The Origins of Early Modern Experimental Philosophy[1]

Peter Anstey and Alberto Vanzo

This is an Accepted Manuscript of an article published by Taylor & Francis in *Intellectual History Review* on 4th October 2012, available online: http://tandfonline.com/10.1080/17496977.2012.725552

One of the most important developments in early modern thought was the emergence of experimental philosophy in the mid-seventeenth century and yet its origins are not particularly well understood. This paper argues that experimental philosophy emerged as the dominant member of a pair of methods in natural philosophy, the speculative versus the experimental, and that this pairing derives from an overarching distinction within philosophy in general that can be traced back through the Renaissance to Aquinas and ultimately to Aristotle.

While our concern is with the emergence of experimental philosophy, we contend that this cannot be understood apart from the distinction between experimental and speculative philosophy. This paper then aims to reconstruct the origins of the distinction between experimental and speculative philosophy, a distinction that pervaded early modern thought, from the famous natural philosophical debate between Robert Boyle and Thomas Hobbes to the first reception of Kant's Critical philosophy. Where did the experimental/speculative distinction come from and how

[1] We would like to thank Helen Hattab, Gideon Manning and audiences at the University of Bucharest and the University of Otago for helpful comments on an earlier version of this paper.

was it established? It is only by answering these questions that we can explain the emergence of early modern experimental philosophy.

The first section of the article sets out the basic historical premise, namely, that experimental philosophy, in contradistinction to speculative philosophy, was the preferred way to practise philosophy in the early modern period. Having established this, we turn to the long pre-history of the experimental/speculative distinction. In order to set its early history in context we need to go back to Aristotle. In Section II we examine the traditional classification of natural philosophy as a speculative discipline from the Stagirite to the seventeenth century. Section III surveys some medieval and early modern attempts to articulate an experiential science (*scientia experimentalis*), which aimed to complement speculative natural philosophy. Then in Section IV we turn to certain tensions in the early modern classifications of natural magic and mechanics, which led to the introduction of an *operative*, non-speculative part of natural philosophy in the writings of Francis Bacon and John Johnston. The paper concludes with a summary of the salient discontinuities between the experimental/speculative distinction of the mid-seventeenth century and its predecessors and a statement of some of the important developments that led to the ascendance of experimental philosophy from the 1660s.

I

From the mid-1660s in England, natural philosophy increasingly came to be understood as being practised in two different ways. It could be done either according

to the new experimental philosophy or according to the speculative philosophy. This is nicely summed up in John Dunton's student manual in the following terms:

> Philosophy may be consider'd under these two Heads, Natural and Moral: The first of which, by Reason of the strange Alterations that have been made in it, may be again Subdivided into *Speculative* and *Experimental*.[2]

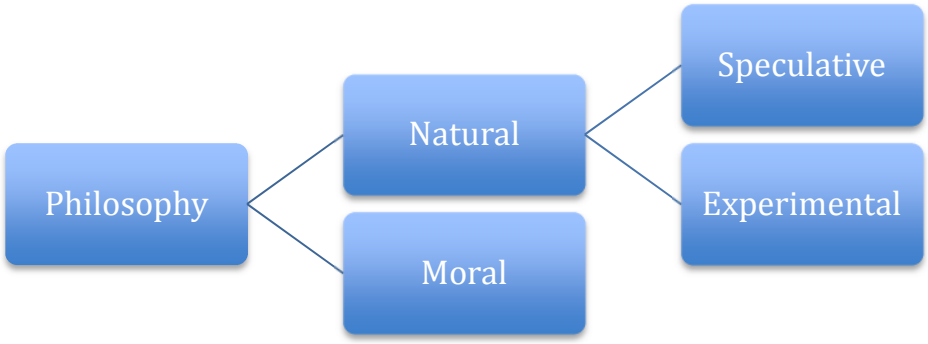

Figure 1. John Dunton's divisions of philosophy.

While natural and moral philosophy were different disciplines or branches of philosophy, experimental and speculative philosophy were competing methodologies in the field of natural philosophy. The opening of John Sergeant's *The Method to Science* brings this out nicely:

> The *METHODS* which I pitch upon to examine, shall be of two sorts, viz. that of *Speculative*, and that of *Experimental* Philosophers; The Former of which

[2] J. Dunton, *The Young-Students-Library* (London, 1692), vi.

> pretend to proceed by *Reason* and *Principles*; the Later by *Induction*; and both of them aim at advancing *Science*.[3]

Experimental philosophy was originally a method for acquiring knowledge of nature. On the positive side it emphasised observation and experiment and negatively it decried hypotheses and speculation. Experimental philosophers believed that only when a sufficient number of observations and experiments had been performed was the natural philosopher in a position to theorise.[4] Experimental philosophers' opposition to hypotheses and speculation was based, in part, on the danger of prepossession, that is, allowing speculative hypotheses to predetermine the way observation was interpreted.[5] Experimental philosophers also criticised the speculative philosophers' lack of recourse to observation, their premature theorising on the basis of speculative hypotheses, and especially the way they constructed systems of natural philosophy.[6]

---

[3] J. Sergeant, *The Method to Science* (London, 1696), Preface, sig. b6r–v.

[4] See, e.g., R. Boyle, *Defence against Linus* (1662), in *The Works of Robert Boyle*, 14 vols, edited by M. Hunter and E. B. Davis (London: Pickering and Chatto,1999–2000), vol. 3, 12.

[5] See, e.g., R. Boyle, *Certain Physiological Essays*, *Works of Robert Boyle*, vol. 2, 13 and *Things above Reason*, *Works of Robert Boyle*, vol. 9, 373.

[6] See P. R. Anstey, 'Experimental versus Speculative Natural Philosophy', in *The Science of Nature in the Seventeenth Century: Patterns of Change in Early Modern Natural Philosophy*, edited by P. R. Anstey and J. A. Schuster (Dordrecht: Springer, 2005), 215–42; S. Gaukroger, *The Emergence of a Scientific Culture: Science and the Shaping of Modernity, 1210–1685* (Oxford: Oxford University Press, 2006), 352–451.

Unlike experimental philosophers, speculative philosophers preferred to work from principles and maxims and to reason from them to create natural philosophical theories. These theories might then be checked against observation, but this was often a *post hoc* element in the process. Speculative philosophers tended to proceed immediately to demonstrative systems of natural philosophy, rather than commencing with observation and experiment. The most commonly cited systems of speculative philosophy were the Aristotelian, the Epicurean and the Cartesian philosophies.[7]

Experimental philosophy emerged as the dominant way to do natural philosophy in England in the latter half of the seventeenth century. However, it did have its detractors, such as Thomas Hobbes, Margaret Cavendish and John Sergeant, each of whom was critical of experimental philosophy and sided with the speculative approach.[8] Nevertheless, as experimental philosophy gained ascendancy, it began to be applied to other branches of philosophy. Of particular importance is the way it was

---

[7] See, e.g., 'The Text of Robert Boyle's "Designe about Natural History"', edited by M. Hunter and P. R. Anstey, 2008 [1666], http://www.bbk.ac.uk/boyle/researchers/works/Occasional_Papers/occasional_paper_3.pdf (Robert Boyle Occasional Papers, no. 3), 2.

[8] See T. Hobbes, *Dialogus physicus* (London, 1661), translated in S. Shapin and S. Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (Princeton: Princeton University Press, 1985), 345–91; M. Cavendish, *Observations upon Experimental Philosophy*, edited by E. O'Neill (Cambridge: Cambridge University Press, 2001 [1666]); J. Sergeant, *The Method to Science*, esp. sig. d5r–d6r.

applied to the human understanding by Locke and others, and to medicine.[9] In the eighteenth century it was also applied to moral philosophy and aesthetics. For instance, Hume's *Treatise* is subtitled 'an Attempt to introduce the Experimental Method of Reasoning into Moral Subjects'.[10]

Experimental philosophy also experienced a geographical expansion. Denis Diderot and the French *Philosophes*, Johann Nikolaus Tetens and the German popular philosophers saw themselves as experimental philosophers (or, as the Germans used to say, observational philosophers).[11] All of these authors contrasted experimental philosophy with speculative philosophy. For instance, Diderot distinguished

> two kinds of philosophy, the experimental and that based on reasoning. The former has its eyes bandaged, walks always feeling its way, grasps whatever falls into its hands and finds precious things in the end. The other gathers these precious things, and tries to make a torch of them; but this pretended torch has

---

[9] For Locke and experimental philosophy see P. R. Anstey, *John Locke and Natural Philosophy* (Oxford: Oxford University Press, 2011). For experimental philosophy and medicine see Id., 'The creation of the English Hippocrates', *Medical History*, 55 (2011), 457–78.

[10] D. Hume, *A Treatise of Human Nature*, 2 vols., edited by D. F. Norton and M. J. Norton (Oxford: Oxford University Press, 2000 [1739–1740]). On experimental philosophy and aesthetics, see, e.g., G. Turnbull, *A Treatise on Ancient Painting* (London: 1740, repr. 1971), 146–8.

[11] See, e.g., D. Diderot, *Pensées sur l'interpretation de la nature* (Amsterdam, 1754); J. N. Tetens, *Philosophische Versuche über die menschliche Natur und ihre Entwicklung* (Leipzig: Weidmanns Erben und Reich, 1777, repr. 1979), vol. 1, iii–iv, vii.

> up to the present served it less well than the gropings of its rival, and this must be so [...][12]

Along similar lines, German experimental philosophers rejected Kant's 'speculative metaphysics' (*speculative Metaphysik*)[13] because it abandoned the experimental approach in favour of 'the most abstract and profound speculations' (*abstractesten und tiefsinnigsten Speculationen*).[14]

II

When seventeenth-century British philosophers began to distinguish between experimental and speculative natural philosophy, they were departing from a

---

[12] Diderot, *Pensées*, article XXIII, quoted from *Diderot Interpreter of Nature: Selected Writings*, translated by J. Stewart and J. Kemp (London: Lawrence and Wishart, 1937), 46: 'deux sortes de philosophies, l'expérimentale et la rationnelle. L'une a les yeux bandés, marche toujours en tâtonnant, saisit tout ce qui tombe sous les mains, et rencontre à fin des choses précieuses. L'autre recueille ces matières précieuses, et tâche de s'en former un flambeau; mais ce flambeau prétendu lui a, jusqu'à présent, moins servi que le tâtonnement à sa rivale'.

