middle of the seventeenth century was a golden moment for the meeting between mathematics and medicine, across Europe.⁹⁶ Early seventeenth-century mathematics, mechanics and astronomy were another venue where in the wake of the rediscovery of ancient texts, experience and natural philosophy were brought closer together, creating a new focus on experiment.⁹⁷ As Peter Dear argued in a classic account, one important source for the move from Aristotelian *experientia* to *experimentum* was the attempt, above all by some academic Jesuits, to justify their claim that mathematics was not solely the study of abstracted quantity, but an essential part of natural philosophy. Figures such as Christopher Clavius, Giuseppe Blancani and (working in geometrical optics) Franciscus Aguilonius and Christoph Scheiner thus came to differentiate specialist observations or ‘experiments’ from general experience; they also used the mathematical nature of their investigations to justify their seemingly artificial (as opposed to natural) status. Recent research has shown that this move was welcomed and effected by natural philosophers slightly more than Dear may have recognised.⁹⁸ The reception of Galileo’s mechanics and hydrostatics also led to much experimental verification of his discoveries, however much he himself had proceeded by speculation as by real experiment.⁹⁹ Pioneering recent work has demonstrated conclusively that the experimental programmes of 1650s Oxford and the early Royal Society were directly shaped by an engagement with Galileo’s texts that was itself informed by humanist modes of reading.¹⁰⁰

⁹³ Levitin 2015a, 255–259.

⁹⁴ Anstey and Vanzo 2012, 89.

⁹⁵ If there was such a ‘movement’ in the 1660s—and we will shortly return to this question—then its members, including Boyle, certainly saw themselves as children of Harvey: see, e.g., Oldenburg to Edward Bernard, 27 June 1671, in Oldenburg 1965–1986, 7: 127 (listing Bacon, Gilbert, Harvey and Boyle as the main English exponents of ‘Experimental and Usefull Philosophy’); also Sargent 1995, 79.

⁹⁶ Bertoloni Meli 2008.

⁹⁷ Schmitt 1970; Bertoloni Meli 2003, 634–640, 642, and the works cited there.

⁹⁸ Dear 1987; Dear 1995, 32–92. Dear’s conclusions are now importantly qualified, with more agency in the formation of physico-mathematics being ascribed to natural philosophers themselves, in Raphael 2015a, esp. 430. See also the essays in Feingold, ed. 2003, esp. Gorman 2003, at 15–16, 21, 24–31.

⁹⁹ De Ceglia 2003, 167–172; Palmerino 2003, 196, 205–10, 214–216; Gavagna 2011.

¹⁰⁰ Raphael 2017, 101–111.

Before that, one culmination of this approach was the work on magnetism by the Jesuit Niccolò Cabeo (*Philosophia magnetica* (1629)), where Cabeo used geometrical methods to move from empirical evidence gathered ‘from signs’ (*ex signis*)—crucially, Cabeo said he was doing natural philosophy, and, come his 1646 commentary on Aristotle’s *Meteorology*, he claimed to be exploring ‘almost the whole of experimental philosophy’.¹⁰¹ This causes some problems for Anstey and Vanzo, as does the use of the phrase by Athanasius Kircher, for certainly the work of neither Jesuit had much to do with Baconianism in any form. In response, they assert that the Jesuits ‘did not disdain speculation’ and so ‘were rather different from British experimental philosophers’.¹⁰²

But Cabeo *did* in fact repeatedly contrast his experimental work with the ‘speculation’ of Aristotle and his followers, which he claimed was derived from their conflation of physics with metaphysics: Aristotle had so often been wrong because he was ‘more accustomed to metaphysical speculation than observation’.¹⁰³ Even when Aristotle had relied on experience, he had too much favoured everyday experience (*experientia quotidiana*) rather than taking up experiment (*experimenta sumat*).¹⁰⁴ More fundamentally, Cabeo and Kircher’s experimentalism was a natural outgrowth of earlier humanist natural philosophy. Cabeo’s use of the term ‘experimental philosophy’ appeared in his *Meteorology* commentary, where it was applied to such subjects as falling bodies and corpuscular matter theory.¹⁰⁵ As it happens, meteorology was another subject which had seen an ‘empirical’ turn in the wake of humanist reconsideration of the subject; Cabeo’s discussion was the culmination of the trend.

Cabeo is thus a perfect example of how the traditions of anti-metaphysical Aristotelian natural philosophy, Jesuit interest in experiment, and practical chymistry came together to produce something that its practitioner recognised as ‘experimental philosophy’, independent of any major Baconian influence, and well before the members of the Royal Society started using the term.¹⁰⁶ Given all this, it should not come as a surprise that Boyle later showed great appreciation for Cabeo’s work, and specifically for the Jesuit’s diagnosis of Aristotle’s tendency to run to ‘obscure and unsatisfactory Distinctions’ drawn from metaphysics, rather than to rely on ‘Physical Ratiocinations, founded upon Experience, or the nature of Things under debate’.¹⁰⁷ Mid-century Englishmen just as quickly recognised Kircher’s work as a source of experimental

¹⁰¹ The title of the book is *In quatuor libros Meteorologicorum Aristotelis commentaria, et quaestiones: Quatuor tomis compraehensa: quibus non solum meteorologica, tum ex antiquorum dictis, tum maxime ex singularum rerum experimentis explicantur, sed etiam uniuersa fere experimentalis philosophia exponitur* (Rome, 1646). See Dear 1995, 64–67, 69–71; Waddell 2015, 45–47, 63–80.

¹⁰² Anstey and Vanzo 2012, 516–517.

¹⁰³ See now the excellent discussion in Martin 2011, 106–124, translated quotation from 109. Martin provides many more examples in his discussion. More generally, see also Martin 2016.

¹⁰⁴ Martin 2011, 115, quoting and translating Cabeo, *Commentaria*, IV, 353. For a direct

example of a canonical issue on which Cabeo thought his experimentalism improved on Aristotelian *experientia*—the capacity of wax and metal to compress—see Martin 2011, 116.

¹⁰⁵ As for Kircher, his focus on ‘experiment’ was also the culmination of many traditions, including that of Renaissance natural history: Findlen 1994, 236–239, 403–404; Fletcher 2011, 129–180; Camenitezki 2003, 265–266; Wardaugh 2008, 25–26, 119.

¹⁰⁶ For the chymical tradition of experimentation, see Newman 2004, esp. 238–289.

¹⁰⁷ *The Origine of Forms and Qualities* (1666/7), B 5: 294–295.

philosophical findings in a range of issues.¹⁰⁸ In the 1650s, pan-European mechanical, mathematical and medical experimental traditions had already come together in Oxford under the aegis of John Wilkins and Sir Charles Scarborough.¹⁰⁹ Little wonder, then, that when Wilkins sought to describe the work of the nascent Royal Society (to the formation of which he was far more important than Boyle), he named it not ‘experimental philosophy’ but ‘Physico-Mathematical Experimentall Learning’.¹¹⁰

Others, too, were at the time combining the anti-metaphysical Aristotelian tradition with chymical experimentation: an important example is Kenelm Digby, whose *Two Treatises* (1644) and other works were vaunted by experimentalists in 1650s and 1660s England despite having primarily a continental, non-Baconian pedigree.¹¹¹ Digby was intimately acquainted with the Minim friar Marin Mersenne, the centre of perhaps the most important natural philosophical network in mid-century Europe. Experimental inquiry was a primary concern of this network. What is of particular interest for us is that Mersenne did actually express an opinion on Baconian method. Rather ironically, he found it far too dogmatic and immodest in its search for certain knowledge of the inner essences of things, whether that search was conducted experimentally or not—Bacon, Mersenne argued in his *La verité des sciences contre les... Pyrrhoniens* (1625), had offered causal explanations far too prematurely. (He also noted that Bacon’s entreaties about the importance of natural history, while useful, had already been made and put into practice by many learned physicians, whom Bacon should have consulted before inventing his own endless rules and distinctions.)¹¹²

Mersenne, as the title of his book suggests, was operating in the context of a discussion of ancient scepticism, and specifically Sextus Empiricus’ denial of the possibility of the knowledge of essences and a causal *scientia*.¹¹³ We need not accept all the range of supposed consequences of the publication of the Latin Sextus (1562) proposed by Richard Popkin to acknowledge that engagement with ancient scepticism had some impact on the development of experiential approaches to natural philosophy.¹¹⁴ Mersenne’s solution to the problem was to emphasise humans’ ignorance of essences and instead to place emphasis on the knowledge of appearances, treated probabilistically as a ‘mathematical science of accidents’.¹¹⁵ This hard probabilism was missing from Bacon, and—withstanding the continued efforts of social historians of science to justify the national stereotype of English probabilism confronting a French search for certainty—

¹⁰⁸ E.g., Robert Payne to Gilbert Sheldon, 11 November 1650, in Pocock 1848, 171; Charleton 1652, 58.

¹⁰⁹ Frank 1980, 45–116; Bennett 1976; Nonnoi 2001; Raphael 2015b; Raphael 2017, 98–128; Kaoukji 2017.

¹¹⁰ Birch 1756–1757, 1: 3. Wilkins himself was the product not only of the movement to mathematise natural philosophy, but also a tradition, which *does* seem to have been particularly prevalent in England, of claiming that practical mechanics was directly relevant to natural philosophy: Bennett 1986, esp. the examples at 13 and 21–22, and the discussion of Wilkins and Ward at 22–23.

¹¹¹ See, e.g., Walter Needham to Richard Busby, 1655, BL MS Add. 4293, fol. 85^r; also

Poole 2014, 20–21. For Digby and the anti-metaphysical Aristotelian tradition, see Levitin 2015a, 245–250. For his chymical work, and its impact on his atomism, see Dobbs 1973; Newman 2001, 305–306. I am working on a longer study of the foundations of Digby’s natural philosophical views.

¹¹² Mersenne 1625, 206–218, esp. 212–214, and 209 for medicine.

¹¹³ At Mersenne 1625, 208, Mersenne suggests that Bacon would have done well to follow the sceptics more.

¹¹⁴ The most interesting recent work is showing how quickly ideas derived from Sextus entered mainstream philosophical pedagogy and discussion: see, e.g., Buccolini 2017.

¹¹⁵ Dear 1984, quotation from 190; Dear 1988.

was developed most forcefully in France, finding systematic articulation in the works of Pierre Gassendi.

Gassendi plays little role in histories of experimental philosophy. Despite the fact that he was explicitly cited as an inspiration by mid-century English natural philosophers, Anstey and Vanzo contrast the English approach with that of the Frenchman, in part because the latter used the expression ‘scientia experimentalis’ rather than ‘philosophia experimentalis’.¹¹⁶ And yet it is possible to make the case that at both the levels of practice and of theory, Gassendi’s works can be treated as the culmination of many of the trends discussed so far, and were in turn some of the most important stimuli for the development of mid-century experimentalism. Gassendi had established his practical experimental credentials in the 1630s and 1640s. It was he who first explained in print the famous barometric experiment—a successor to the Torricelli experiment—performed in 1648 by Florin Périer at Puy-de-Dôme, and later discussed by Pascal.¹¹⁷ From the results he argued not only for the existence of a void, but also adumbrated a primitive version of what would later become known as Boyle’s Law.¹¹⁸ From the late 1610s he conducted extensive collaborative work in observational astronomy designed to extend the Rudolphine Tables, culminating in his observation of the transit of Mercury in 1631; he also performed many optical experiments and did much comparative anatomical work on the structure of the eye.¹¹⁹ Other important experiments concerned the speed of sound, and work in the by then well-established tradition of experimental verification of Galileo’s theories about falling bodies.¹²⁰

Gassendi had from an early stage been a virulent anti-Aristotelian, largely on the basis of the humanist tradition (Francesco Patrizi was a particular influence). Gradually, and in parallel with his experimental practice, he came to defend systematically a non-Aristotelian natural philosophy grounded solely in sense experience, and in a modification of the philosophy of Epicurus. The historiographical focus on Gassendi’s modified Epicureanism has concealed the extent to which his systematisation offered a fully-fledged defence of experiment that was nonetheless very different from Bacon’s. Like Mersenne, Gassendi began with the sceptical position that knowledge of essences was impossible—indeed, this point lay at the heart of his anti-Aristotelianism.¹²¹ This anti-essentialism also rendered him unconvinced by Baconian method, which he discussed at length in the first part of the posthumously-published *Syntagma* (1658), devoted to logic. According to Gassendi, Baconian eliminative induction was unable to achieve its aim of providing solid principles.¹²²

¹¹⁶ Anstey and Vanzo 2012, 515–516. Particularly notable is the repeated English evocation of Nicolas-Claude Fabri de Peiresc as a promoter of experimentalism equal to Bacon: e.g., Oldenburg 1672, 4001–2, quoted but not discussed by Anstey and Vanzo; also Oldenburg to Bernard, 27 June 1671, Oldenburg 1965–1986, 8: 127. All this is based on Gassendi’s *Life of Peiresc* (1637), where Peiresc’s experimentalism is lauded alongside his distaste for natural philosophy based on ‘wit’ and ‘logical and metaphysical niceties’, and he is compared to Bacon. I quote from the English translation: Gassendi 1657, 4: 207–210. This translation was dedicated to Evelyn, who thought that from men

like Peiresc there were ‘so many advantages to be made and experiments gotten’ (Evelyn to Benjamin Maddox, 10 January 1657, in Evelyn 2014, 220).

¹¹⁷ Matton 1994.

¹¹⁸ Massignat 2000.

¹¹⁹ Joy 1987, 106–129; Sakamoto 2009; also Bloch 1971, 326–334; Brundell 1987, 30–47, which is valuable for its use of the MS material.

¹²⁰ Clark 1963; Galluzzi 2000.

¹²¹ For Gassendi’s probabilist-empiricist modification of scepticism, the best account is now Bellis 2017.

¹²² The fullest discussion is now Cassan 2012. As that article shows, to the extent that Gassendi

Instead, Gassendi offered a probabilist syllogistic logic that was underpinned by a theory of sign-based inference that could take the philosopher beyond what is evident to the senses.¹²³ This theory of signs no doubt had some foundations in Gassendi's reading of Sextus, but I suspect that it also had some origin in his engagement with medical semiotics.¹²⁴ Such a theory allowed him to combine epistemic modesty (the unknowability of essences; the impossibility of Aristotelian *scientia*) with experimental optimism, the latter manifested in his repeated claims that technological improvements, e.g., in microscopy, would lead to much improved knowledge of nature. In the meantime, atomism was, according to him, a probable hypothesis that had to be accepted cautiously, but which was at least partially justified by inferential reasoning from macroscopic to microscopic.¹²⁵ Consequently, Gassendi integrated his historical exposition of atomism with the latest experimental findings, such as those made with Torricelli's barometer.¹²⁶

All this manifested itself in language and ideas that can certainly be labelled a conscious defence of something like experimental philosophy, and which at points bear striking similarities to those later deployed in 1660s England. As Gassendi put it in the 'Prooemium' to the *Physica* part of the *Syntagma*, the true natural philosopher would have to track nature just as a hunter tracks a wild animal, working not just as a 'sluggish observer' (*segnis spectator*) looking 'lazily and superficially' (*otiose et superficie*) but who hunts by means of 'many different experiments and observations', even while nature tries to slip away.¹²⁷ Natural philosophy, while technically searching for causes like a contemplative *scientia*, was also akin to an artist's knowledge of 'things of which we ourselves are the authors', which, using anatomy, chemistry and other means, the natural philosopher has to 'break down' (*resolvere*) so as to understand.¹²⁸ Contrary to the Aristotelian ideal, natural philosophy could only be a '*scientia experimentalis, et ut sic dicam apparenialis*'.¹²⁹ Polemically, such a position was contrasted with the lack of relevant experimentation on the part of the scholastics, who had ignored those parts of philosophy 'which ought to be treated in a historical manner rather than by discussion':

How desirable it would be to know the history of stones, metals, plants, animals and other things of this type, the variety of which is already so pleasing to know! But all this, they [the scholastics] say, can be known by stonecutters, goldsmiths, herbalists and hunters. And so considering of no importance what to them seems too vulgar, they boast of choosing that which properly belongs to philosophy. No doubt Aristotle, Democritus and other great men,

approved of Bacon's method, it was as a means of attacking Cartesianism. I suspect Gassendi viewed Baconian induction as hubristically essentialist, like its Aristotelian counterpart, which he discusses and dismisses at Gassendi [1624] 1658, 3: 207b.

