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What Was the Relation of Baroque Culture to the Trajectory of Early Modern Natural Philosophy?

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Abstract

This paper attempts to answer the question posed in its title, by focusing attention on the institution and contested field of discourse of natural philosophy, and its processes of change in the early and mid Seventeenth century. Following the seminal work of José Antonio Maravall, Baroque culture is taken as a set of concerted responses to a wide religio-political crisis. The paper then argues that this period saw a veritable 'crisis within a crisis' occurring in natural philosophy and its cognate and subordinate disciplines, with recruitment of 'Baroque' aims, styles and rules of contestation into natural philosophy by competing players. It is also suggested that some of these Baroque 'cultural genes' survived in the subsequent history of natural philosophy, and thence, following its disintegration, into the social dynamics of the emergent modern sciences, shaping their agonistic natures.

1. Introduction Thinking about "Baroque Science"

There are three broad options available for approaching the question, "What, if anything, were the relations between the Baroque and (the process of) the Scientific Revolution?" [1] With historians of fine art, music, literature and architecture, one could define Baroque style and trace its expression across creative domains including natural philosophy and the sciences. [2] With social and political historians in the manner of, say, Carl Friedrich, one could delineate a social or cultural period as Baroque, so that concrete relations might be delineated between this cul-

ture and contemporary natural philosophising.[1] The idea would be that in a culture or social formation more than artistic expression is at stake—for example, forms and norms of social interaction, resources for self-understanding and public expression by actors, organisational forms and styles, any of which might affect natural philosophy and its subordinate sciences. [3] One could try to show that there is something importantly Baroque about the end product[s] of the Scientific Revolution, in modern science as a whole, perhaps.

It is fair to say that the Baroque Science Project—as conceived by the Editors of this volume and exemplified in their Introduction and respective substantive contributions—offers novel findings along all three of the above options (provided that one does not see option [1] in terms of surface stylistic analogies, but rather in terms of commonalities at deeper epistemic and cultural grammar levels. This paper is more limited in scope. It explores possibilities in option [2], based on the belief that the Scientific Revolution was a complex process of change played out within the domain of natural philosophy and its subordinate sciences. Hence, whatever one might mean by Baroque 'science' or a Baroque shaping or influence on science needs to be found by exploring the structure and dynamics of natural philosophising, whilst simultaneously exploring what was Baroque culture. This also means that this paper concerns a much shorter time segment than the Editors take into view. It deals with the second and third generations of the Seventeenth century, where many scholars locate both the climax of Baroque culture and a moment of intense competition and turbulence within the realm of European natural philosophising—the problem being precisely what relations, if any, existed between the two. (Nevertheless, in the penultimate section of this paper we shall also uncover a possible larger meaning for Baroque science, along the lines of option [3], but only after the main argument has been set out.)

It should also be noted at the outset that this paper is experimental. It was conceived and written in response to the challenge and problematic of the Baroque Science Project, and, as will be seen, its structure and argument depend upon accepting and articulating further certain conceptions current in parts of the literatures on the Scientific Revolution and general Seventeenth century intellectual history. I take this paper as a beginning and a spur to myself and others, not as a definitive statement. That is the spirit in which earlier versions were presented at conferences and workshops of the Baroque Science Project variously held under the auspices of the Editors at the University of Sydney between 2006 and 2009, and that is the manner in which drafts of the paper have been read and constructively criticised by participants therein, and by other colleagues.