[13] E. Platner, *Neue Anthropologie für Aerzte und Weltweise: Mit besonderer Rücksicht auf Physiologie, Pathologie, Moralphilosophie und Aesthetik* (Leipzig: Crusius, 1790), vol. 1, Preface, sig. a5 5.

[14] J. G. H. Feder, *Ueber Raum und Caussalität zur Prüfung der kantischen Philosophie* (Göttingen: Dieterich, 1787), xviii. Feder's sketches of the experimental approach can be found in *Ueber Raum und Caussalität*, ix–x, and in his *Untersuchungen über den menschlichen Willen, dessen Naturtriebe, Verschiedenheiten, Verhältniß zur Tugend und Glückseligkeit und die Grundregeln, die menschlichen Gemüther zu erkennen und zu regieren* (Göttingen: Meyer, 1779–1783, repr. 1968), §4.

centuries-old tradition that regarded natural philosophy as a speculative discipline. That tradition had its roots in Aristotle's classification of the branches of knowledge.

Aristotle proposed that there are three types of knowledge: theoretical, practical and productive (although he sometimes alluded to a bipartite division between theoretical and non-theoretical types of knowledge). Productive knowledge includes rhetoric and art. Practical knowledge concerns how we ought to behave. It includes ethics and politics. Theoretical knowledge aims at truth. It includes metaphysics, natural philosophy or the study of nature, as well as mathematics.[15] All of the different branches of knowledge were to be subsumed under this tripartite division. Aristotle also distinguished between the practical intellect and the speculative intellect in *De anima* and *Nichomachean Ethics*.[16]

---

[15] See, for example, *Nichomachean Ethics* 1139b14–1141b25; *Topics* 145a16, 157a10; *Metaphysics* 1025b19–27, 1064a10–19. For the bipartite classification, see *Metaphysics* 981b25–982a1; *Eudemian Ethics* 1216b11–17; *Topics* 152b2–4. For details, see J. Mariétan, *Problème de la classification des sciences d'Aristote à St-Thomas* (St-Maurice: St-Augustin and Paris: Alcan, 1901), http://www.archive.org/details/problmedelaclas01marigoog, and J. Barnes, *Aristotle: A Very Short Introduction* (London: Routledge, 2000), 40.

[16] See, for example, *De anima* 433a9–20 and *Nichomachean Ethics* 1139a130.

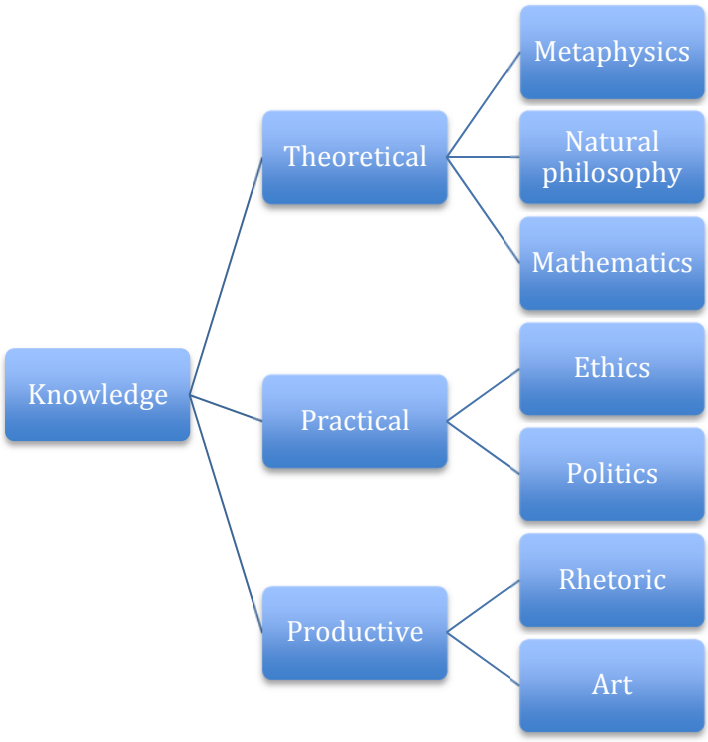

Figure 2. Aristotle's division of knowledge.

It would be wrong to think, however, that Aristotle's division of knowledge was the only division to exert an influence up to the time when the experimental/speculative distinction emerged. The Stoic division of philosophy into logic, physics (including metaphysics and mathematics), and ethics was well known and adopted, among others, by John Locke.[17] Indeed, philosophers in the medieval, Renaissance and early modern periods put forward many alternative classifications besides the Aristotelian and Stoic ones.[18] Joseph S. Freedman holds that divisions of philosophy 'numbered in

---

[17] J. Locke, *An Essay concerning Human Understanding*, edited by P. H. Nidditch (Oxford: Clarendon Press, 1975), IV. xxi. A major ancient source for this classification is Diogenes Laertius. See his *Vitae philosophorum*, edited by H. S. Long (Oxford: Clarendon, 1964), VII 40.

[18] For overviews and further references, see J. A. Weisheipl, 'Classification of Sciences in Medieval Thought', *Mediaeval Studies*, 27 (1965), 54–90; A. M. Blair, 'Organizations of Knowledge', in *The*

the thousands during the sixteenth and seventeenth century' alone.[19] However, the Aristotelian classification and its variations were the most widespread in the early modern period and provided the background for the emergence of the experimental/speculative distinction. As examples of Aristotelian classifications we will consider those by Thomas Aquinas, Franciscus Toletus and Daniel Sennert.

According to Aquinas, there are two objects for the main operations of the rational soul, the good and the true. The former is apprehended by the practical intellect, the latter by the speculative intellect.[20] The speculative intellect is that aspect of reason which is concerned with the true. The speculative intellect operates using speculative principles, such as 'the whole is greater than the part'. The deliverances of the speculative intellect are necessary truths. The knowledge generated is speculative knowledge. The practical intellect, by contrast, operates using practical principles, but does not produce necessary truths. This is practical knowledge.[21] Aquinas has a lengthy discussion in the *Summa theologica* on the question as to whether the

---

Cambridge Companion to Renaissance Philosophy, edited by J. Hankins (Cambridge: Cambridge University Press, 2007), 287–303 (287–93); J. S. Freedman, 'Classifications of Philosophy, the Sciences, and the Arts in Sixteenth- and Seventeenth-century Europe', *Modern Schoolman*, 72 (1994), 37–65.

[19] Freedman, 'Classifications of Philosophy', 39.

[20] Aquinas, *Summa theologiæ* (Cinisello Balsamo, Italy: San Paolo, third edition 1999 [1265–1274]), translated by the Fathers of the English Dominican Province as *Summa theologica* (London: Oates & Washbourne, 1920–1924), I, 79, 11.

[21] Aquinas, *Summa theologiæ*, I–II, 94, 4.

speculative and practical intellects are distinct powers. He is inclined to think that they are not.[22]

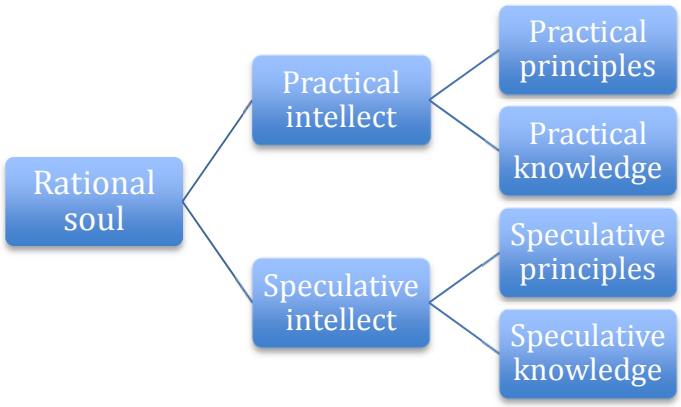

Figure 3. Aquinas' practical/speculative distinction.

This simple summary of Saint Thomas' views is hardly adequate to capture the sophistication of his position, but it is enough to show that in the Western tradition, under the influence of Aristotle, a speculative/practical distinction of *disciplinary domains* found its application in *faculty psychology* in the distinction between speculative and practical intellect, and a concomitant twofold distinction of speculative and practical *knowledge* which, in turn, were founded upon speculative and practical *principles*. Many early modern authors associated disciplinary domains with mental faculties: among others, Tommaso Campanella;[23] Francis Bacon,[24] the

---

[22] Aquinas, *Summa theologiæ*, I, 79, 11.

[23] See L. Blanchet, *Campanella* (Paris: Alcan, 1920), http://www.archive.org/details/campanella00blan, 231.

[24] F. Bacon, *De dignitate et augmentis scientiarum*, in *The Works of Francis Bacon*, 7 vols., edited by J. Spedding, R. Ellis and D. D. Heath (London, 1857–1874), vol. 4, 292.

'patriarck of experimental philosophy';[25] and Franco Burgersdijck, the author of a widely used manual.[26]

During the Renaissance Franciscus Toletus, a Jesuit philosopher and teacher at the prestigious Collegio Romano, followed Aristotle by dividing philosophy into speculative, practical and factive. Speculative philosophy consists in metaphysics, mathematics (pure and applied, or *mathematica media*) and physics. Physics is natural philosophy and it deals with objects that are perceptible via the senses. Metaphysics deals with the principles and properties that are common to all being. Practical philosophy includes ethics, oeconomy (that studies the management of family) and politics. Factive philosophy includes the productive arts and is called *mechanica*.[27] Toletus' tripartite distinction is equivalent to Aristotle's division of knowledge into practical, theoretical and productive.