¹²³ Fisher 2005, 19–190, esp. 106–107: 'Gassendi has a manifestly non-apriorist conception of deductive inference which, quite distinctively for his times, suggests such inferences are merely probable, on the grounds that their premises always derive from sensory claims'; also Lolordo 2007, 94–99.

¹²⁴ For Gassendi in the context of semiotics, see Meier-Oeser 1997, 348–350; more broadly, see Demonet 1992; Nance 1993; French 1998.

¹²⁵ Fisher 2005, 327–365, esp. 336–369, 348–349; Lolordo 2007, 99. See more generally Meinel 1988.

¹²⁶ Gassendi 1649, 1: 425–427; Gassendi 1658, 1: 204–205; see further Beretta 2008, 192–196; Pav 1966; Joy 1987, 185–186.

¹²⁷ Gassendi 1658, 1: 126b.

¹²⁸ Gassendi 1658, 1: 122b–123a. This is the end of the section 'De methodo' of the *Logica*—it is worth noting the comparisons with medicine and ethics at 122b, and likewise the same points at the start of the *Physica* (125b–126b).

¹²⁹ Gassendi 1658 [1624], 3: 207a.

whose learning is so valued, were not developing philosophy, when they searched everywhere for such things? (Gassendi 1658 [1624], 3: 101b)¹³⁰

The emphasis on Democritus as an archetypal experiential philosopher suggests the influence of those like Severinus, for whom Gassendi elsewhere expressed great admiration.¹³¹ However, Gassendi continued, the result of such experimentation would not be *scientia* in the traditional sense. ‘If, in the standard manner, you consider science to be the certain and evident knowledge of something, obtained by means of necessary causes or demonstration, then this experimental knowledge (*ratione illa experimentalis*), or knowledge of appearances, does not come up to the name “Science”’—a conclusion that would be echoed by Locke in the *Essay*.¹³²

Here we have all the rhetorical components of mid-century English discourse, including the anti-essentialism and probabilism missing from Bacon. As for the point that Gassendi spoke of *scientia experimentalis*, rather than *philosophia experimentalis*, it should be noted that Boyle himself—in his earliest use of the experimental/speculative distinction identified by Anstey—spoke of ‘experimental learning’ rather than ‘philosophy’.¹³³ More importantly, Gassendi’s works were immensely popular in England.¹³⁴ Again, my claim is not that Gassendi was archetypal of ‘experimental philosophy’, but that searching for such a thing is fruitless, because it had many sources and inspirations. Mid-century English natural philosophy was much more eclectic—and pan-European in character—than the delineation of a narrowly English and post-1660 ‘experimental philosophy’ will allow.

4.1 Post-1660: England

Let us turn now to Boyle and Hooke themselves, and their counterparts in the Royal Society and in Restoration England. Here we are dealing with two main interpretative claims. One, narrower, is that Boyle and Hooke subscribed to the Baconian view of experimentation, with some modifications (most importantly, abandoning the elaborate version of induction). The wider one is that ‘From the 1660s, the most widespread method by which experimental philosophy was practiced in Britain was the Baconian method of natural history’.¹³⁵ I shall consider both in turn.

There seems little doubt that Boyle was the first to use the phrase ‘experimental philosophy’ systematically. While it had made some appearances in the Hartlib Circle, it

¹³⁰ See also the quotation in Bellis 2017, 148.

¹³¹ For Gassendi’s early and strong admiration for Severinus, see Bloch 1971, 445–456; Hirai 2015, 262.

¹³² Gassendi 1658 [1624], 3: 177b. Cf. Locke 1690, 326–327. Anstey 2011a, 1–30 has Locke advocating his version of ‘experimental philosophy’ in the *Essay*. For an alternative reading, see Serjeantson 2008.

¹³³ Anstey 2005, 218, quoting B 13: 351.

¹³⁴ For examples of Gassendi’s early reception in England, see Feingold 1997, 405–412. There is no plausibility to the old but still often repeated claim that Gassendi’s works met with

widespread clerical or religious opprobrium—for previously unknown examples to the contrary, see, e.g., George Radcliffe to Isaac Basire, 27 November 1647, and 21 January 1648, in Durham University Library, MS Cosin Letter Book 1A, 49, 51; Henry Hammond to Gilbert Sheldon, 6 October 1650, in Pocock 1850, 62–63.

¹³⁵ Anstey and Vanzo 2012, 91–92; also Anstey 2014, 108. This thesis seems to be compatible with the strong anti-revisionist case for the Baconianism of the Royal Society offered in Lynch 2001.

seems clear that its use there was promiscuous and without hard conceptual meaning.¹³⁶ Indeed, to the extent that they considered Baconianism in a theoretical manner at all, members of the circle rejected Bacon's inductivism in favour of the modified syllogistic logic of Jacob Acontius (*De methodo*, 1558) and Joachim Jungius (*Logica Hamburgensis* (1638)). Since they claimed that this would promote the rise of 'experimental learning', and since Hartlib recommended Jungius to Boyle and to other English natural philosophers, one might wish to speculate further on whether this could have been a source for the widespread down-playing of Baconian induction.¹³⁷

There can likewise be no doubt that in their methodological writings, Boyle and Hooke followed quite closely a Baconian model, insisting on the compilation of large-scale natural histories for which they provided tabular schemes and queries to be addressed.¹³⁸ But problems begin when we attempt to connect this broad fact to any kind of more precise delineation of an 'experimental philosophy', itself defined against a 'speculative' variant. I will not focus here on the more trivial linguistic point, already noted, that both Boyle and Hooke allowed plenty of scope for 'speculation' in their statements. Rather, I will identify some historical issues. Boyle, for example, adheres very well in his practice to Anstey's vision of the experimental philosophy, above all in his production of very many natural histories, many of them not concerned with natural kinds. But this only characterises Boyle's career after the mid-1660s (starting with the *New Experiments and Observations Touching Cold* (1665)). Up to then, his interest in natural philosophy (which began in the late 1640s) manifested itself either in apologetic writings, or in 'discursive essays in which he sought to use experimental evidence to vindicate the mechanical hypothesis'; both of these 'take the form of ruminative essays, in which experimental data was adduced, but in a far from systematic way'.¹³⁹ In other words, these works represent not a Baconian Boyle, but one much more influenced by his work with the Oxford physiologists, and his reading of continental natural philosophers like Gassendi and Cabeo. And yet, it is in these texts that Boyle became the first Englishman to talk systematically of 'experimental philosophy', and to contrast it with speculation.¹⁴⁰ The only conclusion that the evidence warrants is that Boyle's influential use of the term did *not*, at least initially, reflect a strict Baconian philosophy of experiment, but was much more promiscuous in deployment, and polemical in intent. Moreover, I think that there is a danger that the stunning results of the last thirty years of Boyle scholarship may lead us to overemphasise how representative he was of Restoration natural philosophy; for all his status as a poster boy, we should not forget that his relationship with the Royal Society was ambiguous, attending far fewer meetings and contributing far less than one might expect.¹⁴¹

¹³⁶ Feingold 2016 seems to me to show this beyond doubt.

¹³⁷ Clucas 1994, quotations from 60–61, 62–63 (both quoting Hartlib Papers 30/4/40A). Jungius was a practising physician and natural philosopher, and his logic was particularly concerned with the 'relationship between experience, mathematics and logic': Clucas 2010, 54. See also the important reconsideration of the well-known Petty-More correspondence in Dobre 2018, esp. 257–258.

¹³⁸ Hunter 2007, reprinted in Hunter 2015, and incorporating the text of Boyle's 'General heads for the natural history of a country'; Hooke's 'General Scheme' is in Hooke 1705, 1–70. See Anstey 2014; Oldroyd 1972; Oldroyd 1987.

¹³⁹ Hunter 2007, 5.

¹⁴⁰ See the examples adduced in Anstey 2005, 218; also Feingold 2016, 14–15.

¹⁴¹ As we are sagely reminded in Hunter 2007, 2–3.

As for Hooke, his posthumously-published ‘General Scheme, or idea of the present state of natural philosophy, and how its defects may be remedied’ of the late-1660s certainly reflects a broadly Baconian agenda. But we must remember that this work was very likely composed not as an abstract methodological treatise accurately describing Hooke’s natural philosophical practice, but for a specific polemical purpose: as a quasi-manifesto for reform presented to the Royal Society.¹⁴² In reality, it is difficult to map such methodological rhetoric onto any consistent practice on Hooke’s part. The work which most closely approximates Hooke’s methodological ideal is his geological lectures (delivered between 1667 and 1700). But these were strongly attacked by other members of the Royal Society, such as Robert Plot and John Wallis, specifically for what they saw as the positing of unfounded hypotheses.¹⁴³ Much of the rest of Hooke’s work, meanwhile, struggles to match the Baconian ideal even in a limited way. The *Micrographia* (1665) obviously contains much experimental material, but its organising principle is that of demonstrating the potential of a piece of equipment, not one of Bacon’s or Hooke’s natural historical categories. More importantly, its first half consists largely of natural philosophical theories—including some on congruity and incongruity that much exceed Boyle’s cautious nescience on the subject—to such an extent that Hooke was famously instructed to give notice by the Royal Society that ‘though they have licenced it [the book], yet they own no theory, nor will be thought to do so: and that the several hypotheses and theories laid down by him therein, are not delivered as certainties, but as conjectures; and that he intends not at all to obtrude or expose them to the world as the opinion of the society’.¹⁴⁴

Subsequently, Hooke went on to a research programme in attraction, especially as applied to celestial mechanics. Here, his ‘method’ (if there was such a thing) again seems to have owed little to Baconianism directly; rather, it was a continuation of the tradition of combining post-Gilbertian theories of attraction with Keplerian physical astronomy, a tradition which was frequently associated with Gresham College and which encompassed figures such as Thomas Harriot, William Crabtree, Jeremiah Horrox, Samuel Foster, John Wilkins, John Wallis, Seth Ward and Christopher Wren.¹⁴⁵ Wren, in his inaugural lecture as Gresham Professor of Astronomy, named Gilbert ‘the Father of the new Philosophy’, as well as mentioning Harvey, Galileo and Kepler and condemning Descartes as ‘but a Builder upon [Gilbert’s] Experiments’—Bacon is conspicuous only by his absence.¹⁴⁶ Within the context of this research, Wren happily spoke of ‘ingeniously deriv[ing]... [a] hypothesis’ and was hardly reticent about producing before the Royal Society a ‘theory’ based only on ‘some observations’.¹⁴⁷ Hooke, meanwhile, saw himself as ‘prosecuting [a] speculation’ (i.e. the continuous attractive influence of a central body) and argued that using his theory of ‘inflection’ (itself derived by non-experimental analogical reasoning from optics to celestial mechanics) one could proceed from ‘some few observations... to

¹⁴² Hunter and Wood 1989, 214–215; Hunter 2007, 13.

¹⁴³ Oldroyd 1972; Turner 1974; Rappaport 1986; Ito 1988; Poole 2010, 104–113, 118–124, 127–130, *passim*.

¹⁴⁴ Birch 1756–57, 1: 491; (Hooke 1665, sig. [A2]^v). See further Hunter 2003, 129–131, 134; Ehrlich 1995, 131–142. Many of Hooke’s later

publications also revolve around demonstrating the potential of instruments: Bennett 1980.

¹⁴⁵ See the classic studies: Johnson 1937, esp. 80, 152–154, 159–160, 169–170, 173–174, 296; Bennett 1975; Bennett 1981.

¹⁴⁶ Wren 1750, 204; Bennett 1982, 56–60.

¹⁴⁷ See the translation of Wren’s words as they appeared in Wallis 1659 in Hall 1965, 141; Birch 1756–1757, 2: 12.

a certainty'.¹⁴⁸ Hooke ended up developing an explanatory hypotheses for planetary motion which, while being critical of Cartesian vortices, was no less speculative, depending as it did on a theory of a vibrating aether.¹⁴⁹

In contrast to much of the experimental rhetoric of Restoration England—and to Anstey's vision of 'experimental philosophy'—Hooke's later methodological writings more and more emphasised the necessity of producing theories *immediately* upon experimentation; they also showed repeated impatience with the endless collecting of natural historical data.¹⁵⁰ Once again, this was less about abstract methodology and more about institutional direction, for it reflected different visions of the Royal Society and its potential reform. One vision, exemplified best by Hooke, held that it should be a body of elite, salaried natural philosophical professionals, who would regularly provide high-level theoretical explanations for their experimental findings. In this respect, Hooke could be perceived as formalizing 'high' or philosophical Baconianism, but he was also an inheritor of the Oxford group of the 1650s, who had long pursued natural philosophy experimentally without following a Baconian method. Another figure who shared in such an elitist vision for the Royal Society was the mathematician William Neile. In 1669 he wrote a set of 'Proposalls' for the Society's experimental practice which, while repeating all the commonplace espousals of experimentalism, insisted that endless experimentation was often fruitless, that the wait for a complete natural history would be indefinite, that 'experiments themselves are but a dry entertainment without the indagation of causes', that 'it seems a little below the name and dignity of Philosophers to sitt still with the bare registering of effects', and that some subjects, such as the 'nature of body and motion in generall', could already be investigated causally by a committee 'as ever they will be after never so many experiments'.¹⁵¹ This last comment was almost certainly a reference to ongoing debates within the Society about motion and collision, debates that were much indebted to Cartesianism (and the tradition of geometrical modelling in physics more generally) and were not conducted in Baconian mode.¹⁵²

But another group—often but not always comprised of more dilettantish *virtuosi* without formal academic experience in natural philosophy—epitomized a 'Baconianism' that was far more interested in rather promiscuous data gathering, structured only by heads of 'inquiries', many of which concerned not experiment but the collection of observation from new places.¹⁵³ Accordingly, it was far less elitist than the Hookeian version, its advocates insisting that 'we have no more reason to expect, that all should be

¹⁴⁸ (Birch 1756–1757, 2: 91); Bennett 1975, 43; Bennett 1981, 173. For Hooke's concept of inflection, central to his work, see now Gal 2002, 17–58, esp. 38: 'Hooke's attitude towards "inflection" is strictly practical: he uses it wherever and however he sees fit, and never allows the theoretical and logical considerations he employs in constructing it to confine him in its deployment'. Of course, there was a significant experimental component to Hooke's defence of his ideas, specifically his use of a conical pendulum (which had been used for similar purposes by Horrox and others): Bennett 1980, 42, and 43–44 for the non-Baconianism of this. There is much scope for more work on the role of analogical thinking in seventeenth-

century experimental philosophy—I have highlighted above its importance for Gassendi.

¹⁴⁹ Hooke 1705, 177–179, discussed in Bennett 1981, 175; also Ehrlich 1995.

¹⁵⁰ See the evidence collected in Hunter and Wood 1989, 214–215; Oldroyd 1972, 117–118.

¹⁵¹ See, e.g., Oldenburg 1965–1986, 5: 263; the 'Proposalls' in Hunter and Wood 1989, 222–224; Bennett 1982, 119, 122.

¹⁵² Hall 1966; Bertoloni Meli 2006, 234–237; Jalobeanu 2011, esp. 112. Anstey and Vanzo (2016, 92) claim that such work was exceptional, and that 'the vast majority of projects... were conceived as contributions to, or deployed the methods of... experimental natural history'.

¹⁵³ Hunter 2007, 14–16.

philosophers or Curators’, or, like Sir John Hoskyns, that ‘meere compiling will content mee’.¹⁵⁴ It manifested itself in ‘random collecting in subjects where it was unconstructive, enabling those lacking in imagination to make a virtue of their abstention from philosophical speculation’—the main generic example being that of the natural history of a county, such as Robert Plot’s *Natural History of Oxfordshire* (1677).¹⁵⁵ If there was anything distinctively English in late seventeenth-century European natural philosophy, it was this kind of work. Unfortunately (at least from Hooke’s point of view), the hard reality was that the Royal Society needed the participation of such *virtuosi*—who were often interested in the divertissement and ‘curiosities’ its activities produced, much to Hooke’s ire—for its institutional survival.¹⁵⁶ But there is no reason to think that they were representative of the Royal Society’s ‘method’ at this or any other point.

