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The paper, tailored to the Catholic intellectual audience at Campion, is an experiment in historiography. It explores what, if anything, can today be usefully retrieved from the Medieval-centric ‘continuist’ historiographies of the rise of Modern Science of Pierre Duhem and Alistair Crombie, by making use of my own preferred categories and approaches to the problem. The ‘Dawson’ mentioned four times in the paper is of course Christopher Dawson, well known to the Campion audience as perhaps the twentieth century’s greatest Anglophone Catholic macro and comparative historian of culture, religion and intellectual life.

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Pierre Duhem and Alistair Crombie Revisited: Or, How to Recover the Formative Role of Medieval Catholic Natural Philosophizing in the Rise of Modern Science

John A. Schuster

Campion College, Sydney, and
Unit for History & Philosophy of Science, University of Sydney

[Abstract] Debate over the positive role of Medieval Catholic institutions and thinkers in the process of emergence of Western science has been rife since the nineteenth century. Advocates, such as the Pierre Duhem, and later, Alistair Crombie, were continually countered by proponents of the view that modern science arose suddenly in the seventeenth century, through a necessary rupture with, and revolution against, Medieval thought and institutions. These deniers came from both the idealist right (Koyré) and the materialist left (Haldane), as well as from champions of a definitive role for Protestantism (Merton).

Historians of science have outgrown those debates, without resolving them. However, recent work on the seventeenth century Scientific Revolution provides hints about how to take seriously the role of the High Medieval heritage in the process. This paper surveys the earlier debate, arguing that Duhem and Crombie suffered from now outmoded historiographical conceptions, and also from cultural assumptions that Catholic advocates of continuity in the West, such as Christopher Dawson, properly rejected. A new form of positive solution is then sketched. It consists in reconceptualizing the precise nature of that ‘dynamic continuity’ of the Western tradition of seeking theoretically systematic and empirically reliable knowledge of nature, which runs from the High Middle Ages, through to the generations of Descartes and Newton. This historiographical strategy is based upon creative articulation back to the Middle Ages from what we now know about the Scientific Revolution itself, using the categories and interpretative frames that leading historians of that event now invoke.

[167] Pierre Duhem (1861–1916), and later, Alistair Crombie (1915–1996) were outstanding Catholic historians of science. They argued vigorously that Medieval Catholic institutions and thinkers played an essential role in the emergence of modern Western science. For over a century, that view has been countered by historians from the Marxist left and the idealist right. They hold that modern science arose suddenly in the seventeenth century, through a revolution against Medieval thought and institutions. Today historians of science largely avoid this debate, lazily assuming it has been resolved against the Catholic Medievalists. In fact, that consensus is illusory. As we shall see, the grounds of rejection of Duhem and Crombie look today just as dubious as the theses of Duhem and Crombie that were rejected. I shall argue that recent work on the seventeenth century Scientific Revolution gives reason to take very seriously the role of the High Medieval heritage in the process. My historiographical strategy is based upon creative articulation back to the Middle Ages from what we now know about the Scientific Revolution itself, using interpretative frames that some historians, including myself, now invoke.

Duhem was a distinguished French physicist, turned outstanding historian and philosopher of science. I focus here on his historical thesis about the continuity of development of modern science from [168] Medieval origins in the Christianized Aristotelianism of the schools.¹ His views on the philosophy of science – particularly the structure of theories, accepted for their conventional simplicity and elegance, and their ability instrumentally to capture wide swathes of experimental results – are still alive in philosophy of science. And, slightly modified, this same “conventionalist” model of physical theory provides one of the pillars of modern, post-Kuhnian thinking in the history of science.²

Duhem brilliantly argued that a scientific theory is simply a human construct, based upon a judgment of conventional simplicity: a matter of experts in a given domain seeing which system of concepts most simply organizes and allows the deduction of the widest range of experimental results. Physical theories, so construed, cannot possibly be “about” metaphysical truths. For Duhem, the devout Catholic, these are supplied by the Church. In a happy reciprocation, the set-up of the medieval Catholic universities had created some space between theology and science. This allowed, after some ructions and scares, the growth of (non-metaphysical) science in the West, building step by step toward the achievements of the seventeenth century.