---

[25] H. Power, *Experimental Philosophy* (London, 1664), 82.

[26] F. Burgersdijck, *Idea philosophiae tum naturalis, tum moralis*, third revised edition (Oxford: Curteyne, 1631), 2: 'speculative philosophy resides in the speculative intellect [...]; practical philosophy is related to the practical intellect' (*philosophia speculativa residet in intellectu speculativo* [...] *Philosophia practica haeret in intellectu practico*). Other authors who associated disciplinary domains with mental faculties are referred to in G. Tonelli Olivieri, 'Galen and Francis Bacon: Faculties of the Soul and the Classification of Knowledge', in *The Shapes of Knowledge from the Renaissance to the Enlightenment*, edited by D. R. Kelley and R. H. Popkin (Dordrecht: Kluwer, 1991), 61–81 (71–3).

[27] See F. Toletus, *Commentaria, una cum quaestionibus, in octo libros Aristotelis de physica auscultatione: Item, in lib. Arist. de generatione et corruptione* (Cologne: Birckmann, 1585), http://books.google.com/books?id=xTg8AAAAcAAJ, sig. A2 1.

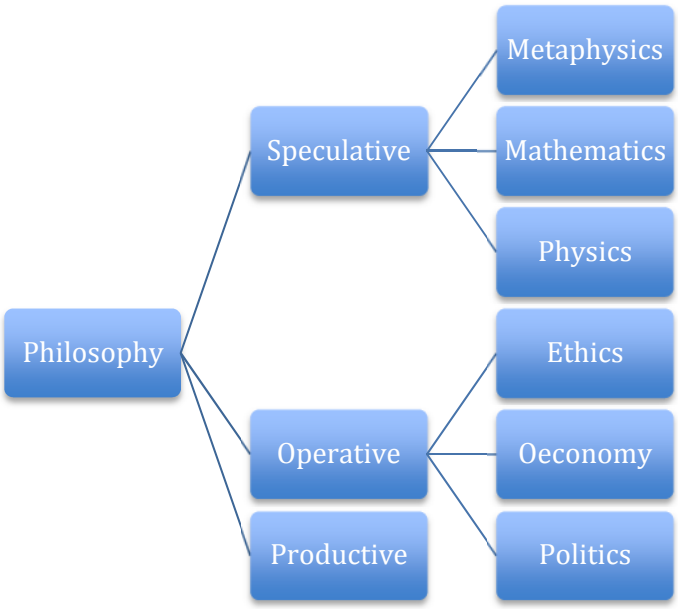

Figure 4. Toletus' operative/speculative distinction.

In the early seventeenth century the German natural philosopher Daniel Sennert accepted Toletus' partitions of theoretical and practical philosophy.[28] However, Sennert criticized Toletus for including the factive disciplines in philosophy because 'they do neither contemplate things divine; nor do they regulate these actions which are proper to Man; nor is honesty the thing they aime at, but Profit, nor does the chief good and Felicity of man consist in them'.[29] 'And who is there that dares reckon Smiths, Carpenters, Joyners, Weavers and such like Artificers, amongst Phylosophers?'[30]

---

[28] D. Sennert, *Epitome naturalis scientiae* (Wittenberg: Heiden, 1618), 12–5; translated as *Thirteen Books of Natural Philosophy* (London, 1660), 5–6.

[29] Sennert, *Epitome*, 8; *Thirteen Books*, 3.

[30] Sennert, *Epitome*, 7; *Thirteen Books*, 3.

Instead, Sennert opts for the twofold distinction:

> I, for my part, take that to be the truest division of Phylosophy, which is delivered by *Aristotle* in the Second Book of his *Metaphysics*, Chap. I. and retained by all sorts of interpreters, viz. into Speculative and Practical. The Speculative part, is that which contemplates all beings or things, with their Principles and Affections or Qualifications, only for knowledg and truths sake: But the practical part of Phylosophy is that whose subject is the Actions of Men [...][31]

As for natural philosophy, Sennert holds that it is a science because 'it demonstrates in a necessary subject the proper affections by the proper Causes: as very many demonstrations touching things natural, do witness'.[32] Natural philosophy is a 'speculative science', rather than a practical science. However, Sennert claims with Zabarella that it is 'superfluous to add the term speculative, seeing if we take the word Science properly, all Sciences are speculative'.[33] Ethics, oeconomy, and politics are sciences only in a broad sense of the term.[34]

---

[31] Sennert, *Epitome*, 5; *Thirteen Books*, 3.

[32] Sennert, *Epitome*, 17; *Thirteen Books*, 6.

[33] Sennert, *Epitome*, 10; *Thirteen Books*, 7; see J. Zabarella, 'De natura logicae', in his *Opera Logica*, third edition (Cologne: Zetzner, 1597, repr. 1966), http://daten.digitale-sammlungen.de/~db/0001/bsb00014535/images/?nav=1&viewmode=1, col. 3.

[34] For a similar scheme that omits politics, see also A. Deusing, *Naturae theatrum universale* (Harderwijk: Gymnasii Typographum, 1644), 21.

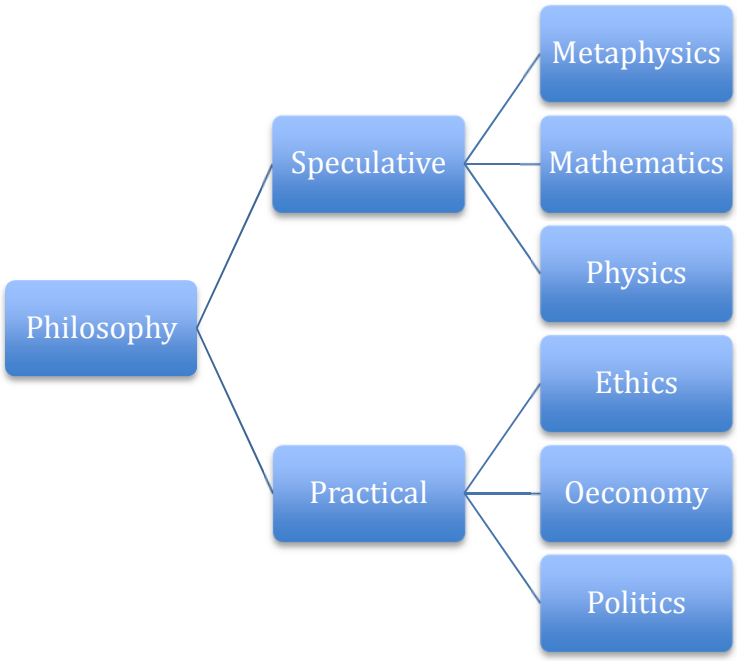

Figure 5. Sennert's division of philosophy.

A comparison of Toletus' and Sennert's views shows that, even among the adopters of the Aristotelian divisions, there was some degree of variety. However, there is one claim on which nearly all authors that distinguished between speculative and practical philosophy before Bacon agreed. This was the claim that natural philosophy was a *speculative*, theoretical, or contemplative discipline, rather than a practical, operative, or productive discipline.[35] Classifications of natural philosophy as a speculative,

---

[35] P. Reif, 'The Textbook Tradition in Natural Philosophy, 1600–1650', *Journal of the History of Ideas*, 30 (1969), 20, notes that this was typical for natural philosophy textbooks published between 1600 and 1650. At least one author before Bacon claimed that there was a non-theoretical, practical part of physics, namely, Johann Grün, a protestant theologian in sixteenth-century Wittenberg. He included the following disciplines within practical physics: medicine and the practical parts of mathematics (practical arithmetic, practical music, optics, astronomy, geodesy and mechanics). See J.

theoretical, or contemplative discipline could be found among Italian Humanists[36] and Aristotelians,[37] Iberian Jesuits,[38] French Scholastics,[39] German academics,[40] German and Dutch physicians[41] and the authors of the manuals used and criticized by English experimental philosophers.[42] Even the post-Ramist Clemens Timpler, who disagreed

---

Grün [Grunius], *Philosophiae origo, progressus, definitio, divisio, dignitas, utilitas* (Wittenberg: Welack, 1587), http://resolver.sub.uni-goettingen.de/purl?PPN663601754, 80–100.

[36] A. Poliziano, 'Praelectio, cui titulus Panepistemon' (1491), in his *Opera* (Basel: Nicolaus Episcopus Iunior, 1553), 462.

[37] Zabarella, 'De natura logicae', col. 2.

[38] *Commentarii Collegii Conimbricensis Societatis Iesu, in octo libros physicorum Aristotelis Stagiritæ* (Lyon: Buysson, 1594, repr. 1984), col. 22–27. Toletus, whom we discussed above, was from Spain.

[39] E. a Sancto Paolo, *Summa philosophiae quadripartita, de rebus dialecticis, moralibus, physicis, & metaphysicis*, third edition (Paris: Chastellain, 1614), vol. 1, 2; P. de Saint-Joseph, *Idea philosophiae naturalis seu physica, Paucis multa complectens de iis quæ spectant ad cognitionem rerum Naturalium*, second edition (Paris: Iosse, 1659), http://books.google.com/books?id=KrNoPW2GoasC, 3–4.

[40] B. Keckermann, 'Positiones de philosophiæ natura & partibus, ex duobus praecognitorum philosophicorum Capitibus', in his *Disputationes philosophicæ, physicæ praesertim* (Hanau: Antonius, 1606), 1–3; J. H. Alsted, *Encyclopædia* (Herborn, 1630, repr. 1989), vol. 1, 3.

[41] See the above discussion of Sennert and note 33 on Deusing.