Anstey, of course, is aware of these differences. Yet he nonetheless tries to minimise them, writing that ‘this range of views is always expressed in terms that are consistent with the fundamental dichotomy of speculative and experimental methods’.¹⁵⁷ But it seems to me that to underplay the *real* differences within the Royal Society in favour of foregrounding similarities of rhetoric is to get things the wrong way round, and that the reality is that both the practice of English experimental natural philosophy, and even the rhetoric that justified it, was not so homogenous. One very obvious point to raise in this regard concerns Baconian experimental natural histories. If it is the case that ‘from the 1660s the most widespread method by which experimental philosophy was practiced was the Baconian method of natural history’, or that ‘there were very few active natural philosophers in England who did not conceive of their task in terms of the construction of natural histories’, one has to ask: who wrote such natural histories (i.e. not just of natural kinds), apart from Boyle?¹⁵⁸ Hooke, as we have seen, may have placed emphasis on the importance of natural history, but nothing in his oeuvre can be compared to a full Baconian or a Boylean natural history. One can point to the gentlemanly natural histories of counties by men like Plot and John Aubrey, or to the various history of trades projects, but as important and popular as these were, they hardly represented the ‘most widespread’ method of philosophising in the Royal Society, or characterised ‘experimental philosophy’.¹⁵⁹ Apart from Boyle’s works (and not including methodological statements by Sprat, etc.), the only example of the ubiquity of a natural historical approach adduced by Anstey and Vanzo is Newton’s early work on light and colours. But I am not convinced by this, and remain much more persuaded by the case for Newton’s work being implicitly critical of the methods he thought characteristic of the Royal Society.¹⁶⁰ One of Newton’s early Jesuit opponents even complained that Newton had not proceeded by the accumulation of much experimental evidence, in contrast to ‘several worthy members of ye Royall Society’, who had ‘bottomed new Theories upon a *Number* of experiments, particularly the ingenious Mr Boyle’.¹⁶¹

¹⁵⁴ See the proposals by ‘A.B.’, printed in Hunter and Wood 1989, 227; Hunter 1981, 68.

¹⁵⁵ Hunter 1981, 17–18.

¹⁵⁶ *Ibid.*, 62–76, with many examples. See also the important statistical analysis in Frank 1976.

¹⁵⁷ Anstey 2005, 226; also 236.

¹⁵⁸ Anstey and Vanzo 2016, 91–92; Anstey 2005, 223.

¹⁵⁹ Hunter 1975, 93–147.

¹⁶⁰ Anstey and Vanzo 2016, 92, relying on Jalobeanu 2014. I favour the classic account of Shapiro 1993, 12–39.

¹⁶¹ Antony Lucas to Oldenburg, 13 October 1676, in Oldenburg 1965–1986, 13: 100 (emphasis in original).

Nor can one find much in the way of systematic natural historical work in the output of those whose statistical analysis has shown were most active in the work of the early Royal Society: men like Wilkins, Thomas Henshaw, William Croone, Jonathan Goddard, Walter Charleton, Christopher Merrett and John Wallis.¹⁶² It is no coincidence that this ‘core’ had mostly received their scientific formation in mid-century Oxford, where their interests had been formed without the need for much recourse to Baconian method or rhetoric.¹⁶³ Oldenburg, it is true, conceived of his role as an organiser of such natural historical collecting, and in 1664 the Royal Society did establish a ‘committee for collecting the phaenomena of nature and all philosophicall experiments hitherto observed, made and recorded,’ envisioned in Baconian terms. But, apart from producing one report, this committee seems to have achieved precisely nothing.¹⁶⁴ Of course, plenty of prominent natural history was done by the likes of Francis Willughby, Robert Morison and John Ray, but this was continuous with earlier European traditions that I have discussed above.¹⁶⁵ Moreover, important recent research has demonstrated that such work stemmed, once again, from well-established institutionalised medicine and natural philosophy.¹⁶⁶

This brings us to the question of rhetoric, and specifically the use of apologetic writings as sources for methodological thinking. Anstey relies a great deal on such writings, especially those by Thomas Sprat and Joseph Glanvill.¹⁶⁷ But these writings were not representative of any corporate Royal Society ‘method’, and were stimulated by their own, pragmatic concerns. Sprat in particular emphasized the natural historical, anti-hypothetical, anti-theoretical and anti-speculative elements of the Society’s work. But this emphasis was designed to bestow an artificial unity on to that work, and ‘experimental’ here often became largely interchangeable with ‘real’, ‘new’, and ‘true’—i.e. it came to mean little more than ‘good’, or non-scholastic.¹⁶⁸ This, I think, is an important point: when used negatively, ‘speculative’ was, for the most part, simply a polemical term, deployed with little concern for conceptual precision. The origins of such a use were a dilution of the old humanist anti-Aristotelian claim that either Aristotle or his followers had corrupted his natural philosophy with logic or metaphysics.¹⁶⁹ Very quickly, it proved convenient to apply it to Cartesianism (or at least to aspects of it), likewise accused of inappropriately importing metaphysics into natural philosophy.¹⁷⁰

¹⁶² One later example of a quasi-natural historical exploration that might suit the Baconian rubric is Nehemiah Grew’s work on colours in his *Anatomy of Plants* (1680): see Roos 2015. But as the book’s title suggests, it was generically a traditional history of natural kinds. Nor was Grew’s work without a significant degree of non-experimental speculation: Anker 2004, esp. 196.

¹⁶³ For these men as the most active, and their background, see Frank 1976, 87–88.

¹⁶⁴ Hunter 1989, 91–93, 104–105.

¹⁶⁵ See the essays in Birkhead 2016; Mandelbrote 2015; Cook 1993, esp. 50–51.

¹⁶⁶ Serjeantson 2016, esp. 76–81, 85–86.

¹⁶⁷ E.g., Anstey 2005, 217, 219, 222, 224.

¹⁶⁸ For this point, see Feingold 2016, 27. For the dangers of taking Sprat or any other apologist as representative, and for their real agendas, see

Wood 1980; Hunter 1992; Hunter 2017 (esp. 16 for important evidence that emphasis on Bacon was designed as much to attract gentry support for the Society as to reflect its method); Levitin 2015a, 295–313. For Glanvill’s very non-Hookean insistence that ‘to make *Hypotheses*, must, I think, be the happy priviledge of succeeding Ages...’ see *Letters and Poems in honour of... Margaret, Dutchess of Newcastle*, London, 1676, 24–25.

¹⁶⁹ For humanist anti-Aristotelianism in the Royal Society apologists, see Levitin 2015a, 295ff.

¹⁷⁰ Anstey and Vanzo identify this development as a post-1680 one: e.g., Vanzo 2016, 53. But for earlier examples, see, e.g., HP 30/4/3A (1654), and those in Ragland 2015. I think this was yet another way in which Gassendi influenced English methodological discourse:

This is supported by the fact that virtually no one actually defended their status as a ‘speculative’ philosopher. The very few figures who can be identified doing so are Margaret Cavendish and John Sergeant.¹⁷¹ But—aside from the fact that both of these were hardly major foes—it should be noted that both of them saw in the aggressive rhetoric of the Royal Society apologists (and later in Locke) a *societal* threat that far transcended concerns with natural philosophical methodology. Cavendish saw in it a threat to the universities, a threat that she associated with Interregnum radicalism; in practice, she was not as dismissive of experiment as is sometimes claimed, and held to a probabilist epistemology that hardly made her typical of traditional ‘speculative’ philosophy.¹⁷² Sergeant, meanwhile, saw a threat to the traditional philosophical foundations of theology—he was writing in response to deist appropriation of Lockean language in the mid-1690s, and it is no coincidence that his main aim was to reassert the disciplinary importance of metaphysics.¹⁷³ But since the experimentalists in reality had no intention of undermining the universities or theology, it is difficult to see this ‘debate’ (to the very limited extent that it existed at all) as a particularly significant one.

Conversely, what *was* significant is that a large number of practising Restoration experimentalists justified their endeavours in ways that were much more subtle, traditional and successful than the crude distinctions and controversial historical sketches of Sprat and Glanvill. This is particularly evident among physicians, whose importance—both intellectual and legitimacy—to the Royal Society is well established, but continues to be underappreciated by historians of science. Many physicians still argued that experimentalism was entirely compatible with the programme of ‘Rationalist Empiricism’ that we have met being developed in sixteenth century Europe, and which was taught at the universities. As I have noted, this was particularly the case in the circle of the important medical researcher and pedagogue Francis Glisson. But it was also the case for more radical and famous medical researchers, such as Thomas Willis, whose chemical and anatomical work earned him a Europe-wide reputation, and who was perhaps second only to Boyle in fame among early Restoration naturalists. Willis *did* use the rhetoric of experimental versus speculative approaches. But much more substantive was his recourse to the traditional defence of experience in learned medicine: although Empiric medicine as it had been inherited by Hippocrates had indeed been corrupted by those who made physic into a ‘general method, as if it were some kind of speculative science’, it was also the case that such Empiric origins should not conceal the need for ‘method and reason’ to supplement ‘naked Experience’.¹⁷⁴ Later, Willis would argue that true physic had to go beyond its merely Empiric (*mere empiricam*) origins and reduced to ‘method’ on the basis of indicative signs, and should search for the *causes* of the operation of medicines. It is particularly interesting that the near-contemporary English

for an early example of a Gassendi-inspired discussion in this vein by someone who used the experimental-speculative distinction in defence of the Royal Society, see Parker 1665, 157–180, discussed in Levitin 2014, 55–59.

¹⁷¹ Anstey 2005, 219; Anstey and Vanzo 2012, 501.

¹⁷² Cavendish 1666; the context is now well explored in Begley 2016, esp. 261–262, 270–271; and Wilkins 2014.

¹⁷³ Sergeant 1696, sigs. b6^{r-v}; for the context, see Levitin 2010. One would be very surprised to find Sergeant being against experiment *tout court*, given his great admiration for Kenelm Digby.

¹⁷⁴ Willis 1659, sigs. [H3]^v–[H4]^v. Only the earlier section is quoted in Anstey 2005, 227.

translation rendered *mere empiricam* as ‘merely Experimental’—a sign of the linguistic imprecision still prevalent in the vernacular in particular. Also significant is that all this was announced in a work called the *Pharmaceutice rationalis*—pharmacy had traditionally been classed as one of the two ‘practical’ (as opposed to ‘theoretical’) parts of medicine.¹⁷⁵ Like so many of his Renaissance predecessors, Willis was elevating disciplines that had previously been considered non-theoretical to philosophical status.¹⁷⁶

Exactly the same can be said for others who have been adduced for the experimental-speculative distinction, such as Thomas Sydenham and Everard Maynwaring.¹⁷⁷ Sydenham, although he did reimagine Hippocrates as a proto-natural historian, ultimately rested his argument on the experiential potential of traditional semiotics. Maynwaring, meanwhile, drew on humanist discussions to develop an incredibly elaborate history of medicine so as to present iatrochymical, experimental approaches as the true inheritor of a ‘good’ Empiricism (that did not rely simply on accidental experience, but on methodical inference), that itself had informed a ‘good’ Rationalism before that had been corrupted by Galen’s false doctrine.¹⁷⁸ The physicians, then, were able to justify experimental practice within the framework of traditional, institutionally accepted methodological language, and in this they proved far more successful than the crude approaches of Sprat and Glanvill, which quickly became an embarrassment to their allies.¹⁷⁹

In short, much of the English defence of experimentalism rested on the conceptual apparatus developed across Europe over the previous two centuries. When we abandon the implicit assumption of English exceptionalism, English sources reveal an eclecticism, subtlety and richness that brings them far closer to their European counterparts. This leads to the obvious question: was there anything unique about the English case?

4.2 Post-1660: Continental Europe¹⁸⁰

As I have already noted, Anstey and Vanzo are sceptical of there being much in the way of experimental philosophy done outside of England in the second half of the seventeenth century, especially in France. According to them, there was ‘absence of an identifiable movement of experimental philosophers in France in the latter decades of the seventeenth century’, a statement justified on the basis of the claim that ‘there is little evidence... that a fully-fledged program of Baconian natural history was ever implemented in the *Académie [des Sciences]* in this period’, and that ‘it is difficult to find one French natural philosopher who openly identified himself as an experimental philosopher’. Experiments

¹⁷⁵ On the basis of Galen, *Int.* K XIV.689 and *Def med.*, K XIX.351; for the division in early modern methodological debates, see Mikkeli 1999, 32–40; Maclean 2002, 69–70; Siraisi 1987, 101–102; Levitin 2015b.

¹⁷⁶ For all the primary evidence, see Willis 1674, 1–3; Willis 1675, sig. a3^r; Willis 1684, 1–2 (new pagination for the translation of *Pharmaceutice rationalis*); for further details, see Levitin 2015a, 288–289.

¹⁷⁷ See, e.g., Anstey 2005, 228–229; Anstey and Vanzo 2016, 92. For a slightly different view, see Anstey 2011b.

¹⁷⁸ Levitin 2015a, 291–294 (Sydenham), 284–286 (Maynwaring). For Maynwaring more

generally, see now the fantastic account in Barry 2018.

¹⁷⁹ Henry Stubbe, in particular, badgered Glanvill into pathetic capitulation, forcing him to admit that the ancients *had* conducted experiments, and mocking Glanvill’s incomprehensible accusation that pre-modern philosophies had been ‘notional’ (which Glanvill used as a variant of ‘speculative’): Levitin 2015a, 312–313.

¹⁸⁰ The following focuses on France and Italy, but one could just as easily chart experimentalism in the Dutch Republic or the German-speaking lands.

were conducted by ‘neo-Cartesians, such as Jacques Rohault’, but they only ‘did this with a view to confirming particular principles of Cartesian natural philosophy’.¹⁸¹

This reading depends on searching for the reified ‘experimental philosophy’ that supposedly dominated in England, and then announcing its non-existence in France. Now, French for the most part lacked the equivalent of the *experientia/experimentum* distinction, with ‘expérience’ regularly standing in for the English ‘experiment’.¹⁸² Unsurprisingly, this meant that open talk of ‘experimental philosophy’ was less prevalent. But I see no reason to think that the French experimentalists, especially those of the Académie des Sciences (formally founded in 1666) were in practice doing much different to their English counterparts. For sure, some Cartesians, such as Rohault and Robert Desgabets, did conceive of experiment primarily as confirmatory of conclusions reached *a priori*.¹⁸³ But among experimentalists, they were a minority. As we have seen, a strong experimental current was already present in the Mersenne circle: the focus was especially on (but not limited to) verification or correction of Galilean physics.¹⁸⁴ But we should not overlook other early seventeenth-century moves, such as the institutionalisation of botany, and thus the experiential ideology it had developed over the previous century.¹⁸⁵

It is true that the meetings of the Montmor Academy in the late 1650s had a Cartesian tendency and could not be described as ‘experimental’ in a meaningful sense: this was recognised by contemporaries in England.¹⁸⁶ But the group who broke away from the Academy to found the loose gathering that was the Compagnie des sciences et des arts, active c.1664–1666—a group that contained, among others, men like Melchisédech Thévenot, Adrien Auzout, Étienne d’Espagnet, Pierre Petit and visitors like Christiaan Huygens, Nicolas Steno and Jan Swammerdam—engaged, both in practice and in words, in what has fairly been labelled a ‘radical experimentalism’, a position active since the early 1660s.¹⁸⁷

Negatively, this move towards experimentalism was inspired by anti-Cartesianism (which went hand in hand with frustration at Rohault’s rhetorical grandstanding at Montmor).¹⁸⁸ Positively, there may have been some second-hand Baconian inspiration—in well-known advice offered to Colbert, Huygens suggested that the imminent Académie should ‘work towards a natural history closely following the design of Verulam’.¹⁸⁹ Undoubtedly, the French experimentalists were partially influenced by developments in England, and their rhetoric can at times bear striking similarities to that across the Channel, including that which contrasted experiment to speculation.¹⁹⁰ But at least in

¹⁸¹ Anstey and Vanzo 2016, 93–94.

¹⁸² Licoppe 1996, 23–24, including examples.

¹⁸³ See now esp. Roux 2013, esp. 54–55; Easton 2013; Dobre 2013; Spink 2018.

¹⁸⁴ See further Bertoloni Meli 2004, 212–237; Lewis 2006, esp. 15–62, 113–140; Raphael 2008; Palmerino, 2010.