Duhem’s Medieval-centric historiography works as follows: scientific theories develop in small, concatenating steps. Even the greatest achievements are woven into a prior history of slow development of their constitutive elements. Nothing in science is *de novo*, or by revolution. The High Middle Ages were not a void between the Greeks and the seventeenth century, but a long period of slow development [169] beyond Aristotle, leading to the threshold of modern science. The working historiographical rule here is that each idea has a predecessor which it resembles more than any other. Find that precursor and trace the path backwards to the next one most resembling that one. So, the path from Medieval universities to Copernicus, Galileo and Newton was by evolution, not toward truth, but toward simpler high level theories that related to an increasing number of empirical laws.³

A.C. Crombie was a towering Oxford-based, Australian Catholic historian of science active from the late 1940s to the 1990s. Those interested in the Catholic intellectual heritage in Australia may know of him. What they may not know is that Crombie had been a distinguished physiologist, before he was encouraged, some say by the Jesuits, to devote his considerable intellect to the history of science. The strategy was to combat the rising tide of the Marxist history of science in Britain, in the form of J.D Bernal, Stephen Mason and others.⁴ The second fruit of this work was his highly scholarly *Robert Grosseteste and the Origins of Experimental Science* (Oxford, Clarendon Press, 1953). His later, even more monumental scholarly work tends to attenuate and overcome the historiographical

¹ Duhem, P. *Le système du monde: histoire des doctrines cosmologiques de Platon à Copernic*, 10 vols. A. Hermann, Paris, 1913-1959.

² The key work on the structure of theory is Duhem, P. *The Aim and Structure of Physical Theory*. Translated by P. Weiner. Princeton University Press, Princeton, 1962. The melding of Duhemian conventionalism with the emerging “post-Kuhnian” micro-sociology of science occurred in seminal works, such as Barnes, B. *T.S.Kuhn and Social Science*. MacMillan, London, 1982 and Collins, H. *Changing Order*. Sage, London, 1985.

³ “The mechanics and physics of which modern times are justifiably proud proceed, by an uninterrupted series of scarcely perceptible improvements, from doctrines professed in the heart of the medieval schools.” Duhem, P. *Origins of Statics*, Translated by G. F. Leneaux et al. Kluwer, Dordrecht, 1991. vol. 1, p.38 (Originally published by Hermann, Paris, 1906).

⁴ Bernal, J.D. *Science in History*, 4 vols. C.A. Watts, London, 1954; Mason, S. *Main Currents in Scientific Thought*. Schuman, New York, 1953.

simplicities, indeed mistakes, of his earlier work.⁵ I concentrate here on his early *Grosseteste* because it determined his standing for a generation in the rapidly enlarging profession of history of science.

The book offers bold historiographical theses. [1] That the key to the origin of modern science is the perfection of proper scientific [170] method; a mixture of mathematical and experimental dimensions, articulated on the original template of Aristotle's doctrine of induction to premises, and the deductive explanation of particulars from the premises thus found. The key steps toward this achievement occurred in the Middle Ages. [2] In particular, these advances occurred in the tradition running from Grosseteste, through Roger Bacon and thence to Archbishop John Peckham and others, who melded neo-Platonic and Aristotelian matter theory and epistemology to create in the field of geometrical optics the first scientific, that is methodologically grounded, example of a "mathematical physics".⁶

Now, the mainly dominant critics of Medieval Continuity theses viewed the seventeenth century as one of Scientific Revolution. They saw Scholastic Aristotelianism and its university matrix as the negative obstacle and foil. Marxists, at one time quite influential in the Western history of science, needed a revolutionary model; so did those wishing to explain modern science as a function of Protestantism.⁷ But the most interesting members of this rupturalist coalition belonged to the conservative, idealist, anti-Marxist mainline professional consensus in the Anglo-American history of science from the 1940s onward. The most important name at the start of this was Alexandre Koyré.