[42] J. Magirus, *Physiologiae peripateticæ libri sex* (London: Billium, 1619), 5–6; C. Scheibler, *Philosophia compendiosa*, sixth edition, revised and enlarged (Oxford: Turner, 1639), 4; Burgersdijck, *Idea philosophiae*, 3. Newton 'was introduced to Aristotelian physics' via Magirus' textbook (R. S. Westfall, *Never at Rest: A Biography of Isaac Newton* [Cambridge: Cambridge University Press, 1980], 84). Locke criticized Scheibler and Burgesdijck in *Some Thoughts concerning Education*, edited by J. W. Yolton and J. S. Yolton (Oxford: Clarendon Press, 1989 [third edition, 1695]), 157. For other mentions of Burgersdijck, Magirus, and Scheibler in Locke's writings, see J. R. Milton, 'The Scholastic Background to Locke's Thought', *Locke Newsletter*, 15 (1984), 25–34.

with most of his contemporaries in regarding natural philosophy as an art, rather than a science, was quick to add that it was a speculative art, rather than a practical or a productive art.[43]

III

There were, however, in the middle ages and the Renaissance, other approaches to the study of nature that were not purely speculative and these, to some extent, anticipated the experimental natural philosophy developed in the early Royal Society. For example, the thirteenth-century philosopher Roger Bacon promoted a practical method for the acquisition of knowledge of the natural world that combined the use of mathematics and detailed descriptions of natural phenomena. Bacon singled out a new discipline that was supposed to apply this method. He called it *experiential science* (*scientia experimentalis*), distinguishing it from the more speculative discipline of natural philosophy. According to Bacon, experiential science has three aims. First, it should provide mathematical descriptions of natural phenomena based on empirical evidence, rather than demonstrative reasonings from principles. Second, it should discover instruments, medical cures, military technologies and it should make

---

[43] C. Timpler, *Physicae seu Philosophiae naturalis systema methodicum in tres partes digestum*, vol. 1 (Hanau, Germany: Antonius, 1613), http://books.google.com/books?id=lH8PAAAAQAAJ, 5–6.

chemical discoveries. Third, it should prognosticate 'the future on the basis of astronomical/astrological knowledge'.[44]

Experiential science, therefore, has practical purposes and it relies on observations and experiments. Nevertheless, Roger Bacon did not advocate a systematic and extensive use of controlled experiments, nor did he put forward a theory, methodology, or philosophy of experiment.[45] It is telling that 'for his description of the first example of an experimental science, the study of the rainbow, Bacon depends on the accounts handed down by Aristotle, Seneca and Avicenna', although 'he is not uncritical of these accounts'.[46] Hence, we should not overestimate the degree to which Roger Bacon's experiential science anticipates either experimental science as we currently understand it, or the experimental natural philosophy advocated by Robert Boyle and the members of the early Royal Society.

It is unlikely that many first-generation experimental philosophers read Roger Bacon's texts, given their predilection for works written in the late sixteenth and

---

[44] J. Hackett, 'Roger Bacon', in *The Stanford Encyclopedia of Philosophy*, edited by E. N. Zalta, Spring 2009 Edition, http://plato.stanford.edu/archives/spr2009/entries/roger-bacon/, §5.4.3.

[45] This also applies to Robert Grosseteste, *pace* A. C. Crombie, for whom the qualitative aspects of modern science originated with Robert Grosseteste and Roger Bacon. See A. C. Crombie, *Robert Grosseteste and the Origins of Experimental Science, 1100–1700* (Oxford: Clarendon, 1953); J. Hackett, '*Scientia Experimentalis*: From Robert Grosseteste to Roger Bacon', in *Robert Grosseteste: New Perspectives on His Thought and Scholarship*, edited by J. McEvoy (Dordrecht: Kluwer, 1994), 89–119.

[46] Hackett, 'Roger Bacon', §5.4.3.

seventeenth centuries.[47] However, a text that was widely read in late sixteenth- and seventeenth-century England took inspiration from Roger Bacon's *scientia experimentalis* to advocate the introduction of an operative, non-speculative form of natural philosophy. This was John Dee's *Mathematical Praeface* to the English translation of Euclid's *Elements*, first published in 1570.[48] At the end of his classification of mathematical disciplines, Dee introduces the new discipline of archemastrie which

> teacheth to bryng to actuall experience sensible, all worthy conclusions by all the Artes Mathematicall purposed, & by true Naturall Philosophie concluded: & both addeth to them a farder scope, in the termes of the same Artes, & also by hys propre Method, and in peculiar termes, procedeth, with helpe of the foresaid Artes [*scil*. the mathematical arts], to the performance of complet Experiences, which of no particular Art, are hable (Formally) to be challenged. [...] *Science* I may call it, rather, then an Arte: for the excellency and Mastershyp it hath, over so many, and so mighty Artes and Sciences. And bycause it procedeth by *Experiences*, and searcheth forth the causes of Conclusions, by *Experiences*: and also putteth the Conclusions them selves, in

---

[47] See Milton, 'The Scholastic Background', 30–1, for Locke. This also applies to Hobbes, whose knowledge of Aristotelianism largely relied on early modern sources. See M. Sgarbi, 'La logica di Hobbes e la tradizione aristotelica', *Lo sguardo*, 5 (2001), 1–14.

[48] J. Dee, 'Mathematicall Præface', in *The elements of geometrie of the most auncient philosopher Euclide of Megara: Whereunto are annexed certaine scholies, annotations, and inuentions, of the best mathematiciens, both of time past, and in this our age*, translated by H. Billingsley (London: Daye, 1570).

> *Experience*, it is named of some, *Scientia Experimentalis*. The *Experimentall Science*. *Nicolaus Cusanus* termeth it so, in hys *Experiments Statikall*, And an other Philosopher, of this land Native [*scil*. Roger Bacon] [...] The Arte carrieth with it, a wonderful Credit: By reason, it certifieth, sensibly, fully, and completely to the utmost power of Nature, and Arte. This Arte, certifieth by *Experience* complete and absolute: and other Artes, with their Argumentes, and Demonstrations, persuade: and in wordes, prove very well their Conclusions. But wordes, and Arguments, are no sensible certifying: nor the full and finall frute of Sciences practicable.[49]

This passage is highly suggestive, not least because it contains one of the earliest occurrences of the expression 'experimental science' in English.[50] Nevertheless, one should not exaggerate the extent to which Dee's archemastrie anticipates modern experimental science or early modern experimental philosophy. By deciphering Dee's cryptic references toward the end of the *Mathematicall Praeface*, Nicholas Clulee has established that archemastrie combines the empirical verification of natural

---

[49] J. Dee, 'Mathematicall Præface', sig. A.iij 1–2. On Dee's reference to Cusanus, see F. Nagel, '*Scientia experimentalis*: Zur Cusanus-Rezeption in England', *Mitteilungen und Forschungsbeiträge der Cusanus-Gesellschaft*, 29 (2005), 95–109.

[50] According to Nagel ('Scientia experimentalis', 106), this is the first occurrence of 'experimental science' in English.

philosophical claims with magical practices such as divination by mirrors and reflecting surfaces.[51]

What archemastrie most clearly anticipates is Francis Bacon's operative natural philosophy, which is, we shall argue, a close antecedent of experimental natural philosophy. Like operative natural philosophy, archemastrie does not replace traditional, speculative natural philosophy. It complements it by adding 'a farder scope'. Unlike traditional, speculative natural philosophy, archemastrie does not rely on demonstrative reasoning: 'it procedeth by *Experiences*, and searcheth forth the causes of Conclusions, by *Experiences*: and also putteth the Conclusions them selves, in *Experience*'. It is an 'Experimentall Science' in the broad, early modern sense of the term 'experimental', best rendered in current language as 'experiential': that is, it relies on observations and experiments. Insofar as it 'procedeth [...] to the performance of complet Experiences', including observations, experiments and magical practices, Archemastrie is an operative discipline. This induces Dee to call it an art, although it could also be called a science for 'its excellency and Mastershyp'. Archemastrie sits uneasily between the realms of art and science, unlike Bacon's operative philosophy that he firmly places within the domain of natural philosophy. In order to understand Bacon's reasons for introducing an operative, non-speculative component of natural philosophy, we need to turn to the disciplinary status of two disciplines: natural magic and mechanics.

---

[51] See N. H. Clulee, 'At the Crossroads of Magic and Science: John Dee's Archemastrie', in *Occult and Scientific Mentalities in the Renaissance*, edited by B. Vickers (Cambridge: Cambridge University Press, 1984), 57–71.

IV

Typically, early modern classifications of the disciplines did not include any form of magic within the realm of natural science. This was not because of a widespread scepticism about magic. The same authors who denied the status of natural science to magic often defended natural magic as a perfectly respectable activity. Natural magic, as distinct from demonic, or black, magic, aimed to bring about effects that may seem preternatural by exploiting the hidden natural powers of things.[52] Given its practical purposes, natural magic could not be part of a purely theoretical science like natural philosophy.[53]

Many practitioners and advocates of natural magic thought otherwise. They regarded it as 'the pinnacle of natural philosophy and its most complete achievement' (*philosophiae naturalis apicem, eiusque absolutissimam consummationem*), as Agrippa wrote in 1533.[54] If natural magic was a part of natural philosophy, then it was

---

[52] See J. Henry, *The Scientific Revolution and the Origins of Modern Science*, second edition (New York: Palgrave, 2002), 55; W. Eamon, *Science and the Secrets of Nature: Books of Secrets in Medieval and Early Modern Culture* (Princeton: Princeton University Press, 1994), 194.

[53] See, e.g., *Commentarii Collegii Conimbricensis*, col. 21.

[54] H. C. Agrippa, 'Censura sive retractatio de magia ex sua declamatione de vanitate scientiarum & excellentia Verbi dei', in his *De occulta Philosophia libri tres* (Cologne: Soter, 1533), http://diglib.hab.de/drucke/77-1-quod-2f-2/start.htm (not included in the 1992 critical edition of the *De occulta philosophia*), ccclii, echoing G. Pico della Mirandola, 'On the Dignity of Man' (1486),

a science. Fifty years after Agrippa, Giambattista della Porta wrote about magic: 'They that have been most skilful in dark and hidden points of learning, do call this knowledge the very highest point, and the perfection of natural Sciences' (*Reconditioris literaturæ viri scientissimi eam ipsam naturalium scientiarium apicem* [...] *esse dicunt*).[55]

Magical texts included highly theoretical treatments of the so-called *scientia* of magic, like that of Ficino, but they also included purely technical manuals and collections of recipes. Della Porta brought out this practical aspect of magic by

---

translated by C. G. Wallis in G. Pico della Mirandola, *On the Dignity of Man; On Being and the One; Heptaplus* (Indianapolis: Bobbs-Merrill, 1965), 26.