In keeping with its exploratory tenor, the first thing question needing to be addressed about the structure of this paper is this: How to deal with existing conceptions of Baroque culture and that old chestnut, a 'general crisis of the Seventeenth Century'? This is because attempts to speak about a Baroque cultural or social epoch are easily conflated with allusions to a 'general crisis'. Part of the problem is

1 Friedrich (1962)

that social historical discussions of the Baroque, such as Carl Friedrich's, do not address the issue of crisis on a sustained historiographical level, whilst crisis theorists use evidence about Baroque art, but do not deal with the Baroque as a social or cultural formation.[2] However, there is a way of working with a conception of Baroque culture, properly related to the turbulence we denominate by the term 'general crisis of the seventeenth century', and done in such a way that both issues can be related to the structure and dynamics of natural philosophy. The result may be some progress on the question, '*Is there any relation between 'the Baroque' and (the process of) the 'Scientific Revolution?'* For the sake of the experimental historiographical argument of this paper, our starting point is the profound work of José Antonio Maravall, in his *Culture of the Baroque: Analysis of a Historical Structure*.[3]

Maravall interprets Baroque culture as a largely deliberate program of culture, put forward, in slightly differing fashions in different states, by elite blocks of monarchical and aristocratic interests who perceived threats to status, social hierarchy, social order and religious orthodoxy from mainly urban 'middling' classes and groups, exercising resistance to political and religious centralisation and in favour of their own interests. This occurred under conditions, emergent in the later sixteenth century and heightening in the next, of urban population expansion and more readily available new communication technology, which helped create more acute and transmissible senses of both problems and of their possible subjection to human solution.[4] These and other phenomena he nominally packaged under the shorthand label 'general crisis'. Maravall is interested in what went into this manufactured, commodified culture product, and also in the lived experience of people born into/living in it, because, once it was widely established, of course, individuals lived and experienced their world through its forms and categories.

Thus, Maravall relates his interpretation of the Baroque to the idea of a general crisis of the seventeenth century, by making the former the overall unintended result of concatenations of particular, intentional elite responses to, or perceptions of, the latter. From the analyst's standpoint, Baroque culture for Maravall is what he calls an "historical structure", by which he means, a constructed interpretive framework taken to have real reference, which coordinates, explains and takes ac-

2 So, on the one hand, Friedrich mixed into his discussion of a Baroque 'age', culture or society, allusions to phenomena that may be taken as direct evidence of building crisis. Similarly, on the other hand, Theodore Rabb (1975) in his first of two sojourns into the territory of the general crisis, discussed Baroque art half a dozen times, but he never theorised the Baroque as an 'age', culture or epoch. Rabb's recent work, The Last Days of the Renaissance (2006) effectively does away with the term crisis. Instead, marshalling much the same evidence, he argues for an early seventeenth century phase of turbulence within, and inflection of, various 'Renaissance' structures and processes, leading to different conditions in the later seventeenth century.

3 I owe this reference to Simon Schaffer, who pointed out its potential relevance to the Baroque Science Project problematic in conversation October 23 2007. Schaffer was pointing to the possible relevance to my natural philosophy ruminations of Maravall's (1973) notion of kitsch, commodified, dramatic display, a staple of Baroque culture, as redeployed by Clark (1992) in relation to kitsch experimental displays in university teaching in late Baroque Germany.

4 Maravall, insists that there are generic properties of his interpretation applicable, with local national twists, to 'Baroque culture' as a pan-Western European phenomenon.

count of the relevant known phenomena and manifestations, and whose own trajectory is in turn historically explicable. At no point does Maravall claim that the general crisis of the seventeenth century is a similar sort of 'structure' He is saying that the best we can do is take appropriate and well documented types of turbulence and conflict in the period, the ones most likely taken notice of by Baroque actors, and *label* them the general crisis.[5]

Following Maravall's strategy, I will relate my interpretation of natural philosophy and the process of the scientific revolution to his interpretation of Baroque culture and the general crisis. I shall deal with natural philosophy as a model or "historical structure"; and, like Maravall, I shall *denote* turbulent, worrying phenomena by the term general crisis. In the case of natural philosophy, however, the term 'crisis' would denote a specified and evidentially supported phase or state of play in this specific sub-culture. Exploring the structure and dynamics of early modern natural philosophising and its attendant more narrow sciences, we find that the so-called Scientific Revolution falls into several stages. One of these, in the early to mid seventeenth century, had a particularly turbulent, 'crisis-like complexion'. Because this turbulent or critical period took place well within the space and time of Maravall's Baroque crisis this phase of natural philosophising constituted a 'crisis within a crisis'.