¹⁸⁵ Spary 2000, 15–48.

¹⁸⁶ Roux 2013, 60–62; Oldenburg 1965–1986, 1: 241, 287.

¹⁸⁷ Roux 2013, 62–72; another important account is McClaughlin 1975, as well as the two classic studies: Brown 1967, 119–147; Sturdy 1995, 16–21.

¹⁸⁸ Roux 2013, 81–84 claims that the attack on Cartesianism for being non-experimental came

only after Edme Mariotte’s *Essai de logique* (1678); again, it seems to me that this trend began somewhat earlier (even without mentioning the influence of Gassendi): see, e.g., Chapelain to Huygens, 20 July 1661, in Huygens 1888–1952, 3: 299, on experimental disproof of a Cartesian ‘conjecture’ concerning attraction.

¹⁸⁹ Huygens to Colbert in 1666, in Huygens 1888–1952, 6: 95–96); see also the ‘Projet de la Compagnie des Sciences et des Arts’, *ibid.*, 4: 325–329.

¹⁹⁰ See the letters of Jean Chapelain from 1661 in Brown 1967, 121–122, quoting and translating Huygens 1888–1952, 3: 272, 299.

Huygens' personal case, there is no way that his actual (eclectic and under-theorised) scientific practice can be categorised as 'Baconian': if a summary has to be offered, it is of a hypothetico-deductivism where experiments were used to confirm mathematical theory (and even this only in the wake of his work on birefringence in Iceland crystals; prior to this, Huygens had followed a more traditional mathematical approach, at least in optics).¹⁹¹

If we *are* to focus on individuals who influenced the Académie, the role of Gassendi was almost certainly more significant than that of Bacon.¹⁹² Nonetheless, when the Académie was formed, English observers from the start conceived it as doing the same kind of experimental science as they were.¹⁹³ I do not know of a single example of an English experimental natural philosopher claiming that their method was qualitatively different to that of their French counterparts. The fact that the members of the Académie did not use a phrase directly equivalent to 'experimental philosophy' seems to me at this point to be largely irrelevant, for even the briefest perusal of documents like the fifteen-point plan of research presented to the society by Claude Perrault on 30 November 1669 reveals the experimental focus of every element of its proceedings.¹⁹⁴ In fact, one central aspect of the organisation of the Académie rendered it a rather closer approximation of the Baconian ideal than the Royal Society: its members were paid for their efforts. This allowed the kind of 'professional' specialisation and systematic research dreamt of by Hooke, but largely impossible in England.¹⁹⁵ This state-sponsored experimentalism was matched by the provision of equipment, from the laboratory installed at the Bibliothèque du Roi—for which a huge record of purchases and experiments conducted survives, much of it still untapped by historians¹⁹⁶—to the immensely costly observatory partly designed by Cassini (lured to Paris by an appropriately immense salary), at which he, Ole Rømer and Jean Picard conducted the observations that led to Rømer's discovery of the speed of light.¹⁹⁷

¹⁹¹ See Dijksterhuis 2004, esp. 2–9, 99, 105–106, 247–248, 256–257, 259–264. For a rare example of Huygens' self-identification, see his overt preference for Galileo over Bacon (whom he praises for what he perceives as a mechanistic explanation of heat, but criticises for not understanding mathematics) in Huygens 1888–1952, 10: 403–404. The fullest survey of Huygens' use of Bacon's methodological ideas denies any significant influence: Sabra 1981, 170–183. On Iceland crystals, Huygens was following in the footsteps of Erasmus Bartholinus, for whose mix of experimental and mathematical approaches, see Buchward and Møller Pedersen (1991); Lohne 1977.

¹⁹² In this I side with McClaughlin 1975, 240 rather than Roux 2013, 70–71. For the role of Gassendists in the early Académie, see Sturdy 1995, 23–24, 124–125, 157; Taton 1966, 36. However, as far as I can see, there are no dedicated studies of the topic. My point is not that the early academicians were doctrinally dogmatic Gassendists (they certainly were not), but that Gassendi's anti-Aristotelian

experimentalist discourse and practice probably inspired them more than Bacon's.

¹⁹³ See, e.g., Oldenburg to Boyle, 8 June 1666, Oldenburg 1965–1986, 3: 155.

¹⁹⁴ The plan is reproduced in detail in Sturdy 1995, 157–158: every single one of the fifteen projects is experimental (seven in 'Physique générale', three in chemistry, one in botany, and four in medicine).

¹⁹⁵ This specialisation was already being insisted on by Perrault in his advice to Colbert of the mid-1660s: Brown 1967, 148–149. For the fullest account of the pensions paid, see Sturdy 1995, 153–156.

¹⁹⁶ See esp. Sturdy 1995, 149–151. The records are in Bibliothèque Nationale de France, Paris, MS Nouvelles Acquisitions 5133–49. Also Salomon-Bayet 1978, 7–25.

¹⁹⁷ The fullest account is still Wolf 1902; for the speed of light, see Van Helden 1983. There is no evidence that English natural philosophers questioned the methodology behind Rømer's findings—quite the opposite: Willmoth 2012; Anstey 2016, esp. 74–76.

As for natural history, the Académie certainly progressed further than the Royal Society in a genuinely collaborative attempt to produce a body of work, conducting huge amounts of dissections and plant gathering, even if the plans to produce two vast volumes—natural histories of both plants and animals—did not quite come to fruition.¹⁹⁸ These natural historical projects also led to a great amount of chemical experimentation, carried out by Samuel Duclos and the apothecary Claude Bourdelin: the latter’s copious and detailed experimental records still survive.¹⁹⁹ Indeed, across France, experimental chemistry was practised extensively, incorporating such Boylean features as the insistence on the use of intermediate causes, as well as frequent experimental corrections of the Englishman.²⁰⁰ But just as in England, surface agreement about the importance of experiment and natural history concealed fundamental tensions. Duclos’ preference was for solution analysis over distillation, aiming at the discovery of the ultimate principles of mixts; his opponent Denis Dodart (elected 1673) considered such aims over-ambitious, himself being more interested in the ‘outer’ properties of plants, their medicinal virtues, and consequently in producing an accurate classification.²⁰¹ Once again, these ideas and debates were happily received by English natural philosophers, with no sense that their French counterparts were doing something methodologically different—if anything, it was the French academicians who had to work harder than their English counterparts ‘to defend their very pursuit of speculative work’.²⁰²

All this helps to explain why Hooke and those who shared his desire for a ‘professionalisation’ of the experimentalism of the Royal Society expressed significant jealousy of the French situation.²⁰³ But at the same time, we must note that in France, just as in England, the most successful defences of experimentalism were those that adopted the eclectic, conciliatory and historically-sensitive approach. Here a crucial text was the *De consensu veteris et novae philosophiae* (1663) by Jean Baptiste du Hamel, the Académie’s secretary between 1666 and 1697. The book was greatly admired by Colbert, who persuaded Du Hamel to prepare a new edition for widespread pedagogical use, an edition which was in turn presented as the corporate view of the Académie and which Perrault would later claim ‘was the most influential single textbook in philosophy and science in the educational institutions of France’.²⁰⁴ Across Europe, the most successful defences of experimental method were those that convincingly explained how it contributed to established practices of traditional natural philosophy.

¹⁹⁸ The works published were the *Mémoires pour servir à l’Histoire naturelle des Animaux* (1671) and the *Mémoires pour servir à l’histoire des plantes* (1676). For the immense amount of work done, see Stroup 1990, 70–83; Guerrini 2015, 50–164.

¹⁹⁹ Boantza 2010, esp. 75–78, 83–84; Stroup 1990, 89–102.

²⁰⁰ Clericuzio 2000, 177–181; Boantza 2007.

²⁰¹ Boantza 2010, esp. 84–90; Boantza 2013, 76–92. For the importance of this incident to the institutional history of the Académie, and much other essential new information, see the very important revisionist account in Meynell 2002.

²⁰² Roos and Boantza 2015, quotation from 375.

²⁰³ Hunter and Wood 1989, 203–204, 216 discussing Richard Waller’s letter to Hans Sloane, 11 April 1699, BL MS Sloane 4037, fol. 249^r, and Hooke’s ‘Proposals for the Advancement of the Royal Society’ (c. 1700–1702; Royal Society MS D.M. 5.12), both of which ‘regretfully pointed out the limitations imposed on the Society in comparison with its French counterpart by its voluntary structure’ and sought ‘a more streamlined and effective society in terms of membership and activities’.

²⁰⁴ Sturdy 1995, 161–162, drawing on Martin 1969, 2: 881. A proper study of Du Hamel is a *desideratum*: for the time being, see Piaia 2011, 21–28.

All in all, I see no reason to disagree with the recent conclusion that ‘the epistemological styles of France of the first *Académie*... and of England of the first Royal Society are identical, at least with regard to the use of experiments’, in contrast to the continuing ‘historiographic prejudice according to which France was blinded by a rationalism so blinkered that it could claim to be universally applicable, while England benefited from the lights of fully-fledged experimentalism’.²⁰⁵

Something similar can be said for Italy, even less prominent than France in standard overviews of the history of experimentalism. Concerted, if unsystematic, experimental work had been going on in the peninsula for much of the early seventeenth century, much of it concerned with testing and modifying Galileo’s conclusions, and further stimulated by the famous Torricelli experiment of 1644.²⁰⁶ This work, which by the 1650s had expanded to include a much wider range of experiments, was sometimes justified by rhetoric strongly contrasting experiential and apriorist ideas in natural philosophy—we have already met such rhetoric in Cabeo, and could easily put forward more, including, as usual, in medicine and chymistry.²⁰⁷ As in France, Italian vernacular did not possess an obvious distinction between experiment and experience, and so it was unlikely that ‘experimental’ was ever going to become the principal methodological buzzword.²⁰⁸ This linguistic ambiguity is reflected in the title of the one book produced by the Accademia del Cimento: the *Saggi di naturali esperienze* (1667)—since a ‘natural experiment’ obviously does not convey the content, Middleton was surely right to translate this as *Experiments in Natural Philosophy*.²⁰⁹ Nonetheless, if we so desire, we can still find talk of ‘experimental philosophy’, and even of a polemical distinction between experience and speculation in natural philosophy.²¹⁰

More important than rhetoric is the fact that a great many experiments were conducted at the Accademia, many of them very similar in intent to those performed in France and England. Like the Parisian academy, it was supplied with an enviable amount of laboratory equipment and materials by its patrons, Prince Leopoldo and Grand Duke Ferdinando II.²¹¹ The experimental programme was dictated by the natural philosophical interests of the patrons, the members and the problems current at the time: Gassendi again seems to have supplied much inspiration, and Bacon is again mostly absent.²¹² Even outside of the *Saggi*, in private, the rhetoric of the members placed experiment at the

²⁰⁵ Roux 2013, 85.

²⁰⁶ Middleton 1964, 10–54; Baldini 2002; Bònoli 2002. More broadly, other experimental discoveries, such as Harveian findings on the arterial pulse, were quickly incorporated into university pedagogy: Raphael 2016, 14–15.

²⁰⁷ See, e.g., Dear 1995, Ch. 3, esp. the example of Roderigo de Arriaga’s insistence that the ‘truth of experience’ obviates the need for ‘profound speculation’ (85). For medicine and chymistry, see Clericuzio 2009.

²⁰⁸ Vanzo 2016, 56.

²⁰⁹ Middleton 1971, 81–82.

²¹⁰ See the quotation from the preface to Geminiano Montanari’s *Pensieri fisico-matematici sopra alcune esperienze fatte in Bologna nell’ Accademia Filosofica* (1667) in Cavazza 1980, 106. For the distinction, see

Agostino Scilla’s *La vana speculazione disingannata dal senso* (1670), a treatise on the organic origins of fossils, now discussed in Romano 2014.

²¹¹ Middleton 1971, 53. For the relationship between instrument makers and the Accademia, see also the vital study by van Helden and Righini Bonelli 1981.

²¹² Middleton 1971, 2–3, 45–7, 56–7, 274–275, 331–332; also the summary in Boschiero 2007, 7–8. See further Gómez 2009, 53–54, 56; Favino 2009, 98, 102. Beretta 2009, at 1–5 is, I think, too taken with the search for specific copies of Gassendi (esp. given the clear evidence of Rinaldini’s reading of the Frenchman), although I am happy to accept his thesis about the influence of Giovanni Nardi’s edition of Lucretius.

foreground of the Accademia's practice: Giovanni Alfonso Borelli, for example, referred to it as 'an Academy set up by such a famous Prince for making experiments in natural things'.²¹³ And just like they did with their French counterparts, English natural philosophers at the Royal Society never seemed to have considered what the Italians were doing as qualitatively different from their own activities.²¹⁴

It seems hard to disagree with the conclusion that, given their superior access to apparatus, the Accademia of Borelli, Viviani and Rinaldini was no less potent an experimental institution than the Royal Society of Boyle and Hooke, its great failure being to publish the *Saggi* in good time.²¹⁵ This is especially the case when one considers the experiments *not* published in the *Saggi*, such as the model-based verification of Huygens' discovery of the rings of Saturn, a procedure Borelli again justified by saying it was conducted 'according to the custom of... [the] Academy, which is to find out the truth by means of experimental tests' (this, of course, did not stop him and many others in Italy and France speculating on the constitution of the rings).²¹⁶ Something similar can be said for chymical experiments, also missing from the *Saggi*, but also conducted extensively, sometimes with the aim of cautiously positing microparticulate explanations of phenomena, akin to Boyle.²¹⁷ It may well be that after the mid-1660s, Boyle was very influential in Italy, but that does not obviate the fact that 'hard' experimentalism had become established there well before, on the basis of an eclectic range of sources, and—once again—largely independent of an overwhelming English influence.

In the above, I have deliberately cited both the *Saggi* and private documents, and given examples of the Accademia's extensive experimental practice and investment in resources, so as to pre-empt the objection that I have supinely accepted public experimental rhetoric at face value. But as in England and France, it is important that, in our obsession with a search for 'new' rhetoric, we do not ignore the importance and pervasiveness of older justificatory language. This has recently been very well demonstrated in the case of Francesco Redi and his books, especially his seminal attack on spontaneous generation, the *Esperienze Intorno alla Generazione degl'Insetti* (1668).²¹⁸ Although Redi exploited the rhetoric of experiment being superior to apriorist reasoning more than any other Italian ('I do not put much faith in matters not made clear to me by experiment', he wrote), his book also contained many doctrinal and

²¹³ Quoted in Middleton 1971, 68–69.

²¹⁴ See, e.g., the evidence brought forward in Middleton 1971, 283–285, 290; also Boschiero 2009, 87–108; and esp. Feingold 2009, 239–241, which even argues, to my mind convincingly, that Boyle saw himself in competition with the Academicians.

²¹⁵ Middleton 1971, 345–346.

²¹⁶ Middleton 1971, 260, quoting Huygens 1888–1952, 3: 152. See above all Van Helden 1973, esp. 244–249. See also the interesting quotation from Cardinal Sforza Pallavicino concerning what he perceived as the method of Borelli's *Theoricæ medicæ planetarum* (1666), in Bertoloni Meli 1998, 397–398. A by-product of the process was extensive experimentation on the relative virtues of different telescopes, and the means for testing

them: Van Helden and Righini Bonelli 1981 esp. 30–39, and for contemporary reference to these as 'experiments' (*esperienze*), see 59, 65, 67, 69, 73, 87, 97, 119, 123, 135, 147, 165. Boschiero 2007, 195–232, 236–237, as usual presents the astronomical work as *ex post facto* justification for theoretical positions already held—like others, I am unconvinced by this argument in such a strong form.

²¹⁷ Clericuzio 2009, 23–24. See also *ibid.*, 25–26 for Borelli's Willis-esque experiments on fermentation, which had an anti-Cartesian dimension.