[55] G. della Porta, *Magiae naturalis libri XX*, second enlarged edition (Naples, 1589), http://books.google.com/books?id=L2kjTEvXAdUC, 2; translated as *Natural Magick* (London, 1658), 2. See G. Pico della Mirandola, *Conclusiones Nongentae*, translated by S. A. Farmer in *Syncretism in the West: Pico's 900 Theses (1486). The Evolution of Traditional, Religious, and Philosophical Systems* (Tempe, Arizona: Medieval & Renaissance Texts & Studies, 1998), thesis II.9.9: 'there is no department of knowledge that gives us more certainty of Christ's divinity than magic and cabala' (*Nulla est scientia, quae nos magis certificet de divinitate Cristi, quam Magia et Cabala*). This claim is echoed in Tiberio Russiliano Sesto Calabrese, *Apologeticus adversus cucullatos*, edited by L. De Franco (Cosenza: Periferia, 1991 [1519]), *cit.* in B. P. Copenhaver, 'Astrology and Magic', in *The Cambridge Companion to Renaissance Philosophy*, 273. The most famous medieval book of natural magic, a collection of recipes widely read in the early modern age, calls magic '*Scientia* magicalis' (pseudo-Albertus Magnus, *Liber aggregationis seu liber secretorum Alberti Magni* (London, s.d.), sig. a ii 1, translated as *The Book of Secrets of Albertus Magnus of the Virtues of Herbs, Stones and Certain Beasts, also a Book of the Marvels of the World*, edited by M. R. Best and F. H. Brightman (Oxford: Clarendon, 1973), 3 [italics added]).

alluding to a famous statement by Pico della Mirandola: 'Others have named it the practical part of natural philosophy, which produces her effects by the mutual and fit application of one natural thing unto another' (*Alii activam naturalis Philosophiæ portionem prodiderunt, effectus suos ex mutua, & opportuna applicatione producentem*).[56] Like other practitioners, della Porta aimed to combine the theoretical and practical aspects of natural magic. His *Twenty Books of Natural Magic* combined an exposition of Ficino's theory of magic with a collection of techniques and recipes.[57] Della Porta would have agreed with Tommaso Campanella's description of natural magic as a 'speculative and at the same time practical' (*speculativa* [...] *ac simul practica*) form of wisdom.[58]

Francis Bacon was highly critical of his predecessors' magical practices, yet he agreed with della Porta and Campanella in regarding natural magic as a science and a part of natural philosophy, but also as a practical or operative discipline. These two features are apparent in Bacon's definition of magic as 'the science which applies the knowledge of hidden forms to the *production* of wonderful operations' (*scientia quae cognitionem* Formarum Abditarum *ad opera admiranda deducat*).[59] Regarding natural

---

[56] Della Porta, *Magiae naturalis libri XX*, 2 (= *Natural Magick*, 2). See Pico della Mirandola, *Conclusiones nongentae*, thesis ii.9.3.

[57] This is noted by B. P. Copenhaver, 'The Occultist Tradition and Its Critics', in *The Cambridge History of Seventeenth-Century Philosophy*, 2 vols., edited by D. Garber and M. Ayers (Cambridge: Cambridge University Press, 1998), vol. 1, 455.

[58] T. Campanella, *De sensu rerum et magia, libri quatuor* (Frankfurt a.M.: Emmelius, 1620), http://books.google.com/books?id=uCw_AAAAcAAJ, 153.

[59] *De augmentis scientiarum*, in *Works of Francis Bacon*, vol. 4, 366–7 (italics added to English text).

magic as a branch of natural philosophy, while acknowledging its operative character, meant introducing an operative, non-speculative part of natural philosophy, as Bacon did as early as 1605 in *The Advancement of Learning*.[60]

The disciplinary shifts that led to the genesis of operative natural philosophy did not only concern natural magic. They also concerned what was sometimes called 'mathematical magic', that is, mechanics.[61] In the Renaissance, mechanics was typically classified as an art, not as a science (or more precisely, as a *scientia*). This classification was accepted by Toletus, who, as we have seen, called the productive arts *mechanica*, and also by Tomeo, a humanist scholar who published an early Latin translation of the pseudo-Aristotelian *Mechanical Problems* (*Quaestiones mechanicae*) in 1525.[62] This classification would be challenged fifty years later, when

---

[60] F. Bacon, *The Advancement of Learning*, in *Oxford Francis Bacon*, vol. 4, edited by M. Kiernan (Oxford: Clarendon Press, 2000), 88. See also *Novum organum*, in *Oxford Francis Bacon*, vol. 11, edited by G. Rees (Oxford: Clarendon Press, 2004), 215 and *De augmentis scientiarum*, in *Works of Francis Bacon*, vol. 4, 365.

[61] For an example of this expression, see J. Wilkins, *Mathematicall Magick: Or, The Wonders that May be Performed by Mechanicall Geometry* (London, 1648). For a survey, see J. P. Zetterberg, 'The Mistaking of "the Mathematicks" for Magic in Tudor and Stuart England', *Sixteenth Century Journal*, 11 (1980), 83–97. On the link between mathematical magic and the new mechanical philosophy, see A. Grafton, *Magic and Technology in Early Modern Europe*: *Dibney Library Lecture. 15 October, 2002* (Washington DC: Smithsonian Institution Libraries, 2005), http://hdl.handle.net/10088/7193.

[62] *Aristotelis Quaestiones mechanicae*, translated by N. Leonico Tomeo in his *Opuscula nuper in lucem aedita* (Venice: Vitalis, 1525). On Tomeo's classification, we rely on W. R. Laird, 'The Scope of Renaissance Mechanics', *Osiris*, second series, 2, 43–68 (49), and H. Hattab, 'From Mechanics to

the Paduan philosopher Niccolò Piccolomini published a widely read paraphrase of the *Mechanical Problems*. Piccolomini no longer regarded mechanics as an art, but as a *scientia*. Like another Paduan Aristotelian, Giuseppe Moletti, Piccolomini classed mechanics as a part of speculative philosophy, more precisely of mathematics.[63] He did not regard it as a part of natural philosophy because the latter concerns natural motions, whereas mechanics concerns unnatural, violent motions.[64] However, mechanics was typically concerned with ways of *effecting* unnatural motions for practical purposes. The Aristotelians acknowledged that being 'directed towards human ends' was '[t]he chief characteristic of mechanics'.[65] Therefore, mechanics sat uneasily within the realm of the speculative sciences.

Given the practical purpose of mechanics, it should not be surprising that Francesco Maurolico (or Maurolyco), one of the leading mathematicians of the sixteenth

---

Mechanism: The Quaestiones Mechanicae and Descartes' Physics', in *The Science of Nature in the Seventeenth Century*, 105.

[63] A. Piccolomini, *In mechanicas quaestiones Aristotelis, Paraphrasis paulo quidem plenior*, second edition (Venice, 1547). Moletti's classifications in a manuscript from the 1580s are summarized in Laird, 'The Scope', 61–2. Elsewhere, Moletti states that mechanics is a science because it is subordinated to the sciences of mathematics as well as natural philosophy. See *The Unfinished Mechanics of Giuseppe Moletti: An Edition and English Translation of His Dialogue on Mechanics, 1576*, edited by W. R. Laird (Toronto: University of Toronto Press, 2000), 78–81, 188–91. Against the classification of mechanics as a part of philosophy, see Sennert's comment cit. in §II.

[64] See A. Piccolomini, 'Praefatio', in his *In mechanicas quaestiones Aristotelis, Paraphrasis paulo quidem plenior*, second edition (Venice, 1565; first edition 1547). Piccolomini's classifications are summarized in Laird, 'The Scope', 50–1, and Hattab, 'From Mechanics', 108.

[65] Laird, 'The Scope', 68.

century, classed mechanics, together with ethics, as a part of *practical* philosophy.[66] By contrast, he classed physics, that is, natural philosophy, and mathematics as parts of speculative philosophy. Yet mechanics was closely associated with those disciplines. It was often regarded as a mixed discipline, deriving from the combination of mathematics with physics. For instance, Maurolico regarded all mechanical theory (*ratio*) as intermediate between mathematics and mechanics.[67] For Niccolò Tartaglia, another eminent writer on mechanics, the *whole* of mechanics derived in part from mathematics and in part from natural philosophy.[68]

Attempts to classify mechanics appear to have reached an impasse. On the one hand, its classification as a speculative science was at odds with its practical orientation. On the other hand, its classification as a practical science did little justice to its intimate connection with the allegedly speculative sciences of mathematics and natural philosophy. Bacon's classification of natural philosophy provides an interesting resolution to this problem. Rejecting the scholastic distinction between natural and violent motions, he classified mechanics as an operative science, which was

---

[66] Maurolico's classification (in his *Problemata Mechanica cum appendice, & ad Magnetem, & ad Pix idem Nauticam pertinentia* [Messina: Brea, 1613]) is reproduced in Hattab, 'From Mechanics', 111. Maurolico's work was published posthumously and composed around 1569.

[67] Laird, 'The Scope', 54. Another important author, Bernardino Baldi, held that the theory of mechanics derives from the combination of mathematics with physical principles (Laird, 'The Scope', 57).