For anyone, like myself, trained in the last two generations of the twentieth century, the case against Duhem and indeed against [171] any gradual continuist history, consisted of two persuasive counts: the accusations of a "mere history of scientific ideas" and of an accompanying Whiggism. We were (correctly) taught that the search for precursor ideas neglects the full context of these earlier ideas and their interactions. Taking unit ideas out of their contemporary theoretical/cultural contexts turns the entire undertaking Whiggish from beginning to end. Why? Because Duhemian historiography conflates resources in a tradition with stages in evolution of an essence. Each step in a history is a weave, and an interpretation from available cultural materials, but not necessarily a minimal change. Christian Aristotelianism carried, and provided, materials for later developments, but was not one step in a progressive sequence, nor did this material "cause" what came later.

As for Crombie in particular, nobody, except him, I dare say, has ever believed that "mathematical physics" was invented in medieval optics. The real problem for Crombie and many like him, was his belief that the rise and use of "the scientific method" was the guide thread to the history of science. It was Koyré, and later Thomas S. Kuhn, who demolished

⁵ Crombie, A.C. *Robert Grosseteste and the Origins of Experimental Science*. Clarendon Press, Oxford, 1953. The best example of his later work is: Crombie, A.C. *Styles of Scientific Thinking in the European Tradition*. Duckworth, London, 1994.

⁶ "Grosseteste, by giving his light metaphysics a new physical meaning and by relating it to geometrical optics, transformed it into mathematical physics and brought it within the realm of experimental verifiability." Crombie, *Grosseteste*, [Note 5] p. 106.

⁷ Merton, R.K.. 'Science, Technology and Society in Seventeenth-Century England', *Osiris* 4, pt 2 (1938). This was Merton's famous Harvard PhD dissertation, later published in paperback by Harper Torchbooks, New York, 1970. On these varieties of historiography, see also Shapin, S. 'Discipline and Bounding: The History and Sociology of Science As Seen Through the Externalism-Internalism Debate', *History of Science* 30 (1992) pp. 333-369; Schuster, J.A. 'Internalist and Externalist Historiographies of the Scientific Revolution', in *Encyclopedia of the Scientific Revolution*. Edited by W. Applebaum. Garland Publishing, New York, 2000, pp.334-36.

this quite erroneous view.⁸

Koyré (1892–1964) was a Jewish, White Russian émigré. He belonged to the second generation of a small group of Continental neo-Kantian historians of philosophy, who had turned their attention [172] to the conceptual development of science. Neo-Kantianism in the historiography of philosophy had stressed the sympathetic understanding of the *sui generis* inner coherence and rationality of earlier, now largely defunct systems of thought; the historical transformation and “progress” of certain concepts across such systems; and the ways in which categorical systems shape or load experience and expression.⁹ Koyré and others transplanted these approaches to the domain of history of science, where they set the historiographical tone for two generations of increasingly professionalized historians of science. As a result, as noted above, the profession rightly came to reject the previously reigning simplistic history of ideas, and “method-centric” historiography. Koyré held that the development of modern science depended upon a revolution in ideas, involving the establishment of a new metaphysics, or set of deep conceptual presuppositions, which in turn shaped thinking, experience and action in the emerging fields of modern science, especially classical mechanics and Copernican astronomy.¹⁰ Galileo's constitution of classical mechanics within the framework of a loosely Platonic metaphysics was Koyré's exemplary case. Galileo succeeded because he worked, perceived and argued within the correct sort of metaphysical framework, a kind of non-mystical, low-case, "platonism", a conviction that the basic furniture of the [173] world consists in mathematical objects, moved according to simple mathematical laws.¹¹