Thus, I aim to show by articulation of Maravall's approach, that there was an early to mid seventeenth century watershed crisis of natural philosophy inside the more general crisis. Natural philosophy did not become Baroque in any simple or straightforward sense. The impacts of the Baroque on natural philosophising; or, better put, the recruitments of Baroque culture into natural philosophising, will be approached by examining how the sub-culture or field of natural philosophising worked, and how its structure and dynamics led to, and were inflected by, this crisis phase in its own history. To these ends, we shall analyse the structure and dynamics of natural philosophy in Section 2, followed in Section 3 by a periodisation of the Scientific Revolution into stages in the evolution of natural philosophising and its attendant narrower, subordinate sciences. Then Section 4 will deal with the peculiarly turbulent and contested nature of natural philosophy in the crisis period, leading to our exploration in Section 5 of recruitments of Baroque culture into natural philosophising during that period. Finally, in Section 6, a further surprising finding will arise concerning the themes of this paper.

5 What Maravall takes to be included in his general crisis is very close in description, given social and state structure differences, to what Trevor-Roper long ago termed the 'crisis of court vs. country' in England. Similarly the trends in state structure, inter and intra state conflict, religious fission and warfare, and cultural pessimism that Rabb (1975) built into his crisis thesis, have chords and echoes in Maravall's vision. The seminal papers by Hobsbawm ('The Crisis of the Seventeenth Century') and Trevor-Roper ('The General Crisis of the Seventeenth Century') on the crisis thesis first appeared in Past and Present and then were reprinted in Aston (1967) pp.5-95.

2. Constructing the Category of Natural Philosophy—Natural Philosophising as Culture and Process

To inquire about the 'Scientific Revolution' and 'the Baroque', we need both to formulate our key categories and to design a workable periodisation concerning the trajectories traced by the entities and processes those categories arguably denote.

In the early modern period the central discipline for the study of nature was natural philosophy.[6] In the first instance natural philosophy is an actor's term, but, if we metaphorically treat natural philosophy as an *iceberg*, actors' usages are merely the tip. We must also theorise the bottom of the iceberg, by modelling the structure and dynamics of the game of natural philosophising, including points that did not or could not have been known to the players. So, I model Early modern natural philosophy as a dynamic, elite sub-culture and field of contestation, theorising about its structure, dynamics and its process over time. [7]

When one 'Natural philosophized' one tried systematically to explain the nature of matter, the cosmological structuring of that matter, the principles of causation and the methodology for acquiring or justifying such natural knowledge.[8] **[Figure 1]** The dominant genus of natural philosophy was, of course, Aristotelianism in various neo-Scholastic species, but the term applied to alternatives of the various competing genera: neo-Platonic, Chemical, Magnetic, mechanistic or, later, Newtonian. Early modern natural philosophers learnt the rules for natural philosophizing at university whilst studying hegemonic neo-Scholastic Aristotelianism. Even alternative systems followed the rules of this game. All natural philosophers and natural philosophies constituted one sub-culture in dynamic process over time.

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6 Peter Anstey and John Schuster, "Introduction" to Anstey and Schuster (2005) To place the evolution of natural philosophy at the centre of one's conception of the Scientific Revolution is not novel, and more scholars are realising the value of such a perspective, but neither is it obvious or agreed upon in the scholarly community. H. Floris Cohen's massive survey of the historiography of the Scientific Revolution (Cohen, 1994) illustrates that the term 'natural philosophy' has been endemically present in the literature, but not systematically theorised, often serving as a synonym for 'science'. Recent attempts to delineate the category of natural philosophy and deploy it in Scientific Revolution historiography include Schuster (1990, 1995); Schuster and Watchirs (1990); Andrew Cunningham (1988, 1991); Cunningham and Williams (1993); Peter Dear (1991, 2001); Peter Harrison (2000, 2002, 2005); and John Henry (2002).