²¹⁸ Our understanding of Redi and his relationship to the Cimento has been very much enhanced by the work on his extensive manuscripts by Walter Bernardi in particular: Bernardi and Guerrini 1999; Bernardi 2008.

methodological references to older work, especially that of Gassendi and Fortunio Liceti, and to a vast range of ancient and humanist discussions. Moreover, his attack on Aristotelian-scholastic theory was never purely methodological, but always combined methodological with doctrinal critique, especially concerning the Aristotelians' unwarranted teleological assumptions.²¹⁹ Redi, like his compatriots Borelli and Marcello Malpighi (most famous for witnessing the link between arteries and veins posited by Harvey) and many contemporary physicians across Europe, also used the traditional language of learned medicine to describe and justify his experimental programme—in Malpighi's case a 'highly interventionist' one.²²⁰ Once again, this was characteristic of a broader eclecticism that easily assimilated new experimental findings into what were conceived of as longstanding research programmes.²²¹

5. Conclusion

I hope to have provided a sizeable quantity of evidence for my thesis: that there was little unique about English experimental philosophy, that measuring developments on the continent against an English standard is misguided, and that the rise of experimentalism is best seen as an eclectic, pan-European response to various developments in the sixteenth century, above all the rediscovery and publication of new ancient sources and the reconfiguration of disciplines within and attached to natural philosophy.

Let me finish by exploring more broadly what this might mean for our conceptualisations of early modern natural philosophical change. Anstey's search for an 'experimental philosophy' with identifiable 'origins' is a case for discontinuity. It might therefore be thought that what I have offered here is a continuity thesis. But I do not debate the cold, hard fact that doing natural philosophy by experiment *did* happen much more in the seventeenth century than it had before, and that this had momentous consequences. I am not, for example, agreeing with the thesis—recently proposed in relation to the Accademia del Cimento—that experimental rhetoric was simply a 'façade' for the 'real' natural philosophical agenda behind it.²²² This is surely wrong, and has been rightly criticised.²²³ But it seems to me that one aspect of this approach has merit, in that its aim is to dispel the search for 'origin stories' for experimental method, 'modern science', or anything of the sort, and rather to see seventeenth-century natural philosophers for what they were: *natural philosophers*. This is not just a trivial question of linguistic anachronism and the abandonment of the term 'science'. Rather, it is about

²¹⁹ Onelli 2017. See also Bonciani 1999. In a high-profile article Paula Findlen argued that Redi's focus on experiment was a function of courtly politics (Findlen 1993—the Redi quotation is from 42)—she retreats from the excesses of this case in Beretta, Feingold, Findlen, Boschiero 2010, 202–203.

²²⁰ See the brilliant account in Bertoloni Meli 2011, esp. 59, 68 (on Malpighi's insistence in 1665 that 'the empirical method should not be disapproved of in medicine, since experience is a better and safer guide than reason' and discussion of indicative signs), 325, 358–359, *passim* (quotation from 360). For collaboration

between physicians and natural philosophers, see also Bertoloni Meli 2008. See also the very interesting pedagogical example adduced in Conforti 2009, 36.

²²¹ For an excellent study of this phenomenon in the case of a central member of the Accademia, see Baldini 2011. But I agree with Raphael 2016, 4, n. 12 that Baldini overemphasises Rinaldini's exceptionalism in this regard.

²²² Boschiero 2007, e.g., at 27.

²²³ See the critical comments in Beretta, Feingold, Findlen and Boschiero 2010, 187–204.

recognising that early modern natural philosophers were ultimately engaged in the same exercise as their Renaissance, medieval and even ancient Greek predecessors.

One of the main reasons that this has been continually obscured is because of the way the social history of science has been practised in the last thirty years. In their obsession with controversy, politics and power, the most vocal social historians have offered accounts that are often very parochial; for example, in which ‘experimental method’ emerged as a function of 1660s English gentlemanly conduct, or in which Newton supposedly insisted on the use of only British glass for the replication of his prism experiments.²²⁴ But the reality is that experimental findings were accepted or rejected not for these reasons; rather ‘agreement with other theories and fields of knowledge, internal coherence, explanatory power and rival explanations mattered as much as experimental tests or agreement with nature’.²²⁵ Anstey and his collaborators’ unashamedly intellectualist approach has proved a welcome change from the unsuccessful attempts of the hard sociologists to tie the rise of experimentalism to political or social features. But it shares with them a focus on developments largely in one country that is not warranted by the evidence.

Methodological critique was never separate from doctrinal; the dismissal of ‘speculative’ philosophies was polemical, born, as we have seen, of the pan-European humanist critique of scholastic Aristotelianism for mixing logic and metaphysics with natural philosophy proper (a polemical accusation subsequently applied to Cartesianism). That is why when mid-century natural philosophers across Europe offered catalogues of those they saw as their immediate predecessors, those catalogues were so often deeply eclectic, listing not just those who followed a specific methodology, but everyone who was perceived to have helped erode the corruptions of scholasticism. When Newton in his later works attacked ‘speculative’ philosophies he was writing polemically, targeting both scholastics and Cartesians, and still engaging in debates about the relationship between metaphysics and natural philosophy that had emerged two centuries earlier.²²⁶

In contrast, Anstey’s project continues to search for an origin for the philosophy of experiment.²²⁷ This in turn leads him to think serially: first there was a Boylean experimental philosophy, then it was ‘replaced’ by a Newtonian one.²²⁸ This has the advantage of imposing a convenient neatness on the material. But it also has the effect of obscuring the eclectic nature of early modern natural philosophy, and the broad natural philosophical framework in which experimentalism developed. Conversely, it was precisely this framework that was highlighted in what I consider to be still the two most important diachronic studies of seventeenth-century natural philosophy: Frank’s *Harvey and the Oxford Physiologists* (1980), and Middleton’s study of the Accademia del Cimento, *The Experimenters* (1971). Both these studies acknowledge the novelty of the experimental work being done in England and Italy. But they also show that that work was addressing traditional questions, particularly concerning contested points of Aristotelian doctrine. This means that almost by definition, experimental work was in practice devoted to the testing of hypotheses, whatever the methodological rhetoric

²²⁴ Shapin and Schaffer 1985; Shapin 1994; Schaffer 1989.

²²⁵ This is the conclusion in the brilliant and seminal Shapiro 1996, 61.

²²⁶ Shapiro 2004; Levitin 2016.

²²⁷ See his disagreement with Peter Dear in Anstey 2014, 132 (‘with respect to the rise of a philosophy of experiment, it [the BBH view] should be regarded as an important early phase’).

²²⁸ Anstey 2015.

justifying it.²²⁹ It also explains the astonishing similarity between the experimental programmes followed in England and Italy, and also in France.²³⁰ Social conditions, religious affiliation, or methodological position cannot explain this similarity: it can only have arisen from a shared, pan-European natural philosophical inheritance.

These conclusions have been confirmed by important recent work in the history of reading, which has shown that experiment did not replace, but went hand-in-hand with humanistic, textual approaches to natural philosophy.²³¹ It is no coincidence that in mid-century England, France and Italy, experimentalists considered it a pressing necessity to conduct systematic programmes of reading ancient and modern books, and to collect and test the experiments conducted within them.²³² There was thus no single experimental ‘method’ or ‘philosophy’. Experiment was not a watershed, but one more gambit in the natural philosophical game of early modernity. In each discipline, that game began with the rediscovery of ancient texts, the clash between ‘lower’ and ‘learned’ practitioners, the incorporation of these new texts and debates into traditional institutions, and, subsequently, an all-round emphasis on direct experience. I know of no early modern natural philosopher—up to and including Newton—who cannot be characterised in one way or the other as the gradual product of humanist reconsideration of ancient natural philosophy: not because they were all beholden to ancient authority, but because they had no reason to consider their discipline to be fundamentally different in aims and scope (if not in doctrine and practice) from what it had always been.²³³ Once we recognise this, and free ourselves from the anachronistic shackles that impel us to search for a ‘modern’ experimental method or science, or to assume that England was in some senses exceptional, we will have taken as important a step to recovering the true nature of early modern natural philosophy as we did when we abandoned categories like ‘rationalist’ and ‘empiricist’.

Bibliography

1. Manuscripts

George Radcliffe to Isaac Basire, 27 November 1647 and 21 January 1648, Durham University Library, MS Cosin Letter Book 1A, 49, 51.

Richard Waller to Hans Sloane, 11 April 1699, BL MS Sloane 4037, fol. 249^r

Walter Needham to Richard Busby, 1655, BL MS Add. 4293, fol. 85^r

Hartlib Papers (HP) 30/4/3A

Bibliothèque Nationale de France, Paris, MS Nouvelles Acquisitions 5133–49

2. Printed Books

Acontius, J. (1558) *De methodo*, Basel.

²²⁹ See, e.g., Middleton 1971, 339.

²³⁰ This becomes clear from a comparative reading of Frank 1980; Middleton 1971; and Meli 2011. See also Feingold 2009.

²³¹ Raphael 2017.

²³² Compare the astonishingly similar projects described in Fontenelle 1733, 1: 16 (on the early *Académie*); Middleton, 90–91 (Cimento); Levitin 2015a (1650s England).

²³³ Levitin 2015a, Chs. 4 and 5 is in effect a long-form demonstration of this point.

- Anker, P. (2004) 'The economy of nature in the botany of Nehemiah Grew (1641–1672)', *Archives of Natural History*, 31: 191–207.
- Anstey, P. R. (2005) 'Experimental versus speculative natural philosophy' in eds. P. R. Anstey and J. A. Schuster 2005, pp. 215–242.
- . (2011a) *John Locke and Natural Philosophy*, Oxford: Oxford University Press.
- . (2011b) 'The creation of the English Hippocrates', *Medical History*, 55: 457–478.
- . (2012) 'Francis Bacon and the classification of natural history', *Early Science and Medicine*, 17: 11–31.
- . (2014) 'Philosophy of experiment in early modern England: the case of Bacon, Boyle and Hooke', *Early Science and Medicine*, 19: 103–122.
- . (2015) 'Experimental pedagogy and the eclipse of Robert Boyle in England', *Intellectual History Review*, 25: 115–131.
- . (2016) 'Locke on measurement', *Studies in History and Philosophy of Science*, 60: 70–81.
- Anstey, P. R. and Schuster, J. A., eds. (2005) *The Science of Nature in the Seventeenth Century: Patterns of Change in Early Modern Natural Philosophy*, Dordrecht: Springer.
- Anstey P. R. and Vanzo, A. (2012) 'The origins of early modern experimental philosophy', *Intellectual History Review*, 22: 499–518.
- . (2016) 'Early modern experimental philosophy' in eds. J. Sytsma and W. Buckwalter 2016, pp. 87–102.
- Archibald, T. trans. (1991) *Erasmus Bartholinus, Experiments on Birefringent Icelandic Crystal*, Copenhagen: Danish National Library.
- Baader G. and Winau, R., eds. (1989) *Die hippokratischen Epidemien*, Stuttgart: Franz Steiner.
- Bacon, F. (1861–1879) *The Works of Francis Bacon*, 14 vols, eds. J. Spedding, R. Ellis and D. D. Heath, London: Longmans.
- . (1996) *Philosophical Studies, c. 1611–c. 1619*, ed. G. Rees, *The Oxford Francis Bacon*, vol. 6, Oxford: Clarendon Press.
- . (2000a) *The Advancement of Learning*, ed. M. Kiernan, *The Oxford Francis Bacon*, vol. 4, Oxford: Clarendon Press.
- . (2004) *The Instauration magna, Part 2: Novum organum and Associated Texts*, ed. G. Rees, *The Oxford Francis Bacon*, vol. 11, Oxford: Clarendon Press.
- . (2007) *The Instauration magna. Part 3: Historia naturalis et experimentalis: Historia ventorum and Historia vitæ & mortis*, ed. G. Rees, *The Oxford Francis Bacon*, vol. 12, Oxford: Clarendon Press.
- Baldini, U. (2002) 'Riccioli e Grimaldi', in ed. M. T. Borgato 2002, pp. 1–48.
- . (2011) 'Tra due paradigmi? La "Naturalis philosophia" di Carlo Rinaldini' in *Galileo e la scuola galileiana nelle università del Seicento*, Bologna: Clueb, pp. 189–222.
- Baroncini, G. (1992) *Forme di esperienza e rivoluzione scientifica*, Florence: Olchski.
- Barry, J. (2018) 'The "Compleat Physician" and experimentation in medicines: Everard Maynwaring (c.1629–1713) and the Restoration debate on medical practice in London', *Medical History*, 62: 155–176.
- Begley, J. (2016) 'Margaret Cavendish, the last natural philosopher', Unpublished DPhil thesis, University of Oxford.
- Bellis, D. (2017) 'Nos in Diem Vivimus: Gassendi's probabilism and academic philosophy from day to day' in eds. P. J. Smith and S. Charles 2017, pp. 125–152.
- Bennett, J. (1975) 'Hooke and Wren on the system of the world: some points towards an historical account', *British Journal for the History of Science*, 8: 32–61.
- . (1976) 'A note on the theories of respiration and muscular action in England, c. 1660', *Medical History*, 20: 59–69.
- . (1980) 'Robert Hooke as mechanic and natural philosopher', *Notes and Records of the Royal Society*, 35: 33–48.

- . (1981) 'Cosmology and the magnetical philosophy, 1640–1680', *Journal of the History of Astronomy*, 12: 165–177.
- . (1982) *The mathematical Science of Christopher Wren*, Cambridge: Cambridge University Press.
- . (1986) 'The mechanics' philosophy and the mechanical philosophy', *History of Science*, 24: 1–28.
- Bennett, J., Hunter, M., Cooper, M. and Jardine, L., eds. (2003) *London's Leonardo: The Life and Work of Robert Hooke*, Oxford: Oxford University Press.
- Beretta, M. (2008) 'Gli Scienziati e l'edizione del *De rerum natura*' in eds. M. Beretta and F. Citti 2008, pp. 177–224.
- Beretta, M., (2009) 'Lucretius as hidden *auctoritas* of the Cimento' in eds. M. Beretta, A. Clericuzio and L. Principe 2009, pp. 1–16.
- Beretta M. and Citti, F., eds. (2008) *Lucrezio: La natura e la scienza*, Florence: Olschki.
- Beretta, M., Clericuzio, A. and Principe, L., eds. (2009) *The Accademia del Cimento and its European Context*, Sagamore Beach: Science History Publications, pp. 1–16.
- Beretta, M., Feingold, M., Findlen, P. and Boschiero, L. (2010) 'Regress and rhetoric at the Tuscan court', *Metascience*, 19: 187–210.
- Bernardi W. and Guerrini, L., eds. (1999) *Francesco Redi: Un protagonista della scienza moderna*, Florence: Olchski.
- Bernardi, W. (2008) *Il paggio e l'anatomista*, Florence: Olchski.
- Bertoloni Meli, D. (1998) 'Shadows and deception: from Borelli's *Theoricae* to the *Saggi* of the Cimento', *British Journal for the History of Science*, 31: 383–402.
- . (2003) 'Mechanics' in eds. K. Park and L. Daston 2006, Cambridge: Cambridge University Press, pp. 632–672.
- . (2004) 'The role of numerical tables in Galileo and Mersenne', *Perspectives on Science*, 12: 212–237.
- . (2006) *Thinking with Objects: the Transformation of Mechanics in the Seventeenth Century*, Baltimore: Johns Hopkins University Press.
- . (2008) 'The collaboration between anatomists and mathematicians in the mid-seventeenth century', *Early Science and Medicine*, 13: 665–709.
- . (2011) *Mechanism, Experiment, Disease: Marcello Malpighi and Seventeenth-Century Anatomy*, Baltimore: Johns Hopkins University Press.
- Biener, Z. and Schliesser, E., eds. (2014) *Newton and Empiricism*, Oxford: Oxford University Press.
- Birch, T., (1756–1757) *The History of the Royal Society*, 4 vols, London.
- Birkhead, T., ed. (2016) *Virtuoso by Nature: The Scientific Worlds of Francis Willughby FRS (1635–1672)*, Leiden: Brill.
- Bloch, O. (1971) *La philosophie de Gassendi*, The Hague: M. Nijhoff.
- Blum, P. (1988) 'Der Standardkurs der katholischen Schulphilosophie im 17. Jahrhundert', in *Aristotelismus und Renaissance*, eds. E. Keßler et al., Wiesbaden: Harrassowitz, 127–148.
- Boantza, V. (2007) 'Reflections on matter and manner: Duclos reads Boyle, 1668–69' in ed. L. Principe 2007, pp. 181–92.
- . (2010) 'Alkahest and fire: debating matter, chymistry and natural history at the early Parisian Academy of Sciences' in eds. C. Wolfe and O. Gal 2010, pp. 75–92.
- . (2013) *Matter and Method in the Long Chemical Revolution: Laws of another Order*, Farnham: Ashgate.
- Boate, G. (1652) *Irelands Naturall History*, London.
- Bonciani, A. (1999) 'Esitazioni metodologiche di un empirista radicale' in *Francesco Redi: Un protagonista della scienza moderna*, Florence: Olchski, pp. 31–45.