It followed that the most significant changes are revolutionary, not incremental; dependent upon metaphysical, conceptual and theoretical disjunctions. The Scientific Revolution was just that, not the outcome of slowly cumulating steps, starting in the Middle Ages. This was the default position of Koyré, and also the position of Koyré's many devotees and protégées, such as the young Thomas Kuhn (1922-1996), who in turn supervised many doctorates, including mine. It also followed on the Koyré/Kuhn view that a general,

⁸ I have published four papers on the same topic, taking the position beyond mere debunking, to explain that both the necessary cognitive incapacity of general methods, as well as their inevitable attraction for believers necessarily result from their common structural features as forms of discourse. Schuster, J. A. 'Methodologies as Mythic Structures: A Preface to the Future Historiography of Method', *Metascience: Review of the Australasian Assoc. for the History, Philosophy and Social Studies of Science* 1-2 (1984) pp.15-36; Schuster, J. A. 'Cartesian Method as Mythic Speech: A Diachronic and Structural Analysis', in *The Politics and Rhetoric of Scientific Method*. Edited by J.A. Schuster and R.R. Yeo. Reidel, Dordrecht, 1986. pp. 33-95; Schuster, J. A. 'Whatever Should We Do with Cartesian Method: Reclaiming Descartes for the History of Science', in *Essays on the Philosophy and Science of René Descartes*. Edited by S. Voss. OUP, Oxford, 1993, pp. 195-223; Schuster, J. A. and Richards, E. 'The Myth of Feminine Method: A Challenge for Gender Studies and the Social Studies of Science', *Social Studies of Science* 19 (1989) pp. 697-720.

⁹ See Kuhn, T.S, *The Essential Tension: Selected Studies in Scientific Tradition and Change*. University of Chicago Press, Chicago, pp. 11, 108-110, 149-50. Other key figures in this translation of neo-Kantian perspectives into the history of science were the immensely influential Ernst Cassirer (who like Koyré eventually emigrated to the United States) and, in France, Leon Brunschvicg and Emile Myerson.

¹⁰ As for Crombie's central idea that optics, not mechanics was the locus of the first move toward modern science, that of course was left aside, as not likely, given what was even then known about the brilliant optical work of Kepler (1604), Descartes (1637) and Newton (1704). However, in recent years Crombie's general intuition about the import of optics in the rise of modern science has turned out to have more life in it than his detractors originally imagined, albeit, on the terrain of a quite different historiographical approach, as is mentioned below Note 19.

¹¹ Koyré, A . *Etudes Galiléennes*. Hermann, Paris, 1939; English translation, *Galileo Studies*. Translated by J. Mepham. Harvester, Hassocks, Sussex, 1978; Koyré, A . *Metaphysics and Measurement: Essays in Scientific Revolution*. Chapman & Hall, London, 1969.

transferable method is neither necessary nor sufficient for the pursuit of genuinely scientific thinking. Reviewing Crombie's *Grosseteste*, Koyré thundered,

No science has ever started with a treatise on method and progressed by the application of such an abstractly derived method.¹²

Three generations of historians of science have tended, correctly, to agree. Grand doctrines of method, Bacon's, Descartes', Newton's, Popper's, even Grosseteste's do not and cannot account for the scientific work of discovery or explanation; they merely provide rhetorical topdressing for factual and theoretical claims, always necessarily arrived at in entirely different, more messy, ways that are inescapably shaped by the particular values and modes of debate governing a particular research front at a particular time.

So, this mainline historiography grew from rejecting, and apparently refuting, Catholic Medieval Continuity theories. But, it has its own limitations: looking at isolated achievements in the seventeenth [174] century and hopping amongst them is really no better. (All you have done is by fiat exclude questions about Medieval sources, causes, conditions.) Koyré and the others certainly got "metaphysics" back into the story, but at the cost of reading out [1] religious metaphysics, and [2] anything to do with Aristotelianism, hence Scholasticism.