[68] N. Tartaglia, *Quesiti et inventioni diverse* (Venice, 1546), 81, translated in *Mechanics in Sixteenth-Century Italy: Selections from Tartaglia, Benedetti, Guido Ubaldo, & Galileo*, edited by S. Drake and I. E. Drabkin (Madison: University of Wisconsin Press, 1969), 111.

correlated to physics on the speculative side of natural philosophy. He grouped mechanics with magic, which itself was correlated to speculative metaphysics.[69]

Thus, Bacon's schema has a robust operative, that is, non-speculative, side to natural philosophy. Furthermore, Bacon also identified a form of mechanics that he regarded as a constituent of natural history.[70] This grafting in of mechanics to the operative side natural philosophy and the intimate connection between mechanics and natural history provided an important precedent for the inclusion of mechanics as a part of experimental philosophy later in the century. It reflected the conviction of a growing number of intellectuals that the technical subjects are highly relevant to natural philosophy. The Spanish Humanist Juan Luis Vives, while a tutor at the English court, had exhorted scholars to pay attention to technical problems regarding the construction of machines, agriculture, weaving, and navigation as early as 1531.[71] Georgius Agricola's widely read *De re metallica* (*Of Metals*), published in Basel in 1556, 'clearly illustrated the relevance of craft knowledge to an understanding of the nature of the world'.[72] Around 1562, Sir Humphrey Gilbert linked natural philosophy

---

[69] F. Bacon, *De augmentis scientiarum*, in *Works of Francis Bacon*, vol. 4, 365.

[70] F. Bacon, *De augmentis scientiarum*, in *Works of Francis Bacon*, vol. 4, 365–6. See also *Parasceve*, in *Oxford Francis Bacon*, vol. 11, 461.

[71] J. L. Vives, *De disciplinis libri XX* (Antwerp: Hillenius, 1531); partial translation by F. Watson as *On Education* (Cambridge: Cambridge University Press, 1913), http://www.archive.org/details/vivesoneducation00viveuoft.

[72] J. Henry, *The Scientific Revolution and the Origins of Modern Science*, 34. See G. Agricola, *De re metallica libri XII* (Basle, 1556); translated by H. C. Hoover and L. H. Hoover (London: The Mining Magazine, 1912).

to the teaching of technical subjects in his plan for Queen Elizabeth's Academy.[73] Then in 1600, William Gilbert availed himself of works published by craftsmen in his *De magnete*, where he combined a natural-philosophical discussion of magnetism with technical discussions of problems of navigation, nautical instruments, techniques for fusing metals and problems of mining engineering.[74] At the same time, a mechanicist philosophy of nature was emerging, according to which living beings and the whole world are machines operating according to mechanical regularities.[75] This implies that those laws apply to natural and unnatural motions and, hence, are objects of study of natural philosophy. Many experimental philosophers would embrace this view. It provided an even stronger underpinning for the inclusion of the non-speculative, operative discipline of mechanics within natural philosophy than Bacon offered.

---

[73] See P. Rossi, *Philosophy, Technology, and the Arts in the Early Modern Era*, edited by B. Nelson, translated by S. Attanasio (New York: Harper & Row, 1970), 9–10.

[74] This is noted by Rossi, *Philosophy, Technology, and the Arts*, 40–1.

[75] In Italy, Giuseppe Moletti claimed that 'nature uses mechanics in its own works' in lectures from the 1580s. In France, Henri de Monantheuil claimed that the whole world is a machine in 1599. See W. R. Laird, 'Nature, Mechanics, and Voluntary Movement in Giuseppe Moletti's Lectures on the Pseudo-Aristotelian *Mechanica*', in *Mechanics and Natural Philosophy before the Scientific Revolution*, edited by W. R. Laird and S. Roux (New York: Springer, 2008), 173, 183; H. de Monantheuil, *Aristotelis Mechanica Graeca, emendata, Latina facta, & Commentariis illustrata* (Paris: Perier, 1599), http://echo.mpiwg-berlin.mpg.de/ECHOdocuViewfull?mode=imagepath&url=/mpiwg/online/permanent/library/MD6SU509/pageimg&viewMode=images, Dedication, 3. For a thorough discussion of the changing status of mechanics in the fifteenth and early sixteenth centuries and its relation to mechanism, see H. Hattab, *Descartes on Forms and Mechanisms* (Cambridge: Cambridge University Press, 2009), 85–119.

Francis Bacon's mature schema for philosophy is found in his *De augmentis scientiarum* of 1623. Bacon's basic tripartite division of knowledge is into history, poesy and philosophy. These divisions correspond, for Bacon, to the three intellectual faculties of memory, imagination and reason. He divides the third branch of knowledge, philosophy, into three: of the deity, of nature and of man.[76] Philosophy of nature, as we have seen, is divided into speculative and operative. Speculative philosophy is divided into metaphysics and physics. Operative philosophy is divided into mechanics and magic.

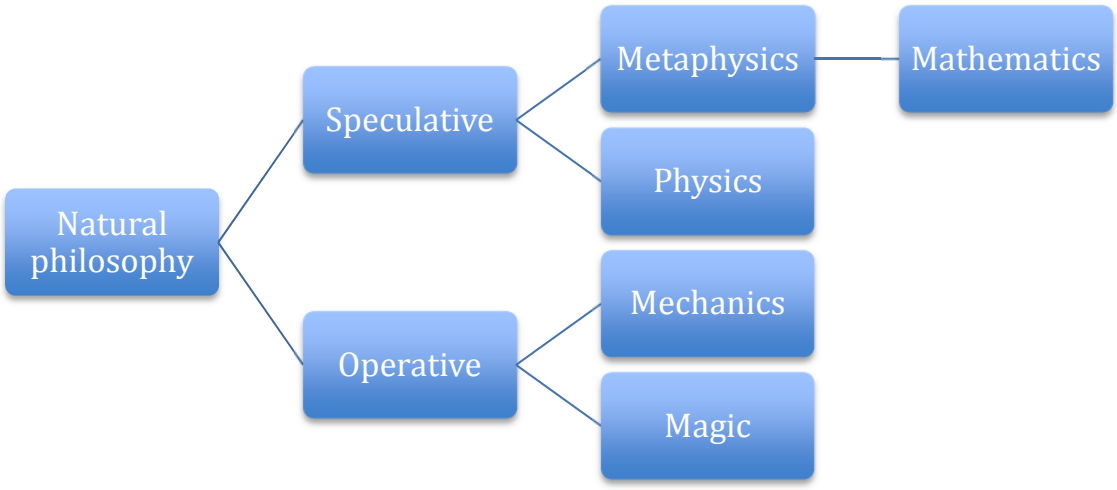

Figure 6. Francis Bacon's mature division of natural philosophy.

[76] F. Bacon, *De augmentis scientiarum*, in *Works of Francis Bacon*, vol. 4, 336.

Bacon's operative/speculative distinction contains one very important development on that of Toletus: it pertains to *natural philosophy* and not to philosophy in general. A further, minor, difference is that Bacon regards mathematics as a branch of metaphysics rather than as a part of speculative philosophy in its own right. Moreover, it is worth pointing out given developments later in the century, that for Bacon natural history is one of three parts of history, but that its content overlaps with physic in speculative philosophy and with mechanic in operative philosophy. For Bacon, natural history and natural philosophy are, therefore, not discrete disciplines.[77]

The profound influence of Bacon's reconfiguring of natural philosophy is nicely illustrated in the work of John Johnston.[78] Johnston was a natural historian who spent much of his adult life on the Continent and published in Latin. His work has generally escaped notice amongst historians of English science, but he studied in Cambridge and London and seems to represent a fairly independent voice concerning developments in natural philosophy in the period before the establishment of the Royal Society. Johnston's two natural histories, shaped by his Millenarian pedagogical ideals, occupy an intermediate position 'between the works of his humanist predecessors and those of his more resolutely empirical successors'.[79] Johnston adopts a conventional twofold division of philosophy in his *Naturæ*

---

[77] See P. R. Anstey, 'Francis Bacon and the Classification of Natural History', *Early Science and Medicine*, in press.

[78] Gordon Miller noted Bacon's influence on Johnston in 'Beasts of the Divine Jerusalem: John Johnston's Natural History and the Launching of Millenarian Pedagogy in the Seventeenth Century', *History of Science*, 46 (2008), 203–43, 215.

[79] Miller, 'Beasts of the Divine Jerusalem', 233.

constantia of 1634, translated into English in 1657: 'But Philosophie being either speculative, or practicall, and that we speak of in this part [i.e. speculative philosophy] comprehends under it, *Metaphysicks*, *Physickes*, and *Mathematickes* [...]'.[80] There is no mention of Descartes in his discussion of metaphysics, instead he refers to a gallery of scholastics: Averroes, Thomas, Scotus, Sánchez, Suarez, Fonseca and Masius.

We note here, however, one absolutely crucial development. This is the claim that 'the practick part of Philosophy was, till now, in the greatest darknesse; at last in our age the way to it was opened by famons [sic] *Verulam* [...] *in his New Organum*, his Sylva Silvarum, his Historie of Life and Death, and of Windes'.[81] From the wider context it is clear that Johnston is referring to the practical part of *natural* philosophy.

Johnston's picture of natural philosophy is a transitional one. It begins looking just like that of Sennert, with the standard divisions and with reference to scholastic masters' treatments of metaphysics. But when he discusses the advances in natural philosophy, he regards Bacon's *Novum organum* and his exemplar natural histories as being representative instances of the practical part of natural philosophy, even though natural philosophy is classified as a speculative science.

---

[80] J. Johnston, *A History of the Constancy of Nature* (London, 1657), 82 (=*Naturæ constantia* (Amsterdam, 1634), 68).

[81] J. Johnston, *A History of the Constancy of Nature*, 84 (= *Naturæ constantia*, 69).

V

It is now time to draw some conclusions from the foregoing discussion. First, it is clear that there are some salient discontinuities between the experimental/speculative distinction in the early modern period and the practical/speculative distinction that derived ultimately from Aristotle. From the 1660s the experimental/speculative distinction is an all-encompassing division pertaining to *natural philosophy*. By contrast, the speculative/operative distinction, from Aquinas through Toletus to Johnston, pertains to *philosophy in general* and not to natural philosophy in particular. The main exception to this obvious discontinuity is the position of Francis Bacon, who restricts the speculative/operative distinction to natural philosophy. It may be that this fundamental Baconian shift was an important factor in the emergence of the experimental/speculative distinction in England in the 1660s. Whatever the case, this shift of domain of application from philosophy to natural philosophy represents a crucial development.