- Bònoli, F. (2002) 'Riccioli e gli strumenti dell'astronomia' in ed. M. Borgato 2002, pp. 133–158.
- Borelli, G. A. (1666) *Theoricae mediceorum planetarum*, Florence.
- Borgato, M. T., ed. (2002) *Giambattista Riccioli e il merito scientifico dei Gesuiti nell'età Barocca*, Florence: Olschki.
- Boriaud, J.-Y., ed. (2012) *La pensée scientifique de Cardan*, Paris: Les Belles lettres.
- Boschiero, L. (2007) *Experiment and Natural Philosophy in Seventeenth-Century Tuscany*, Dordrecht: Springer.
- . (2009) 'Robert Southwell and Vincenzo Viviani: their friendship and an attempt at Italian-English scientific collaboration', *Parergon*, 26: 87–108.
- Boyle, R. (1999–2000) *The Works of Robert Boyle*, 14 vols, eds. M. Hunter and E. B. Davis, London: Pickering and Chatto.
- Brown, H. (1967) *Scientific Organisations in Seventeenth Century France*, New York: Russell & Russell. 1st edn 1934.
- Brundell, B. (1987) *Pierre Gassendi: From Aristotelianism to a New Natural Philosophy*, Dordrecht: Reidel.
- Buccolini, C. (2017) 'The philosophy of Francisco Sanches: academic scepticism and conjectural empiricism' in eds. P. J. Smith and S. Charles 2017, pp. 1–24.
- Buchwald J. and K. Møller Pedersen (1991) 'Bartholin, his discovery, and its significance', in trans. T. Archibald 1991, pp. 9–29.
- Bylebyl, J. (1979) 'The School of Padua: humanistic medicine in the sixteenth Century', in eds. C. Webster and M. Pelling 1979, pp. 335–370.
- Cabeo, N. (1629) *Philosophia magnetica*, Ferrara.
- . (1646) *In quatuor libros Meteorologicorum Aristotelis commentaria, et quaestiones: Quatuor tomis comprahensa: quibus non solum meteorologica, tum ex antiquorum dictis, tum maxime ex singularum rerum experimentis explicantur, sed etiam uniuersa fere experimentalis philosophia exponitur*, Rome.
- Camenitezki, C. S. (2003) 'The celestial pilgrimages of Valentin Stansel (1621–1705), Jesuit astronomer and missionary in Brazil' in ed. M. Feingold 2003, pp. 249–266.
- Cassan, E. (2012) 'The status of Bacon in Gassendi's *Syntagma philosophicum* history of logic', *Societate si Politica*, 6: 80–89.
- Cassirer E. (1922–1923) *Das Erkenntnisproblem in der Philosophie und Wissenschaft der neueren Zeit*, 3 vols, Berlin: B. Cassirer.
- Cavazza, M. (1980) 'Bologna and the Royal Society in the seventeenth century', *Notes and Records of the Royal Society*, 35: 105–123.
- Cavendish, M. (1666) *Observations upon Experimental Philosophy*, London.
- Charleton, W. (1652) *The Darknes of Atheism Dispelled by the Light of Nature*, London.
- . (1657) *The Immortality of the Human Soul*, London.
- Clark, T. (1963) 'Pierre Gassendi and the physics of Galileo', *Isis*, 54: 351–370.
- Clericuzio, A. (2000) *Elements, Principles and Corpuscles: A Study of Atomism and Chemistry in the Seventeenth Century*, Dordrecht: Kluwer.
- . (2009) 'Chemical medicines in Rome: Pietro Castelli and the vitriol debate (1616–1626)' in eds. M. Pia Donata and J. Kraye 2009, pp. 281–302.
- . (2009) 'The other side of the Accademia del Cimento: Borelli's chemical investigations' in eds. M. Beretta, A. Clericuzio and L. Principe 2009, pp. 17–30.
- Clucas, S. (1994) 'In search of "the true logick": methodological eclecticism among the "Baconian reformers"' in eds. M. Greengrass, M. Leslie and T. Raynor 1994, pp. 51–74.
- . (2010) '*Scientia* and *inductio scientifica* in the *Logica Hamburgensis* of Joachim Jungius' in eds. T. Sorell, G. A. J. Rogers and J. Kraye 2010, pp. 53–70.
- Conforti, M. (2009) 'The experimenters' anatomy' in eds. M. Beretta, A. Clericuzio and L. Principe 2009, pp. 31–44.

- Cook, H. (1993) 'The cutting edge of a revolution? Medicine and natural history near the shores of the North Sea' in *Renaissance and Revolution*, eds. J. V. Field and F. A. J. L. James 1993, pp. 45–62.
- . (2007) *Matters of Exchange. Commerce, Medicine, and Science in the Dutch Golden Age*, New Haven: Yale University Press.
- Cunningham, A. (1985) 'Fabricius and the "Aristotle project" in anatomical teaching and research in Padua' in eds. A. Wear, R. K. French and I. M. Lonie 1985, pp. 195–222.
- . (1997) *The Anatomical Renaissance: The Resurrection of the Anatomical Projects of the Ancients*, Aldershot: Scolar Press.
- Daston, L. and Lünbeck, E., eds. (2011) *Histories of Scientific Observation*, Chicago: University of Chicago Press.
- De Ceglia, F. P. (2003) 'Additio illa non videtur edenda: Giuseppe Biancani, reader of Galileo in an unedited censored text' in ed. M. Feingold 2003, pp. 159–186.
- Dear, P. (1984) 'Marin Mersenne and the probabilistic roots of "mitigated scepticism"', *Journal of the History of Philosophy*, 22: 173–205.
- . (1987) 'Jesuit mathematical science and the reconstitution of experience in the early seventeenth century', *Studies in History and Philosophy of Science*, 18: 133–175.
- . (1988) *Mersenne and the Learning of the Schools*, Ithaca: Cornell University Press.
- . (1995) *Discipline and Experience: The Mathematical Way in the Scientific Revolution*, Chicago: University of Chicago Press.
- . (2012) 'Historiography of not-so-recent science', *History of Science*, 1: 197–211.
- Demonet, M.-L. (1992) *Les voix du signe: nature et origine du langage à la Renaissance (1480–1580)*, Paris: H. Champion.
- di Pietro, P. (1970) *Epistolario di Gabriele Falloppia*, Ferrara: Università degli studi di Ferrara.
- Dibon, P. (1954) *La philosophie Néerlandaise au siècle d'or: L'enseignement philosophique dans les universités à l'époque précatésienne (1575–1650)*, Amsterdam: Elsevier.
- Digby, K. (1644) *Two Treatises*, Paris.
- Dijksterhuis, F. (2004) *Lenses and Waves: Christiaan Huygens and the Mathematical Science of Optics in the Seventeenth Century*, Dordrecht: Kluwer.
- Dionisotti, A. C., Grafton, A. and Kraye, J., eds. (1988) *The Uses of Greek and Latin: Historical Essays*, London: Warburg Institute.
- Distelzweig, P., Goldberg, B. and Ragland, E. R., eds. (2015) *Early Modern Medicine and Natural Philosophy*, Dordrecht: Springer.
- Dobbs, B. J. T. (1973) 'Studies in the natural philosophy of Sir Kenelm Digby, II', *Ambix*, 20: 143–163.
- Dodart, D. (1676) *Mémoires pour servir à l'histoire des plantes*, Paris.
- Dobre, M. (2013) 'Rohault's Cartesian physics' in eds. M. Dobre and T. Nyden 2013, pp. 203–226.
- . (2018) 'Henry More and William Petty: revisiting an early modern polemic', *Early Science and Medicine*, 23: 244–264.
- Dobre M. and T. Nyden, (2013a) 'Introduction' in eds. M. Dobre and T. Nyden 2013b, pp. 1–24.
- Dobre M. and Nyden, T., eds. (2013b) *Cartesian Empiricisms*, Dordrecht: Springer.
- Domínguez Reboiras, F., Imbach, R, Pindl-Büchel, T. and Walter, P., eds. (1995) *Aristotelica et Lulliana*, The Hague: Nijhoff.
- Eamon, W. (1994) *Science and the Secrets of Nature*, Princeton: Princeton University Press.
- Easton, P. (2013) 'Robert Desgabets on the physics and metaphysics of blood transfusion' in eds. M. Dobre and T. Nyden 2013b, pp. 185–202.
- Egmond, F. (2017) 'Experimenting with living nature: documented practices of sixteenth-century naturalists and *naturalia* collectors', *Journal of Early Modern Studies*, 6: 21–46.

- Ehrlich, M. E. (1995) 'Mechanism and activity in the scientific revolution: the case of Robert Hooke', *Annals of Science*, 52: 127–151.
- Evelyn, J. (2014) *The Letterbooks of John Evelyn*, eds. D. Chambers and D. Galbraith, Toronto: University of Toronto Press.
- Favino, F. (2009) 'On the Cimento's "Oak Academies": an unknown contribution by Antonio Oliva' in eds. M. Beretta, A. Clericuzio and L. Principe 2009, pp. 91–120.
- Feingold, M. (1997) 'The mathematical sciences and new philosophies' in ed. N. Tyacke 1997, pp. 359–448.
- ed. (2003) *The New Science and Jesuit Science: Seventeenth Century Perspectives*, Dordrecht: Springer.
- (2009) 'The Accademia del Cimento and the Royal Society', in eds. M. Beretta, A. Clericuzio and L. Principe 2009, pp. 229–242.
- (2016) 'Experimental philosophy: invention and rebirth of a seventeenth-century concept', *Early Science and Medicine*, 21: 1–28.
- Field, J. V. and James, F. A. J. L., eds. (1993) *Renaissance and Revolution: Humanists, Scholars, Craftsmen and Natural Philosophers in Early Modern Europe*, Cambridge: Cambridge University Press.
- Findlen, P. (1993) 'Controlling the experiment: rhetoric, court patronage and the experimental method of Francesco Redi', *History of Science*, 31: 35–64.
- (1994) *Possessing Nature: Museums, Collecting, and Scientific Culture in Early Modern Italy*, Berkeley: University of California Press.
- (2006a) 'Anatomy theaters, botanical gardens, and natural history collections' in eds. K. Park and L. Daston 2006, pp. 272–289.
- (2006b) 'Natural history' in eds. K. Park and L. Daston 2006, pp. 435–468.
- Fisher, S. (2005) *Pierre Gassendi's Philosophy and Science: Atomism for Empiricists*, Leiden: Brill.
- Fletcher, J. (2011) *A Study of the Life and Works of Athanasius Kircher, 'Germanus Incredibilis'*, Leiden: Brill.
- Fontenelle, B. Le Bovier de (1733) *Histoire de l'Académie Royale des Sciences*, 2 vols: Paris.
- Frank, R. Jr (1976) 'Institutional structure and scientific activity in the early Royal Society', in *Proceedings of the Fourteenth Congress of the History of Science*, Tokyo, 4: 82–101.
- (1979) 'The physician as virtuoso in seventeenth-century England', in *English Scientific Virtuosi in the Sixteenth and Seventeenth Centuries*, Los Angeles: William Clark Memorial Library, pp. 57–114.
- (1980) *Harvey and the Oxford Physiologists*, Berkeley: University of California Press.
- French, R. (1980) *William Harvey's Natural Philosophy*, Cambridge: Cambridge University Press.
- (1998) 'Sign conceptions in medicine from the Renaissance to the early nineteenth century', in *Semiotik*, eds. R. Posner K. Robering and T. A. Seboek, Berlin: de Gruyter, 2: 1354–61.
- Gal, O. (2002) *Meanest Foundations and Nobler Superstructures*, Dordrecht: Springer.
- Galluzzi, P. (2000) 'Gassendi and l'Affaire Galilée of the laws of motion', *Science in Context*, 13: 509–545.
- Garbari F., Tongiorgi Tomasi, Tosi, A., eds. (1991) *Giardino dei Semplici: L'Orto botanico di Pisa dal XVI al XIX secolo*, Pisa: Pacini.
- Garber, D. (2014) 'Merchants of light and mystery men: Bacon's last projects in natural history', *Journal of Early Modern Studies*, 3: 91–106.
- (2016) 'Telesio among the novatores: Telesio's reception in the seventeenth century' in eds. C. Muratori and G. Paganini 2016, pp. 119–134.

- Garber, D. and Roux, S., eds. (2013) *The Mechanization of Natural Philosophy*, Dordrecht: Springer.
- Gassendi, P. (1649) *Animadversiones in decimum librum Diogenis Laertii*, 3 vols, Lyon.
- . (1657) *The Mirrour of True Nobility*, London.
- . (1658) *Opera omnia*, 6 vols, Lyon.
- Gavagna, V. (2011) ‘Paolo Casati e la scuola galileiana’, in *Galileo e la scuola galileiana nelle università del Seicento*, Bologna: Clueb, pp. 311–326.
- Gaza, T. (1579) [1476] ‘In libros de animalibus praefatio’, *Aristotelis Stagiritae operum, tomus secundus*, Leiden.
- Glanvill, J. (1676) *Essays on Several Important Subjects in Philosophy and Religion*, London.
- . (1676) *Letters and Poems in Honour of the Incomparable Princess, Margaret, Dutchess of Newcastle*, London.
- Goldberg, B. (2016) ‘William Harvey on anatomy and experience’, *Perspectives on Science*, 24: 305–323.
- Gómez, S. (2009) ‘Experiments and thoughts on light around the Accademia del Cimento’ in eds. M. Beretta, A. Clericuzio and L. Principe 2009, pp. 45–58.
- Goodall, C. (1676) *The Colledge of Physicians Vindicated*, London.
- Gooding, D., Pinch, T. and Schaffer, S., eds. (1989) *The Uses of Experiment: Studies in the Natural Sciences*, Cambridge: Cambridge University Press.
- Gorman, M. (2003) ‘Mathematics and modesty in the Society of Jesus: the Problems of Christoph Grienberger’, in ed. M. Feingold 2003, Dordrecht: Springer, pp. 1–120.
- Grafton, A. (2009a) ‘Where was Salomon’s House? Ecclesiastical history and the intellectual origins of Bacon’s *New Atlantis*’ in ed. A. Grafton 2009b, pp. 98–113.
- . ed. (2009b) *Worlds Made by Words*, Cambridge, MA: Harvard University Press.
- . (2018) ‘Philological and artisanal knowledge making in Renaissance natural history: a study in cultures of knowledge’, *History of Humanities*, 3: 39–55.
- Grafton A. and Siraisi, N., eds. (1999) *Natural Particulars*, Cambridge, MA: MIT Press.
- Greengrass, M., Leslie, M. and Raynor, T., eds. (1994) *Samuel Hartlib and Universal Reformation: Studies in Intellectual Communication*, Cambridge: Cambridge University Press.
- Grew, N. (1680) *Anatomy of Plants*, London.
- Guerrini, A. (2013) ‘Experiments, causation and the uses of vivisection’, *Journal of the History of Biology*, 46: 227–254.
- . (2015) *The Courtiers’ Anatomists*, Chicago: University of Chicago Press.
- Hall, A. R. (1965) ‘Wren’s problem’, *Notes and Records of the Royal Society*, 20: 140–144.
- . (1966) ‘Mechanics and the Royal Society, 1669–1670’, *British Journal for the History of Science*, 3: 24–38.
- Halleux, R. (1980) ‘La controverse sur les origines de la chimie, de Paracelse à Borrichius’ in ed. J. C. Margolin 1980, 2: 807–819.
- Harkness, D. E. (2007) *The Jewel House: Elizabethan London and the Scientific Revolution*, New Haven: Yale University Press.
- Harvey, W. (1651) *Exercitationes de generatione animalium*, London.
- Heller, J. L. and Meyer, F. G. (1983) ‘Conrad Gesner to Leonhart Fuchs, October 18, 1556’, *Huntia*, 5: 65–69.
- Henry, J. (2008) ‘The fragmentation of Renaissance occultism and the decline of magic’, *History of Science*, 46: 1–48.
- Hirai, H. (2014) ‘Mysteries of living corpuscles: atomism and the origin of life in Sennert, Gassendi and Kircher’ in eds. P. Distelzweig, B. Goldberg and E. R. Ragland 2015, pp. 255–270.