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What would a Christopher Dawson-like figure make of all this? I imagine something like this: surprisingly, like their Marxist and Koyréan opponents, Crombie and Duhem take a scientific and secularist approach. Yes, universities were the site of the developments they trace. But, for both, the best one can say is that the Medieval Catholic set-up allowed space in which these islands of real science popped up. Duhem the physicist, and Crombie the physiologist, were deeply pro Catholic, but they were also secularist and Enlightenment oriented in their thinking about the history of science.¹³ We need something better, Dawson might opine, and that something better comes from concentrating not on islands of scientificity, but on the continuity of the institutionalization of natural philosophy in the universities from the Middle Ages to the climax of the Scientific Revolution. The space in Medieval scholasticism was not between theology and emerging islands of "science"; it was between theology and the entire field or institution of natural philosophizing. Just as Koyré and his Marxist antagonists had little use for the massive, constantly reproducing institution of natural philosophy in the universities, so did Crombie and Duhem, because of their search for a Whiggishly conceived linear filiation of steps to scientific modernity.

David Lindberg, a great historian of Medieval science, writes this about the Christianised Scholastic Aristotelian undergraduate curriculum in the medieval universities: [175]

For the first time in history, there was an educational effort of international scope, undertaken by scholars conscious of their intellectual and professional unity, offering standardized higher education to an entire generation of students.¹⁴

¹² Koyré, A. 'The Origins of Modern Science', *Diogenes* 16 (1956), pp. 1-22; reprinted in *The Scientific Revolution*. Edited by V. Bullough. Holt, Rinehart and Winston, New York, 1970. pp.115-121, at p.118.

¹³ In this connection, given the theme of the Champion Colloquium, it is worth noting the following: the history of science was arguably the first humanities field fully and essentially to emancipate itself from naïve Enlightenment ideology, accomplishing this between Koyré in the 1930s and the post-Kuhnians of my own generation, by the later 1970s.

¹⁴ Lindberg, D. *The Beginnings of Western Science*. University of Chicago Press, Chicago, 1992. p.212

Perhaps Lindberg should have said, "...to entire generations of students". This institutionalisation of a religiously more or less acceptable version of one genus of ancient natural philosophy, Aristotelianism, continued right into the early modern era. Either it's important or it's not. It is not important, if in the seventeenth century as Aristotelian natural philosophy died, the entire institution of European natural philosophizing died. It did not. To adopt an evolutionary metaphor, we must not mistake extinction of the dominant genus for both the liquidation of the entire family and the cancelation of the biological processes that constituted both the family and its genera. Natural philosophizing as an institution and a culture lived on through the seventeenth century: it was both the locus of the key changes that occurred, and the historical subject modified by those changes.¹⁵ If natural philosophizing, in the wider field sense, died in the seventeenth century and was replaced by "real science", then indeed the development of Catholic Scholastic Aristotelianism and its institutions in the High Middle Ages was a blockage. But if all those changes occurred within a continuing, continent wide, culture and institution, then the Scientific Revolution cannot be explained without understanding the game of natural philosophizing, set up in the High Middle Ages. [176]

So, turning to the seventeenth century, we need a good historiographical model of natural philosophy as a field and an institution as it continued in that century. This will allow us to see that all relevant developments occurred within debates, struggles and negotiations that took place inside that field of natural philosophizing: by *all*, I include the mathematisation of certain disciplines and the development of experimental approaches to others.¹⁶

Early modern natural philosophy was not just neo-Scholastic Aristotelianism. Of course, the dominant genus of natural philosophy was Aristotelianism in various neo-Scholastic species, but the term applied to alternatives of similar scope and aim; that is, to any particular species of the various competing genera: neo-Platonic, mechanistic or, later, Newtonian. When "natural philosophizing", one tried systematically to explain the nature of matter, the cosmological structuring of that matter, the principles of causation, and the methodology supposedly used for acquiring or justifying such knowledge. Natural philosophers learned what I call the "grammar of natural philosophizing" at university while studying the hegemonic Aristotelianism. Even alternative systems followed the rules of this game. All natural philosophers and natural philosophies constituted one sub-culture in a dynamic process over time.¹⁷ We should not equate "natural philosophy" to Scholastic Aristotelianism. Nor should we accept that after about 1660 natural philosophy died and was replaced by an essentially different activity, Science.