Ironically, however, by the mid-eighteenth century the experimental/speculative distinction was applied to philosophy in general, though this was not a return to the old operative/speculative distinction deriving from Aristotle, but rather it stemmed from a desire to apply the prevailing method of natural philosophy to other branches

of philosophy. For example, allusions to the experimental method of the experimental philosophy were commonplace in Scottish moral philosophy.[82]

A second, related discontinuity is that natural philosophy changed from being a speculative science to being *either* a speculative *or* an operative (i.e. experimental) science. To be sure, this transition occurred over a number of generations as a result *inter alia*, of the re-evaluation of the status of mechanics and magic and the role of experiment. But by the mid-seventeenth century the broader conception of natural philosophy adumbrated by Francis Bacon and others had become the dominant view. In spite of this, remnants of the Renaissance view persisted well into the early modern period. For example, we can see the persistence of the scholastic distinction between speculative and practical principles in John Locke's early *Essays on the Law of Nature* of c.1664:

> If the law of nature were written in our hearts, it would have to be inferred that *speculative as well as practical principles* are inscribed. But this seems difficult to prove; for if we try to search out the first and best known principle of the sciences (namely, that it is impossible that the same thing should at the same time both be and not be), it will be readily agreed that this principle is not inscribed by nature as an axiom in our hearts nor taken for granted by anyone before he has either learned it from another or (which is the proper method of establishing principles) proved it to himself by induction and by

---

[82] See, e.g., G. Turnbull, *The Principles of Moral Philosophy: An Enquiry into the Wise and Good Government of the Moral World* (London, 1740), Epistle Dedicatory, i; Preface, i–iii.

> observing particulars. Thus it appears to me that *no principles, either practical or speculative*, are written in the minds of men by nature.[83]

Of course, this is the kernel of Book One of Locke's *Essay concerning Human Understanding* (1690), in which he dismisses innate speculative and practical principles.

A third point of discontinuity is that scholastic faculty psychology, which underpinned the distinction between speculative and practical knowledge and principles, drops out of the picture. Given that the experimental/speculative distinction emerged as a way of demarcating approaches to the practice of natural philosophy, it is hardly surprising that faculty psychology is virtually completely absent in the writings of the early Fellows of the Royal Society and those promoters of the experimental philosophy within their ambit. Few, if any, natural philosophers had time for the theory of the speculative and practical intellect, for they were concerned rather with the method of acquiring knowledge of nature through observation and experiment.[84] This is not true, however, of religious discourse where

---

[83] J. Locke, *Essays on the Law of Nature*, edited by W. von Leyden (Oxford: Clarendon Press, 1954), 145 (italics added).

[84] In the 'Preliminary Discourse' to the *Encyclopédie* d'Alembert does deploy Bacon's three intellectual faculties, memory, imagination and reason, as a partial justification for following the Baconian division of knowledge into history, poesy and philosophy. However, these faculties play no significant explanatory role in d'Alembert's division of the sciences. See *Preliminary Discourse to the Encyclopedia of Diderot*, translated by R. N. Schwab (Chicago: University of Chicago Press, 1995), 50–5, 143.

the terms remained in use well into the seventeenth century. Take for example the divine Richard Baxter who mentions the practical intellect in both his *Saints' Everlasting Rest* (1654) and his *Catholick Theologie: Plain, Pure, Peaceable* (1675).[85]

Another absolutely decisive difference between the experimental/speculative distinction and the traditional operative/speculative distinction is the fact that the content of the operative side is completely redefined. From the time of Aristotle the operative part of philosophy had typically included ethics, politics and oeconomy, or some variant. As we have seen, however, in the work of Francis Bacon, the operative branch of natural philosophy includes mechanics and magic. Moreover, as we have seen, in the *De augmentis scientiarum* Bacon claims that '[t]here is also a kind of Mechanic often merely empirical and operative, which does not depend on Physic; but this I have remitted to Natural History, taking it away from Natural Philosophy' (*Mechanicam saepius mere empiricam et operariam, quae a Physica non pendeat; verum hanc in Historiam Naturalem conjecimus, a Philosophia Naturali segregamus*).[86] While a full exposition of Bacon's view is not possible here, it is important to point out that, for Bacon, natural history has three subjects, namely generations, pretergenerations (monsters) and arts or mechanic. What he claims in the *De augmentis scientiarum* is that one aspect of the operative part of natural

---

[85] See R. Baxter, *The Saints' Everlasting Rest* (London, 1654), 230 and *Catholick Theologie: Plain, Pure, Peaceable: For Pacification of the Dogmatical Word-Warriours* (London, 1675), 153. See also R. South, *A Sermon Preached at the Cathedral of St. Paul, Novem. 9, 1662* (London, 1663), 14–5 and M. Hale, *The Primitive Origination of Mankind* (London, 1677), 47.

[86] F. Bacon, *De augmentis scientiarum*, *Works of Francis Bacon*, vol. 4, 365–6 = *Works of Francis Bacon*, vol. 1, 572.

philosophy belongs to natural history. In other words, Bacon identifies a type of mechanics in the operative branch of natural philosophy with mechanics or arts in natural history.

Proceeding chronologically, it is natural to view the schema of John Johnston as providing a transitional view in so far as he speaks of the operative part of philosophy in terms of Bacon's natural histories. And by the time that the experimental/speculative distinction emerged in the 1660s, the operative part had come to be entirely characterised in terms of observation and experiment. This brings us to another important development: operative, or practical, philosophy becomes experimental.

At some point in the decades between the death of Bacon and the founding of the Royal Society, natural philosophers in England ceased to speak of the operative, or practical, part of philosophy and began to speak of experimental philosophy. This is explicitly acknowledged by Henry Oldenburg, the first Secretary of the Royal Society, who gives a very interesting potted history of the emergence of the experimental philosophy:

> In the last Age, when Operative Philosophy began to recover ground, and to tread on the heels of triumphant Philology; emergent adventures and great success were encountered by dangerous oppositions and strong obstructions: Galilaeus and others in Italy suffered extremities for their Celestial Discoveries; and here in England Sr. Walter Raleigh, when he was in his greatest luster, was notoriously slaundered, to have erected a School of

> Atheism, because he gave contenance to Chymistry, to practical Arts, and to curious Mechanical Operations, and design'd to form the best of them into a Colledge, And Queen Elizabeths Gilbert was a long time esteem'd extravagant for his Magnetismes; and Harvey for his diligent researches in pursuance of the Circulation of the Blood.
>
> But when our renowed Lord Bacon had demonstrated the Methods for a perfect Restauration of all parts of Real knowledge; and the Generous and Philosophical Peyreskus had, soon after, agitated in all parts to redeem the most instructive Antiquities, and to excite Experimental Essays, and fresh Discoveries; The success became on a sudden stupendious, and Effective philosophy began to sparkle, and even to flow into beams of bright-shining Light, all over the World.[87]

Oldenburg's potted history tells us whom he regarded as seminal contributors to the emergence of the experimental philosophy, but it does not give us any inkling into the emergence of the expression 'experimental philosophy'. Unlike 'scientia experimentalis' that was used all over Europe,[88] 'experimental philosophy' became a

---

[87] H. Oldenburg, 'A preface to the eighth year', *Philosophical Transactions*, 8 (1672), 4001–2. Mihnea Dobre alerted us to this reference.

[88] Dee in England, Gassendi in France, Campanella in Italy, Calvin in Geneva, and the royal physician of the Spanish kings all used the expression 'scientia experimentalis' in the sixteenth or early seventeenth century. See P. Gassendi, *Exercitationes paradoxicae adversus Aristoteleos* (composed between 1620 and 1624), in his *Opera Omnia*, vol. 3 (Lyon, 1658, repr. 1964), 207; T. Campanella, *Apologia pro Galileo, mathematico florentino: Ubi disquisitur, utrum ratio philosophandi, quam Galileus celebrat, faveat sacris scripturis, an adversetur* (Frankfurt a.M.: Tampachius, 1622),

common English expression only from the 1650s and by the 1670s, it was used in other languages like French and Italian.[89] The earliest use of that expression in English that we have found is in Samuel Hartlib's private 'Ephemerides' in 1635, just nine years after Bacon's death.[90] On the Continent, Athanasius Kircher used the Latin expression 'philosophia experimentalis' in 1641 in the preface of his second book on magnetism, one of the most important and widely read books on this topic after Gilbert's *De magnete*. Five years later, Niccolò Cabeo used the same expression in the extended title of his commentary on Aristotle's *Metereology*.[91] Cabeo's commentary was cited twice in Robert Boyle's *Spring of the Air* (1660), which is the

---

http://diglib.museogalileo.it/rd/bdv?/bdviewer/bid=367745, 15; translated by R. J. Blackwell as *A Defense of Galileo, the Mathematician from Florence* (Notre Dame: University of Notre Dame Press, 1994), 57; J. Calvin, *Praelectiones in duodecim prophetas minores*, in his *Opera quae supersunt omnia*, edited by E. Baum in *Corpus Reformatorum*, vol. 44 (Braunschweig: Schwetschke, 1890), col. 162; A. Ponce de Santa Cruz, 'De natura Medicinæ', in his *Opuscula medica et philosophica* (Madrid: Iunta, 1624), http://books.google.com/books?id=8wIrhofwb4wC, 3. On John Dee, see §III above.

[89] See N. Malebranche, *De la recherche de la vérité* (1674–1675), sixth edition 1712, translated by T. M. Lennon and P. J. Olscamp as *The Search after Truth* (Cambridge: Cambridge University Press, 1997), vol. 2, part II, VIII, 4; D. Bartoli, *De' simboli trasportati al morale* (Venice: Hertz, 1677), http://books.google.com/books?id=1owDAAAAcAAJ, 305–7.