- Hoffmann, T. (2003) 'Dimensionen des Erkenntnisproblems bei Girolamo Fracastoro. Ein Beitrag zur Fortentwicklung der aristotelischen Gnoseologie in der italienischen Renaissance', *Vivarium*, 41: 144–174.
- Hooke, R. (1705) *Posthumous Works*, ed. R. Waller, London.
- . (1665) *Micrographia*, London.
- eds. M. Horstmanshoff, King, H. and Zittel, C., eds. (2012) *Blood, Sweat, and Tears: The Changing Concepts of Physiology from Antiquity into Early Modern Europe*, Leiden: Brill.
- Hunter, I. (2001) *Rival Enlightenments: Civil and Metaphysical Philosophy in Early Modern Germany*, Cambridge: Cambridge University Press.
- Hunter, M. (1975) *John Aubrey and the Realm of Learning*, London: Duckworth.
- . (1989) *Establishing the New Science*, Woodbridge: Boydell.
- . (1992) 'Latitudinarianism and the "ideology" of the Royal Society: Thomas Sprat's *History of the Royal Society* (1667) reconsidered' in eds. R. Kroll, R. Ashcraft and P. Zagorin 1992, pp. 199–229.
- . (2003) 'Hooke the natural philosopher', in eds. J. Bennett, M. Hunter, M. Cooper and L. Jardine 2003, pp. 105–162.
- . (2007) '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.
- . (2015) *Boyle Studies*, Farnham: Ashgate.
- . (2017) *The Image of Restoration Science: The Frontispiece to Thomas Sprat's History of the Royal Society (1667)*, Farnham: Ashgate.
- Hunter M. and Wood, P. (1989) 'Towards Solomon's House: rival strategies for reforming the early Royal Society' in M. Hunter 1989, pp. 185–244.
- Huygens, Christiaan (1888–1952) *Oeuvres complètes*, 22 vols, The Hague: Nijhoff.
- Ito, Y. (1988) 'Hooke's cyclic theory of the earth in the context of seventeenth century England', *British Journal for the History of Science*, 21: 295–314.
- Jalobeanu, D. (2011) 'The Cartesians of the Royal Society: the debate over collisions and the nature of body (1668–1670)' in eds. D. Jalobeanu and P. R. Anstey 2011, pp. 103–129.
- Jalobeanu, D. (2014) 'Constructing natural historical facts: Baconian natural history in Newton's first paper on light and colors' in eds. Z. Biener and E. Schliesser 2014, pp. 39–65.
- . (2015) *The Art of Experimental Natural History: Francis Bacon in Context*, Bucharest: Zeta Books.
- Jalobeanu, D. and Anstey, P. R., eds. (2011) *Vanishing Matter and the Laws of Motion: Descartes and Beyond*, New York: Routledge.
- Jardine, L. (1974) *Francis Bacon: Discovery and the Art of Discourse*, Cambridge: Cambridge University Press.
- Jensen, K. (2001) 'Description, division, definition: Caesalpinus and the study of plants as an independent discipline', in ed. M. Pade 2001, pp. 185–206.
- Johnson, F. (1937) *Astronomical Thought in Renaissance England*, Baltimore: Johns Hopkins University Press.
- Joy, L. (1987) *Gassendi the Atomist*, Cambridge: Cambridge University Press.
- Jungius (1638) *Logica Hamburgensis*, Hamburg.
- Kaoukji, N. (2017) 'Mathematical magick (1648) and the mechanics of discovery' in ed. W. Poole 2017, pp. 158–181.
- Keil, G. and Schmitz, R., eds. (1984) *Humanismus und Medizin*, Weinheim: Acta Humaniora.
- Keßler, E. (1995) 'Physik oder Metaphysik. Beobachtungen zum Begriff der Naturwissenschaft in der Methodendiskussion des 16. Jahrhunderts' in eds. F. Domínguez Reboiras et al. 1995, pp. 223–44.

- . (2001) 'Metaphysics or empirical science? The two faces of Aristotelian natural philosophy in the sixteenth century' in ed. M. Pade 2001, pp. 79–102.
- Keßler, E., Lohr, C. H. and Sparn, W., eds. (1988) *Aristotelismus und Renaissance*, Wiesbaden: Harrassowitz.
- Kroll, R, Ashcraft, R. and Zagorin, P., eds. (1992) *Philosophy, Science, and Religion in England, 1640–1700*, Cambridge: Cambridge University Press.
- Kusukawa, S. (1996) 'Bacon's classification of knowledge' in ed. M. Peltonen 2006, pp. 47–74.
- Lambert, J. (2013) 'Mechanism and surgery: Dionis' *Anatomy* (1690)' in eds. D. Garber and S. Roux 2013, pp. 263–284.
- Lennox, J. (2006) 'The comparative study of animal development: William Harvey's Aristotelianism' in ed. J. Smith 2006, pp. 21–46.
- Leu, U. (2016) *Conrad Gessner (1516–1565): Universalgelehrter und Naturforscher der Renaissance*, Zurich: Neue Zürcher Zeitung.
- Leu, U. and Ruoss, M., eds. (2016) *Conrad Gessner, 1516–2016: Facetten eines Universums*, Zurich: Neue Zürcher Zeitung.
- Levitin, D. (2010) 'Reconsidering John Sergeant's attacks on Locke's *Essay*', *Intellectual History Review*, 20: 457–477.
- . (2014) 'Rethinking English physico-theology: Samuel Parker's *Tentamina de Deo* (1665)', *Early Science and Medicine*: 19: 28–75.
- . (2015a) *Ancient Wisdom in the Age of the New Science: Histories of Philosophy in England, c.1640–1700*, Cambridge: Cambridge University Press.
- . (2015b) "'Made up from many experimentall notions". The Society of Apothecaries, medical humanism, and the rhetoric of experience in 1630s London', *Journal of the History of Medicine and Allied Sciences*, 70: 539–587.
- . (2016) 'Newton and scholastic philosophy', *British Journal for the History of Science*, 49: 53–77.
- Lewis, J. (2006) *Galileo in France*, New York: Peter Lang.
- Licoppe, C. (1996) *La formation de la pratique scientifique*, Paris: Découverte.
- Locke, J. (1690) *An Essay concerning Humane Understanding*, London.
- Lohne, J. (1977) 'Nova experimenta crystalli Islandici disdiaclastici', *Centaurus*, 21: 106–48.
- Lohr, C. (1988) 'The sixteenth-century transformation of the Aristotelian natural philosophy' in eds. E. Keßler, C. H. Lohr and W. Sparn 1988, pp. 89–99.
- Lolordo, A. (2007) *Pierre Gassendi and the Birth of Early Modern Philosophy*, Cambridge: Cambridge University Press.
- Lonie, I. (1985) 'The "Paris Hippocratics": teaching and research in Paris in the second half of the sixteenth century' in eds. A. Wear, R. K. French and I. M. Lonie 1985, pp. 155–172.
- Lunsingh Scheurleer, T. H. and Posthumus Meyjes G. H. M., eds. (1975) *Leiden University in the Seventeenth Century: An Exchange of Learning*, Leiden: Brill.
- Lüthy, C. (2000) 'The fourfold Democritus on the stage of early modern science', *Isis*, 91: 443–479.
- Lüthy, C., Murdoch, J. and Newman, W. R., eds. (2001) *Late Medieval and Early Modern Corpuscular Matter Theories*, Leiden: Brill.
- Lynch, W. (2001) *Solomon's Child: Method in the Early Royal Society of London*, Stanford: Stanford University Press.
- Maclaurin, J., ed. (2012) *Rationis Defensor*, Dordrecht: Springer.
- Maclean, I. (2002) *Logic, Signs and Nature in the Renaissance: The Case of Learned Medicine*, Cambridge: Cambridge University Press.
- . (2005) 'White crows, graying hair, and eyelashes: problems for natural historians in the reception of Aristotelian logic and biology from Pomponazzi to Bacon' in eds. G. Pomata and N. Siraisi 2005, pp. 147–180.

- . (2011) 'The logic of physiognomy in the late Renaissance', *Early Science and Medicine*, 16: 275–295.
- Mandelbrote, S. (2015) 'The publication and illustration of Robert Morison's *Plantarum historiae universalis Oxoniensis*', *Huntington Library Quarterly*, 78: 349–379.
- Manzo, S. (2001) 'Francis Bacon and atomism: a reappraisal' in eds. C. Lüthy, J. Murdoch and W. R. Newman 2001, pp. 209–243.
- Margolin, J. C., ed. (1980) *Acta conventus neo-Latini Turonensis*, 2 vols, Paris: J. Vrin.
- Mariotte, E. (1678) *Essai de logique*, Paris.
- Martin, C. (2016) 'The aeolipile as experimental model in early modern natural philosophy', *Perspectives on Science*, 24: 264–84.
- . (2011) *Renaissance Meteorology: Pomponazzi to Descartes*, Baltimore: Johns Hopkins University Press.
- Martin, H.-J. (1969) *Livre, pouvoirs et société à Paris: au XVIIe siècle (1598–1701)*, 2 vols, Geneva: Droz.
- Margolin, J. C., ed. (1980) *Acta Conventus neo-Latini Turonensis*, 2 vols, Paris: J. Vrin.
- Massignat, C. (2000) 'Gassendi et l'élasticité de l'air: une étape entre Pascal et la loi de Boyle-Mariotte', *Revue d'Histoire des Sciences*, 53: 179–203.
- Matton, S. (1994) 'Gassendi, Mosnier, et la grande expérience du Puy de Dôme' in *Pierre Gassendi, 1592–1655*, 2 vols, Digne: Société scientifique et littéraire des Alpes-de-Haute-Provence, 303–320.
- McCloughlin, T. (1975) 'Sur les rapports entre la Compagnie de Thévenot et l'Académie royale des Sciences', *Revue d'histoire des sciences*, 28: 235–242.
- Meier-Oeser, S. (1997) *Die Spur des Zeichens. Das Zeichen und seine Funktion in der Philosophie des Mittelalters und der frühen Neuzeit*, Berlin: de Gruyter.
- Meinel, C. (1988) 'Early seventeenth-century atomism: theory, epistemology, and the insufficiency of experiment', *Isis*, 79: 68–103.
- Mersenne, M. (1625) *La vérité des sciences contre les septiques ou Pyrrhoniens*, Paris.
- Meynell, G. (2002) *The French Academy of Sciences, 1666–91*, Dover: n.p.
- Middleton, W. E. K. (1964) *The History of the Barometer*, Baltimore: Johns Hopkins University Press.
- . (1971) *The Experimenters: A Study of the Accademia del cimento*, Baltimore: Johns Hopkins University Press.
- Mikkeli, H. (1992) *An Aristotelian Response to Renaissance Humanism*, Helsinki: Suomen Historiallinen Seura.
- . (1999) *Hygiene in the early modern medical tradition*, Helsinki: Suomen Historiallinen Seura.
- Minelli, A., ed., (1995) *The Botanical Garden of Padua, 1545–1995*, Venice: Marsilio Editori.
- Monfasani, J. (1999) 'The pseudo-Aristotelian *Problemata* and Aristotle's *De animalibus* in the Renaissance' in eds. A. Grafton and N. Siraisi 1999, pp. 205–247.
- Montanari, G. (1667) *Pensieri fisico-matematici sopra alcune esperienze fatte in Bologna nell'Accademia Filosofica*, Bologna.
- Muratori, C. (2017) 'The body speaks Italian: Giuseppe Liceti and the conflict of philosophy and medicine in the Renaissance', *Intellectual History Review*, 27: 473–492.
- Muratori, C. and Paganini, G., eds. (2016) *Early Modern Philosophers and the Renaissance Legacy*, Dordrecht: Springer.
- Nance, B. (1993) 'Determining the patient's temperament: an excursion into seventeenth-century medical semiology', *Bulletin of the History of Medicine*, 67: 417–438.
- Newman, W. R. (2001) 'Experimental corpuscular theory in Aristotelian alchemy: from Geber to Sennert' in eds. C. Lüthy, J. Murdoch and W. R. Newman 2001, pp. 291–330.
- . (2004) *Promethean Ambitions: Alchemy and the Quest to Perfect Nature*, Chicago: University of Chicago Press.

- Nonnoi, G. (2001) 'La scienze e la filosofia Galileiane nel *New world* di John Wilkins', *Nuncius*, 16: 49–84.
- Nutton, V. (1985) 'Humanistic Surgery' in eds. A. Wear, R. K. French and I. M. Lonie 1985, pp. 75–99.
- . (1988) 'Prisci dissectionum professores: Greek texts and Renaissance anatomists' in eds. A. C. Dionisotti, A. Grafton and J. Kraye 1988, pp. 111–126.
- . (1989) 'Hippocrates in the Renaissance' in eds. G. Baader and R. Winau 1989, pp. 420–439.
- . (1997) 'The rise of medical humanism: Ferrara, 1464–1555', *Renaissance Studies*, 11: 2–19.
- O'Malley, C. F. (1964) *Andreas Vesalius of Brussels, 1514–1564*, Berkeley: University of California Press.
- Oldenburg, H. (1672) 'A preface to the eighth year', *Philosophical Transactions*, 8: 4001–2.
- . (1965–1986) *The Correspondence of Henry Oldenburg*, 13 vols, eds. A. R. Hall and M. B. Hall, Madison, Milwaukee and London: University of Wisconsin Press, Mansell and Taylor and Francis.
- Oldroyd, D. (1972) 'Robert Hooke's methodology of science as exemplified in his "Discourse of Earthquakes"', *British Journal for the History of Science*, 6: 109–130.
- . (1987) 'Some writings of Robert Hooke on procedures for the prosecution of scientific inquiry, including his "Lectures of Things Requisite to a Natural History"', *Notes and Records of the Royal Society*, 41: 146–167.
- Onelli, C. (2017) 'La retorica dell'esperimento: per una rilettura delle Esperienze intorno alla generazione degl'insetti (1668) di Francesco Redi', *Italian Studies*, 72: 42–57.
- Orland, B. (2012) 'White blood and red milk. Analogical reasoning in medical practice and experimental physiology (1560–1730)' in eds. M. Horstmanshoff, H. King and C. Zittel 2012, pp. 443–478.
- Pade, M., ed. (2001) *Renaissance Readings of the Corpus Aristotelicum*, Copenhagen: Museum Tusulanum.
- Pagel, W. (1982) *Paracelsus*, 2nd rev. edn, Basel: Karger.
- Palmerino, C. R. (2003) 'Two Jesuit responses to Galileo's science of motion: Honoré Fabri and Pierre Le Cazre' in ed. M. Feingold 2003, pp. 187–228.
- . (2010) 'Experiments, mathematics, physical causes: how Mersenne came to doubt the validity of Galileo's law of free fall', *Perspectives on Science*, 18: 50–76.
- Park, K. and Daston, L., eds. (2006) *The Cambridge History of Science*, vol. 3: *Early Modern Science*, Cambridge: Cambridge University Press.
- Parker, S. (1665) *Tentamina physico-theologica de Deo: sive, Theologica scholastica ad normam novæ & reformatæ philosophiæ concinnata*, London.
- Patrick, S. (1662) *A brief account of the new sect of latitude-men together with some reflections upon the new philosophy*, London.
- Pav, P. (1966) 'Gassendi's statement of the principle of inertia', *Isis*, 57: 24–34.
- Peltonen, M., ed. (1996) *The Cambridge Companion to Bacon*, Cambridge: Cambridge University Press.
- Perfetti, S. (1995) "'Cultius atque integrius". Teodoro Gaza, traduttore umanistico del *De partibus animalium*', *Rinascimento*, 35: 253–286.
- . (1999) 'Three different ways of interpreting Aristotle's *De partibus animalium*: Pietro Pomponazzi, Niccolò Leonico Tomeo and Agostino Nifo' in eds. C. Steel, G. Guldentops and P. Buellens 1999, pp. 297–316.
- . (2000) *Aristotle's Zoology and its Renaissance Commentators, 1521–1601*, Leuven: Leuven University Press.
- Perrault, C. (1671) *Mémoires pour servir à l'Histoire naturelle des Animaux*, Paris.
- Pia Donata, M. and Kraye, J., eds. (2009) *Conflicting Duties: Science, Medicine and Religion in Rome, 1550–1750*, London: Warburg Institute.