¹⁵ Early statements of the centrality of the category of natural philosophy in Scientific Revolution historiography include: Cunningham, Andrew. 'Getting the Game Right: Some Plain Words on the Identity and Invention of Science', *Studies in History and Philosophy of Science*, 19 (1988), pp. 365-389. Cunningham, Andrew. 'How the *Principia* got its Name; Or, Taking Natural Philosophy Seriously', *History of Science* 24 (1991) pp. 377-392. Schuster, J. A. 'The Scientific Revolution,' in *The Companion to the History of Modern Science*. Edited by R. C. Olby, G. N. Cantor, J. R. R. Christie and M. J. S. Hodge. Routledge, London, 1990. pp. 217-242.

¹⁶ Schuster, John. 'L'Aristotelismo e le sue Alternative', in *La Rivoluzione Scientifica*. Edited by D. Garber. Istituto della Enciclopedia Italiana, Rome, 2002, pp.337-357. [An English translation 'Aristotelianism and its Alternatives' is available on my website: <http://descartes-agonistes.com>.] See also Chapter 2, of Schuster, J.A. *Descartes-Agonistes: Physico-mathematics, Method and Corpuscular-mechanism 1618-1633*, Springer, Dordrecht, 2012, in press.

¹⁷ Put another way, natural philosophy was not one theory of nature, but rather a long-lived, continent-wide institution-cum-field of discourse that contained various systematic and piecemeal claims about the knowledge of nature.

Between 1590 and 1650, alternative natural philosophies corrosive [177] of Aristotelianism proliferated. In the critical early to mid seventeenth century, we see a set of transformations, what I have termed a civil war, inside the contested culture of natural philosophizing. The hegemonic neo-Scholasticism of the Reformation and Counter Reformation was challenged intellectually and organizationally. By the third generation of the Seventeenth century the cultural dominance of Aristotelianism collapsed. The mechanist philosophy of nature, in several variants, became the dominant form, and after a period of consolidation and institutionalization, in latter third of the seventeenth century the mechanical philosophy was modified and partly displaced by the post-mechanist philosophy of Newton.¹⁸

Everything important we see in nature knowledge-making and -breaking initiatives in this period played out inside this turbulent culture of natural philosophizing, not outside or over against it. Let me illustrate how this field and process model works in the case of mathematization.

First of all, mathematical sciences already existed, having passed from Hellenistic times right down to the early Modern. In the Schools, these disciplines – hydrostatics, statics, geometrical optics, geometrical astronomy and harmonics – were termed the mixed mathematical sciences. According to Aristotelians, these disciplines used mathematics not in an explanatory way – that is, to explore the natural philosophical categories of matter and cause – but rather instrumentally, to facilitate problem solving.

What happened in the seventeenth century happened inside, not against the field of natural philosophizing: certain natural [178] philosophical radicals, with good mathematics credentials, made moves under a banner that some of them enunciated, and which we can adopt as an historiographical category as well, to wit, “physico-mathematics.” This denoted a commitment to radically revising the conventional Scholastic Aristotelian view of the mixed mathematical sciences as subordinate to natural philosophy, non-explanatory and merely descriptive. The mixed mathematical disciplines were somehow to become more intimately related to natural philosophical issues of matter and cause. Paradoxically – and this is very important – physico-mathematics was not about the mathematization of natural philosophy. Rather the mixed mathematical sciences were to become, as I have taken to saying, more “physicalized,” more closely integrated into natural philosophizing, regardless of which species of natural philosophy the physico-mathematician endorsed.¹⁹ Kepler, Galileo, Descartes and other early seventeenth century figures worked in this manner. This was not the *de novo* invention of “science” by peculiar geniuses, but a turbulent process within an already existing social institution – natural philosophizing. The mathematically adept “physicalisers” were bending the rule, taught in the Schools, about where mathematically