[90] Hartlib Papers 29/3/37B.

[91] A. Kircher, *Magnes sive de arte magnetica opus tripartitum* (Rome: Grignani, 1641), http://books.google.com/books?id=3pA_AAAAcAAJ, final page of the Prooemium; N. Cabeo, *In quatuor libros meteorologicorum Aristotelis commentaria, et quaestiones quatuor tomis compræhensa, quibus non solum meteorologica, tum ex antiquorum dictis, tum maxime ex singularum rerum experimentis explicantur sed etiam vniuersa fere experimentalis philosophia exponitur* (Rome: Corbelletti, 1646).

earliest printed book in English to use the expression 'experimental philosophy'.[92] In the 1680s, the editors of Cabeo's and Kircher's works featured the expression 'experimental philosophy' in the titles of those works, as did other Continental authors.[93] They were trying to exploit what had then become a popular brand.

Nevertheless, Kircher and Cabeo were rather different from British experimental philosophers. Both were Jesuit natural philosophers active in Italy and interested in magnetism.[94] The study of magnetism fell within the field of *physica particularis*. This was the part of physics that describes specific natural phenomena. As such, it was more apt to experimental treatment than the more abstract *physica generalis* that

---

[92] R. Boyle, *New Experiments Physico-Mechanicall Touching the Spring of the Air and its Effects*, in *Works of Robert Boyle*, 14 vols., edited by M. Hunter and E. B. Davis (London: Pickering and Chatto, 1999–2000), vol. 1, 143, 158, 207. Citations from Cabeo's commentary are on pp. 258, 271. An anonymous referee for the Journal alerted us to the use of the term 'experimentall Naturall Philosophy' in a broadside by Balthazar Gerbier entitled *To all Fathers of Noble Families, and lovers of Vertue* (1648).

[93] A. Kircher, *Physiologia Kircheriana Experimentalis: Qua Summa Argumentorum Multitudine & Varietate Naturalium rerum scientia per experimenta Physica, Mathematica, Medica, Chymica, Musica, Magnetica, Mechanica comprobatur atque stabilitur*, edited by J. S. Koestler (Amsterdam: Janssonio-Waesbergius, 1680), http://books.google.com/books?id=nnwog1ET0XoC; A. B. Denstonius, *Pan-sophia enchiretica seu Philosophia Universalis Experimentalis* (Nuremberg: Zieger, 1682), http://books.google.com/books?id=3QsuAAAAcAAJ; N. Cabeo, *Philosophia experimentalis: Sive in III. Librum meterologicorum Aristotelis commentaria, et quaestiones* (Rome: Dondini, 1686).

[94] Yet Cabeo's *Philosophia magnetica* (Ferrara: Succius, 1629) was not an original work. See M. Ugaglia, 'The Science of Magnetism Before Gilbert: Leonardo Garzoni's Treatise on the Loadstone', *Annals of Science*, 63 (2006), 72.

discussed features of nature.[95] However, magnetism was not a canonical subject[96] and was sometimes discussed in treatises on natural magic.[97] Given the difficulty of observing magnetic phenomena in nature, the study of magnetism relied heavily on experiments. Compared with traditional Aristotelian natural philosophy, Cabeo's and Kircher's works were examples of the 'new style of natural philosophy' practised by several Jesuits, a philosophy that relied heavily on experiments and 'made free use of mathematical tools'.[98] However, Cabeo, and especially Kircher, did not disdain speculation and did not conceive of the experimental and speculative approaches as alternative methodologies in the field of natural philosophy.

Interestingly, recent work by Peter Harrison has revealed that by the time Hartlib, Cabeo and Kircher started using the expression 'experimental philosophy', the term 'experimental', in contrast to 'speculative', was already in common use in the religious literature. For example, in 1606 Arthur Dent compared the reprobate with the elect in the following terms:

---

[95] See Daniel Sennert's attack against the empty speculations of authors discussing *physica generalis* in his *Hypomnemata physica* (Frankfurt a.M.: Schleich, 1636), http://books.google.com/books?id=HWc5AAAAcAAJ, Prooemium, sig. †† 5 5. Gideon Manning alerted us to this reference.

[96] This is noted in Ugaglia, 'The Science of Magnetism', 67.

[97] Book VII of della Porta's *Magiae naturalis libri XX* was entirely devoted to magnetism and provided materials for Gilbert's *De magnete*.

[98] P. Dear, 'Cabeo, Niccolò', in *New Dictionary of Scientific Biography*, edited by N. Koertge (Detroit: Scribner's Sons, 2008), vol. 2, 2.

> The knowledge of the reprobate doth puffe up. The knowledge of the elect doth humble. [...] The knowledge of the elect is spirituall, and experimentall. The knowledge of the reprobate is speculative.[99]

More work needs to be done on these very interesting semantic developments,[100] but what is clear is that the experimental terminology was not the exclusive domain of natural philosophers and that there were multiple sources from which the terminology of the new approach to natural philosophy could have drawn. No doubt as the experimental work of Galileo, Torricelli, Harvey and others became well known, the importance of experiment in the acquisition of knowledge of nature emerged as the prominent feature of the practice of the new philosophy. A case in point is Francis Bacon, in whose later writings we find a nascent philosophy of experiment, which was to have a strong influence on the natural philosophers of the early Royal Society and beyond.[101]

---

[99] A. Dent, *A pastime for parents* […] *contayning the most principall grounds of Christian religion*, second edition, London, 1606, sig. ℭb 4–5, quoted in P. Harrison, 'Experimental Religion and Experimental Science in Early Modern England', *Intellectual History Review*, 21 (2011), 413–33, 420.

[100] For a study of the emergence of the term 'experiment' see P. Dear, 'The Meanings of Experience' in *The Cambridge History of Science*, vol. 3: *Early Modern Science*, edited by K. Park and L. Daston (Cambridge: Cambridge University Press, 2006), 106–31.

[101] See, for example, R.-M. Sargent, 'Learning from Experience: Boyle's Construction of an Experimental Philosophy', in *Robert Boyle Reconsidered*, edited by M. Hunter (Cambridge: Cambridge University Press, 1994), 57–78; M. Hunter, *Establishing the New Science: The Experience of the Early Royal Society* (Woodbridge: Boydell Press, 1989); William T. Lynch, *Solomon's Child: Method in the Early Royal Society of London* (Stanford: Stanford University Press, 2001), 1–33.

Last, but not least, is the development of an antagonism between experimental and speculative philosophy. In England, there was a precedent for this in Francis Bacon's warnings against the ill-informed development of theories, his idols of the theatre, and natural philosophical speculations that lacked adequate observations and experiments.[102] On the Continent, the antagonism between experiment and speculation could be found in the medical debates that unfolded in the Netherlands between the 1640s and the 1660s. Physicians like Cornelis van Hogelande and Franciscus de le Boë Sylvius 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.[103] On the whole, such antagonism is not a characteristic of the scholastic treatments of operative and speculative philosophy. By contrast, from the 1660s in England there is an almost monotonous call to avoid the hypotheses and 'castles in the air' of the speculative philosophers. Again and again the methodological writings of the new philosophers pit experimental philosophy against its speculative counterpart. To be sure, some like Boyle, argued for the mutual assistance that both

---

[102] F. Bacon, *Novum organum*, *Oxford Francis Bacon*, vol. 11, 97–107.

[103] C. van Hogelande, *Cogitationes quibus Dei Existentia item Animae Spiritalitas, et possibilis cum corpore unio, demonstratur: nec non, brevis Historia Oeconomiae Corporis Animalis, proponitur, atque Mechanice explicatur* (Amsterdam: Elzevirius, 1646), http://books.google.com/books?id=yo0PAAAAQAAJ, 195–6; see F. de le Boë Sylvius, disputation *De Febribus Prima*, held in Leiden in 1661, props. 19–20, in his *Opera medica, hoc est, disputationum medicarum decas* (Geneva: De Tournes, 1681), http://books.google.com/books?id=wm5EAAAAcAAJ, p. 26. Evan Ragland alerted us to these references.

might render each other.[104] But the majority of writers were more inclined to highlight the opposition of experiment to speculation and to warn their readers off the latter. This manifested itself in strong anti-hypothetical rhetoric, most famously in Newton, and in attacks on principles and maxims as found in Locke's *Essay*.[105] Interestingly, a parallel of this antagonism is to be found in the religious writings of the period in England, which suggests a more general trend to favour experience/experiment over armchair reflection in the acquisition of knowledge.

From the foregoing survey it is clear that the experimental/speculative distinction is in many ways discontinuous with the common divisions of knowledge and, in particular, the place of natural philosophy within those divisions in late Renaissance writings. Furthermore, in spite of its obvious debt to Francis Bacon, it is discontinuous in many respects with his conception of the nature and classification of natural philosophy. And yet, it is also apparent that the operative/speculative distinction, deriving ultimately from Aristotle, provided the fundamental dichotomy from which the later distinction derived.

We conclude, therefore, that not only are the origins of early modern experimental philosophy inextricably tied to the distinction between experimental and speculative

---

[104] See P. R. Anstey and M. Hunter, 'Robert Boyle's "Designe about Natural History"', *Early Science and Medicine*, 13 (2008), 83–126, 97–9, for references and discussion.

[105] Locke, *Essay* IV. vii. For Newton on hypotheses see *Opticks* (London, 1717), 380 and *The* Principia*: Mathematical Principles of Natural Philosophy*, translated by I. B. Cohen and A. Whitman (Berkeley: University of California Press, 1999 [1713]), 943.

philosophy, but that this distinction, in turn, had precedents and analogues in the writings of Francis Bacon, in the schemes of knowledge of the late Renaissance scholastics and even in the thought of Aquinas and Aristotle. There may not be a simple line of development from Aristotle to the emergence of the experimental philosophy in England in the late 1650s, however, the evidence assembled here establishes that early modern experimental philosophy did not appear *de novo* in the middle of the seventeenth century.

Otago University

University of Birmingham