- Piaia, G. (2011) 'The histories of philosophy in France in the age of Descartes' in eds. G. Piaia and G. Santinello 2011, pp. 3–91.
- Piaia, G. and Santinello, G., eds. (2011) *Models of the History of Philosophy*, vol. 2: *From the Cartesian Age to Brucker*, Dordrecht: Springer. 1st edn 1979 in Italian.
- Plot, R. (1677) *Natural History of Oxfordshire*, Oxford.
- Pocock, N. (1848) 'Illustrations of the state of the Church during the Great Rebellion', *The Theologian and Ecclesiastic*, 6.
- . (1850) 'Illustrations of the state of the Church during the Great Rebellion', *Theologian and ecclesiastic*, 7.
- Pomata, G. (2005) 'Praxis historialis: the uses of *historia* in early modern medicine' in eds. G. Pomata and N. Siraisi 2005, pp. 105–146.
- . (2010) 'Sharing cases: the *Observationes* in early modern medicine', *Early Science and Medicine*, 15: 193–236.
- . (2011a) 'Observation rising: birth of an epistemic genre, 1500–1650' in eds. L. Daston and E. Lünbeck 2011, pp. 45–80.
- . (2011b) 'A word of the Empirics: the ancient concept of observation and its recovery in early modern medicine', *Annals of Science*, 68: 1–25.
- Pomata, G. and Siraisi, N., eds. (2005) *Historia: Empiricism and Erudition in Early Modern Europe*, Cambridge, MA: MIT Press.
- Pomponazzi, P. (1525) *Tractatus acutissimi, utillimi et mere peripatetici*, Venice.
- Poole, W. (2010) *The World Makers*, Oxford: Peter Lang.
- . (2014) *Wadham College Books in the Age of John Wilkins*, n.p.
- . ed. (2014) *John Wilkins (1614–1672): New Essays*, Leiden: Brill.
- Pousseur, J.-M. (1990) 'Bacon, a critic of Telesio' in ed. W. Sessions 1990, pp. 105–117.
- Principe, L., ed. (2007) *Chymists and Chymistry: Studies in the History of Alchemy and Early Modern Chemistry*, Sagamore Beach: Science History Publications.
- Ragland, E. (2015) 'Mechanism, the senses, and reason: Franciscus Sylvius and Leiden debates over anatomical knowledge after Harvey and Descartes' in eds. P. Distelzweig, B. Goldberg and E. R. Ragland 2015, pp. 173–205.
- . (2017a) 'Experimental clinical medicine and drug action in mid-seventeenth-century Leiden', *Bulletin of the History of Medicine*, 91: 331–361.
- . (2017b) "'Making Trials" in sixteenth- and early seventeenth century European academic medicine', *Isis*, 103: 503–528.
- Raphael, R. (2008) 'Galileo's *Discorsi* and Mersenne's *Nouvelles Pensées*: Mersenne as a reader of Galilean "Experience"', *Nuncius*, 23: 7–36.
- . (2015a) 'Copernicanism in the classroom: Jesuit natural philosophy and mathematics after 1633', *Journal for the History of Astronomy*, 46: 419–440.
- . (2015b) 'Galileo's *Discorsi* as a tool for the analytical art', *Annals of Science*, 72: 99–123.
- . (2016) 'Eclecticism as a vibrant philosophical program: Claude Bérigard and Mauro Mancini on the University of Pisa', *History of Universities*, 29: 1–24.
- . (2017) *Reading Galileo*, Baltimore: Johns Hopkins University Press.
- Rappaport, R. (1986) 'Hooke on earthquakes: lectures, strategy and audience', *British Journal for the History of Science*, 19: 129–146.
- Reeds, K. (1991) *Botany in Medieval and Renaissance Universities*, New York: Garland.
- Rees, G. (1975) 'Francis Bacon's semi-Paracelsian cosmology', *Ambix*, 22: 81–101, 161–173.
- . (1980) 'Atomism and "subtlety" in Francis Bacon's philosophy', *Annals of Science*, 37: 549–571.
- . (1981) 'An unpublished manuscript by Francis Bacon: *Sylva sylvarum* drafts and other working notes', *Annals of Science*, 38: 377–412.

- Reiner, H. (1955) 'Die Entstehung der Lehre vom bibliothekarischen Ursprung des Namens Metaphysik. Geschichte einer Wissenschaftslegende', *Zeitschrift für philosophie Forschung*, 9: 77–99.
- Riddle, J. (1980) 'Dioscorides', in *Catalogus translationum et commentariorum*, eds. P. Kristeller et al., 8 vols, Washington, DC, 1960–, vol. 4: 1–143.
- Romano, M. (2014) "'The vain speculation disillusioned by the sense": the Italian painter Agostino Scilla (1629–1700) called "The Discoloured", and the correct interpretation of fossils as "lithified organisms" that once lived in the sea', *Historical Biology*, 26: 631–651.
- Roos, A. M. (2015) 'The saline chymistry of color in seventeenth-century natural history', *Early Science and Medicine*, 20: 562–588.
- Roos, A. M. and Boantz, V. (2015) 'Mineral waters across the channel: matter theory and natural history from Samuel Duclos's minerallogenesis to Martin Lister's chymical magnetism, ca. 1666–86', *Notes and Records of the Royal Society*, 69: 373–394.
- Rossi, P. (1954) 'Il metodo induttivo e la polemica antioccultistica in G. Fracastoro', *Rivista critica di storia della filosofia* (1954): 485–499.
- Roux, S. (2013) 'Was there a Cartesian experimentalism in 1660s France?' in eds. M. Dobre and T. Nyden 2013, pp. 47–88.
- Ruland, M. (1578–1596) *Curationum empiricarum et historicarum*, Basel.
- Rusu, D.-C. (2017) 'Rethinking *Sylva Sylvarum*: Francis Bacon's use of Giambattista Della Porta's *Magia naturalis*', *Perspectives on Science*, 25: 1–34.
- Rusu D.-C. and Lüthy, C. (2017) 'Extracts from a paper laboratory: the nature of Francis Bacon's *Sylva sylvarum*', *Intellectual History Review*, 27: 171–202.
- Sabra, A. (1981) *Theories of Light from Descartes to Newton*, 2nd edn, Cambridge: Cambridge University Press.
- Sakamoto, K. (2009) 'The German Hercules's heir: Pierre Gassendi's reception of Keplerian ideas', *Journal of the History of Ideas*, 70: 69–91.
- Salomon-Bayet, C. (1978) *L'institution de la science et l'expérience du vivant: méthode et l'expérience à l'Académie Royal des Sciences, 1666–1793*, Paris: Flammarion.
- Sargent, R.-M. (1995) *The Diffident Naturalist: Robert Boyle and the Philosophy of Experiment*, Chicago: University of Chicago Press.
- Schaffer, S. (1989) 'Glass works: Newton's prisms and the uses of experiment' in eds. D. Gooding, T. Pinch and S. Schaffer 1989, pp. 67–104.
- Schmitt, C. (1970) 'A fresh look at mechanics in 16th-century Italy', *Studies in History and Philosophy of Science*, 1: 161–175.
- . (1985) 'Aristotle among the physicians' in eds. A. Wear, R. K. French and I. M. Lonie 1985, pp. 1–15.
- . (1969) 'Experience and experiment: a comparison of Zabarella's view with Galileo's in *De motu*', *Studies in the Renaissance*, 16: 80–138.
- . (1984) 'William Harvey and Renaissance Aristotelianism: a consideration of the *Praefatio* to "*De generatione animalium*" (1651)' in eds. G. Keil and R. Schmitz 1984, pp. 117–138.
- Scilla, A. (1670) *La vana speculazione disingannata dal senso*, Naples.
- Serjeantson, R. (2008) "'Human understanding" and the genre of Locke's *Essay*', *Intellectual History Review*, 18: 157–171.
- . (2014) 'Francis Bacon and the "interpretation of nature" in the late Renaissance', *Isis*, 105: 681–705.
- . (2016) 'The education of Francis Willughby' in ed. T. Birkhead 2016, pp. 44–98.
- Sessions, W., ed. (1990) *Francis Bacon's Legacy of Texts*, New York: AMS Press.
- Severinus, P. (1571) *Idea medicinae philosophicae: fundamenta continens totius doctrinae Paracelsicae, Hippocraticae, & Galenicæ*, Basel.

- Sgarbi, M. (2012) *The Aristotelian Tradition and the Rise of British Empiricism: Logic and Epistemology in the British Isles (1570–1689)*, Dordrecht: Springer.
- Shackelford, J. (2002) *A Philosophical Path for Paracelsian Medicine: The Ideas, Intellectual Context, and Influence of Petrus Severinus, 1540–1602*, Copenhagen: Museum Tusulanum.
- Shapin, S. (1994) *A Social History of Truth*, Chicago: University of Chicago Press.
- Shapin S. and Schaffer, S. (1985) *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life*, Princeton: Princeton University Press.
- Shapiro, A. (1993) *Fits, Passions and Paroxysms: Physics, Method and Chemistry and Newton's Theories of Colored Bodies and Fits of Easy Reflection*, Cambridge: Cambridge University Press.
- . (1996) 'The gradual acceptance of Newton's theory of light and color, 1672–1727', *Perspectives on Science*, 4: 59–140.
- . (2004) 'Newton's experimental philosophy', *Early Science and Medicine*, 9: 185–217.
- Siraisi, N. (1987) *Avicenna in Renaissance Italy*, Princeton: Princeton University Press.
- . (1990) 'Giovanni Argenterio and sixteenth-century medical innovation: between princely patronage and academic controversy', *Osiris*, 2: 161–180.
- . (1997) *The Clock and the Mirror*, Princeton: University Press.
- . (2012) 'Cardan et l'histoire de la médecine' in ed. J.-Y. Boriaud 2012, pp. 71–94.
- Smith, J., ed. (2006) *The Problem of Animal Generation in Early Modern Philosophy*, Cambridge: Cambridge University Press.
- Smith, P. (2004) *The Body of the Artisan*, Chicago: University of Chicago Press.
- Smith, P. J. and Charles, S., eds. (2017) *Academic Scepticism in the Development of Early Modern Philosophy*, Cham: Springer.
- Sorell, T., Rogers, G. A. J. and Kraye, J., eds. (2010) *Scientia in Early Modern Philosophy: Seventeenth-Century Thinkers on Demonstrative Knowledge from First Principles*, Dordrecht: Springer.
- Spary, E. (2000) *Utopia's garden: French Natural History from Old Regime to Revolution*, Chicago: University of Chicago Press.
- Spink, A. (2018) 'The experimental physics of Jacques Rohault', *British Journal for the History of Philosophy*, 26: 850–870.
- Steel, C., Guldentops, G. and Buellens, P., eds. (1999) *Aristotle's Animals in the Middle Ages and Renaissance*, Leuven: Leuven University Press.
- Stroup, A. (1990) *A Company of Scientists: Botany, Patronage, and Community at the Seventeenth-Century Parisian Royal Academy of Sciences*, Berkeley: University of California Press.
- Stubbe, H. (1670) *Legends no Histories, or, a Specimen of some Animadversions upon The History of the Royal Society*, London.
- Sturdy, D. (1995) *Science and Social Status: The Members of the Académie des sciences, 1666–1750*, Woodbridge: Boydell.
- Sylvius, F. De le Boë (1681) *Opera medica*, Geneva.
- Sytsma, J. and Buckwalter, W., eds. (2016) *A Companion to Experimental Philosophy*, Oxford: Blackwell.
- Taton, R. (1966) *Les origines de l'Académie royale des sciences*, Paris: Palais de la découverte.
- Telesio, B. (1586 [1565]) *De rerum natura juxta propria principia libri IX*, Naples.
- Turner, A. (1974) 'Hooke's theory of the Earth's axial displacement: some contemporary opinion', *British Journal for the History of Science*, 7: 166–170.
- Tyacke, N., ed. (1997) *The History of the University of Oxford*, vol. 4, Oxford: Oxford University Press.
- Van Helden, A. (1973) 'The Accademia del Cimento and Saturn's Ring', *Physis*, 15: 237–259.

- . (1983) ‘Roemer’s speed of light’, *Journal for the History of Astronomy*, 14: 137–141.
- Van Helden, A. and Righini Bonelli, M. L. (1981) *Divini and Campani: A Forgotten Chapter in the History of the Accademia del Cimento*, Florence: Istituto e museo di storia della scienza.
- Van Hogelande, C. (1646) *Cogitationes quibus Dei existentia item animae spiritualitas, et possibilis cum corpore unio, demonstrator*, Amsterdam.
- Van Miert, D. (2009) *Humanism in an Age of Science*, Leiden: Brill.
- Vanzo, A. (2012) ‘Kant on Experiment’, in *Rationis Defensor*, ed. J. Maclaurin, Dordrecht: Springer, pp. 75–96.
- . (2014) ‘From empirics to empiricists’, *Intellectual History Review*, 24: 517–538.
- . (2016) ‘Experiment and speculation in seventeenth-century Italy: the case of Geminiano Montanari’, *Studies in History and Philosophy of Science*, 56: 52–61.
- Various (1676) *Letters and Poems in Honour of... Margaret, Dutchess of Newcastle*, London.
- Vesalius, A. (1543) *De humani corporis fabrica*, Basel.
- Visentini, M. (1984) *L’Orto botanico di Padova e il giardino del Rinascimento*, Milan: Polifilo.
- Waddell, M. (2015) *Jesuit Science and the End of Nature’s Secrets*, Farnham: Ashgate.
- Wardaugh, B. (2008) *Music, Experiment and Mathematics in England, 1653–1705*, Farnham: Ashgate.
- Wear, A. (1983) ‘William Harvey and the “way of anatomists”’, *History of Science*, 21: 223–249.
- Wear, A., French, R. K. and Lonie, I. M., eds. (1985) *The Medical Renaissance of the Sixteenth Century*, Cambridge: Cambridge University Press.
- Webster, C. (1967) ‘The College of Physicians: “Solomon’s House” in commonwealth England’, *Bulletin of the History of Medicine*, 41: 393–412.
- . (1982) *From Paracelsus to Newton*, Cambridge: Cambridge University Press.
- Webster, C. and Pelling, M., eds. (1979) *Health, Medicine and Mortality in the Sixteenth Century*, Cambridge: Cambridge University Press.
- Weeks, S. (2007a) ‘Francis Bacon’s science of magic’, Unpublished PhD thesis, University of Leeds.
- . (2007b) ‘Francis Bacon and the art-nature distinction’, *Ambix*, 54: 117–145.
- Wilkins, E. (2014) ‘Margaret Cavendish and the Royal Society’, *Notes and Records of the Royal Society*, 68: 245–260.
- Willis, T. (1659) *Diatribae duae medico-philosophicae, quarum prior agit de fermentatione... altera de febris*, London.
- . (1674) *Pharmaceutice rationalis. Sive diatriba de medicamentorum operationibus in humano corpore*, Oxford.
- . (1675) *Pharmaceutice rationalis... pars secunda*, Oxford.
- . (1684) *Dr. Willis’s Practice of Physick*, London.
- Willmoth, F. (2012) ‘Römer, Flamsteed, Cassini and the speed of light’, *Centaurus*, 54: 39–57.
- Wilmott, M. (1984) ‘Francesco Patrizi da Cherso’s humanist critique of Aristotle’, Unpublished PhD thesis, The Warburg Institute.
- Wittie, R. (1669) *Pyrologia mimica, or, An answer to Hydrologia Chymica of William Sympson*, London.
- Wolf, C. (1902) *Histoire de l’Observatoire de Paris de sa fondation à 1793*, Paris: Gauthier-Villars.
- Wolfe C. and Gal, O., eds. (2010) *The Body as Object and Instrument of Knowledge*, Dordrecht: Springer.
- Wood, P. (1980) ‘Methodology and apologetics: Thomas Sprat’s “History of the Royal Society”’, *British Journal for the History of Science*, 13: 1–26.
- Wren, C. (1750) *Parentalia: or, Memoirs of the Family of the Wrens*, London.