¹⁸ Schuster, ‘The Scientific Revolution’ [Note 15]; Schuster J. A. and Watchirs, G. ‘Natural Philosophy, Experiment and Discourse: Beyond the Kuhn/Bachelard Problematic,’ in *Experimental Inquiries: Historical, Philosophical and Social Studies of Experimentation in Science*. Edited by. H. E. Le Grande. Kluwer, Dordrecht, 1990. pp 1-47. Schuster, J.A.. ‘What was the relation of Baroque culture to the trajectory of Early Modern Natural Philosophy?’, in *Science in the Age of the Baroque*. Edited by O. Gal and R. Chen-Morris, *Archives internationales d’histoire des idées* 209 (2012) pp. 1-35.

¹⁹ Gaukroger S. and Schuster, J. A. ‘The Hydrostatic Paradox and the Origins of Cartesian Dynamics’, *Studies in the History and Philosophy of Science* 33 (2002) pp.535-572. On the issue of physico-mathematical initiatives in optics see Schuster, J.A. ‘Physico-mathematics and the search for causes in Descartes’ Optics—1619-1637’, *Synthese* 185 (2012), pp. 467-499. [Published online 2011, DOI 10.1007/s11229-011-9979-4.] This issue of *Synthese* also contains papers on Kepler’s physico-mathematical approach to optics by Sven Dupré, Ofer Gal and Raz Chen-Morris. The discovery of the physico-mathematical style of these early seventeenth century opticians throws an interesting light on the older claims of Crombie concerning the import of optics in the rise of modern science, cf. above Note 10. Physico-mathematics forms a major theme in Schuster, *Descartes-agonistes* [Note 16 above].

based disciplines sat *vis à vis* natural philosophy. This was a radical challenge, not to displace natural philosophy but to change it. As mentioned earlier, similar arguments can be made about the emergence of experimental approaches inside natural philosophy. [179]

Returning to the big picture, from 1650 the culture of natural philosophizing continued to evolve under internal contestation, and external drivers. Regions of the field fragmented into more modern looking, science-like, disciplines. By the mid to late eighteenth century it is fair to say that the five hundred year old institution of European natural philosophizing was dead, replaced by a galaxy of successor disciplines, some physico-mathematical, like classical mechanics and physical optics; some experimental like electricity and the science of heat. All had emerged from within the natural philosophical contestation of the previous century and bore its genealogical marks – in some of their concepts, and their questions about matter and cause – even as the answers multiplied and diverged.²⁰

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In sum, every important seventeenth century development occurred inside the continuing, contested life of the larger field of natural philosophizing. That there was this larger field in turn depended upon a High Medieval development of world historical import: the establishment of a European system of universities, all teaching variants of Christianised Aristotelian natural philosophy. Whether in the fourteenth century or the seventeenth, a Scholastic Aristotelian university education taught that nature has a coherent, systematic unity and that correspondingly systematic knowledge about it – about matter, cause and cosmos – can be obtained. This template also applied to all jostling species of natural philosophical challengers to Aristotelianism. The Medieval Catholic institution or culture of natural philosophizing was unprecedented. No previous society that had similarly been heir to classical sciences and philosophy achieved [180] this: not Hellenistic culture, nor Roman, nor Islamic.²¹ The Medieval natural philosophical set-up did not, and could not, produce modern science; but it was an absolutely necessary condition for that happening later. Not sufficient, but absolutely necessary.

Necessary causes are very important, especially if they continue to exist right through the process of change being explained. Military historians will tell you that the Roman Army provided a necessary but not a sufficient exemplar for all modern European armies.²² Evidence about the exemplar was picked up and reinterpreted in the seventeenth century after a long hiatus. In the history of European nature knowledge, there was no hiatus, once the unprecedented, continent wide, university based system of Christianized natural philosophizing was created.

The institution of natural philosophy, and its rules of claim formation, continued as present realities right through the eventual period of intense change that began around 1600. The culture and institution of natural philosophizing was both the locus and target of all the changes that began around 1600. But it was not the endogenous source of all those changes. What needs explaining are what I call the solvents and catalysts for the increased turmoil and

²⁰ Schuster and Watchirs, 'Natural Philosophy, Experiment and Discourse: Beyond the Kuhn/Bachelard Problematic' [Note 18 above]; Schuster, 'What was the relation of Baroque culture to the trajectory of Early Modern Natural Philosophy?' [Note 18 above]; and Schuster, 'The Scientific Revolution' [Note 15 above].

²¹ Cohen H.F. *How Modern Science Came into the World: Four Civilizations, One 17th-Century Breakthrough*, Amsterdam University Press, Amsterdam, 2010. Cf. my essay review of Cohen, Schuster, J. A. 'The European Birth of Modern Science: An Exercise in Macro and Comparative History', *Metascience* (2012) in press [published on-line, March 2012: DOI 10.1007/s11016-012-9645-6].

²² Keegan, J. *A History of Warfare*. Vintage, New York, 1994. pp.263-281.

contestation within the natural philosophical field in the early modern. They include, first and foremost, the Reformation and Counter Reformation, which entrenched neo-scholastic Aristotelianism even further, on both sides, whilst heating up natural philosophy/theology relations. The medieval “space” between theology and natural philosophy narrowed dramatically, stimulating mutually irritating contestation in both realms at the same time that consensus became impossible. Copernicanism [181] was fed into this mêlée; not as an instrumental calculating device, but by effective physico-mathematicians, who took it realistically (that is “physico-mathematically”) as a natural philosophical challenge about the organization of matter and cause in the cosmos. Aristotelianism could not accommodate this; the field was liquefied and raised to boiling temperature.²³ The rise of practically oriented mathematicians and masters of the other practical arts was a function of state formation, warfare and commercial capitalist developments. (The Marxists had been half right, as historians of science of various stripes have long suspected.) But, the key thing is that some men of practice had higher, natural philosophical, aims, and some natural philosophers, trained within but now outside the universities also saw tools and rhetoric to be recruited into the field from these developments. Bacon, Descartes, Galileo, Beeckman, Gilbert – all the critical early seventeenth century players – show these traits, *qua* natural philosophers.²⁴ They all wanted “regime change” in natural philosophy, not its total destruction. The Scientific Revolution is best understood within a sharpened and refined model of what the field or culture of natural philosophizing was all about.

To conclude, let me first say that I have tried to exorcise some of the secularist, scientific and naively progressivist assumptions made about Medieval science by Crombie and Duhem. Such historiographical assumptions, I believe, much exercised Christopher [182] Dawson when contemplating the history of the West. So, I find myself more like Dawson than even his explicitly Catholic contemporaries in the history of science, although those contemporaries are amongst my own specialist disciplinary ancestors. Hence, I can underscore my central theme by pointing out the following: this paper originally had a subtitle: *How New Thinking about the seventeenth Century Scientific Revolution Points the Way to Re-thinking the Formative Role of Medieval Catholic Natural Philosophizing, and its Institutions, in the Process of the Scientific Revolution*. That captures what I have tried to do, as, finally; does this aphorism:

The High Medieval system of natural philosophizing was historically unique; that system could not of itself have produced the modern sciences; but, the modern sciences emerged from that system—indeed from within it, given the requisite but contingent catalysts.

²³ In my model of natural philosophy as a field of contestation and institution, I use the term ‘hot spot’ [in the field] to denote the controversy and turmoil of the Copernican debate and similar but smaller processes inside the domain of natural philosophizing. See Schuster, ‘What was the relation of Baroque culture to the trajectory of Early Modern Natural Philosophy?’, pp. 15-16 [Note 18 above]; and Schuster, *Descartes—agonistes*, pp. 59-62 [Note 16 above].

²⁴ The best and earliest post-Marxist statement of these sorts of points was contained in Rossi, Paolo. *Philosophy, Technology and the Arts in the Early Modern Era*. Harper and Row, New York, 1970.