7 The same historiographical strategy needs to be applied to other' terms such as, 'physico-mathematics', natural theology, mixed mathematics, method and natural theology (see Dr Larissa Johnson-Aldrige—Kaleidoscopic Natural Theology: The Dynamics of Natural Theological Discourse in Seventeenth and Early Eighteenth Century England, UNSW, unpublished dissertation, 2009). This strategy is applied throughout my forthcoming study of the young Descartes: Descartes Agonistes, Physico-Mathematics, Method and Mechanism 1618-33. Materials tending toward the findings of the latter are contained in Schuster (1995, 2000, 2005); Gaukroger and Schuster (2002).

8 Knowledge was not actually discovered and demonstrated by method—see Bachelard (1949), Kuhn (1970), Feyerabend (1975); Schuster and Yeo (1986); Schuster (1986, 1993) and others. Rather method discourse provided universally understood packaging and rhetorical framing for claims of natural philosophical type, and by means of the tools of logic provided natural philosophical players, as subjective agents, the technical capability for reflexively criticising, comparing, overthrowing and radically reworking the claims of others and of themselves.

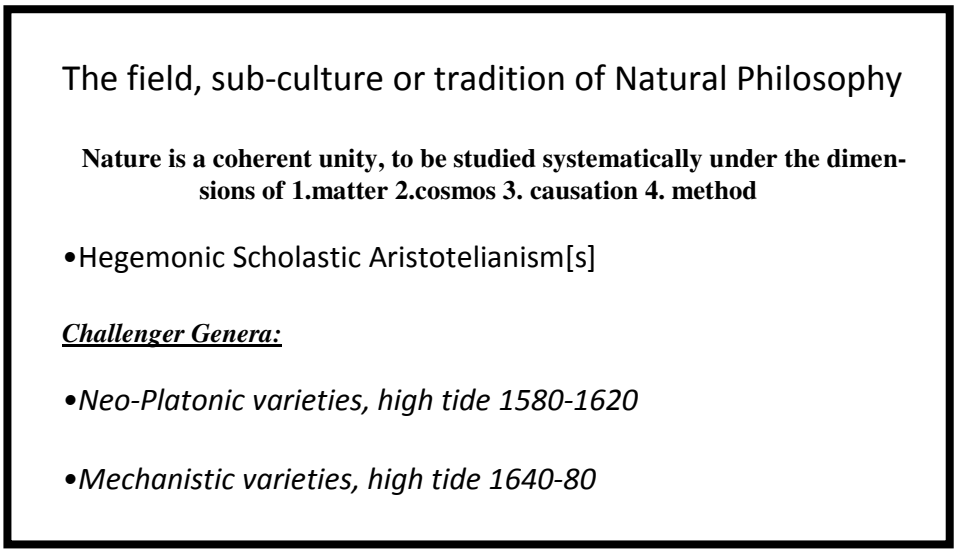

Figure 1: Natural Philosophy—Generic Structure, Competing Genera

We should not simply 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.[9] At its climax in the early and mid seventeenth century—during the 'crisis within a crisis'—the Scientific Revolution was a set of transformations, a civil war, inside the seething, contested culture of natural philosophising. That culture continued to evolve under internal contestation, and external drivers, and variously elided and fragmented into more modern looking, science-like, disciplines and domains, plural, over a period of 150 years from 1650.[10]

That there was a European culture of natural philosophising depended upon a High Medieval development of world historical import—the establishment of a European system of universities all teaching variants of a Christianised Aristotelian corpus in logic and natural philosophy.[11] This fact continued and evolved into

9 Schuster and Taylor (1996, 1997); Schuster (2002).

10 Other contemporary knowledge systems, such as natural history and natural theology also need to be theorised in this manner and the entire set examined for their dynamics and articulations over time. I have written several overviews of the Scientific Revolution in this style. Schuster (2002), also Schuster and Watchirs (1990); and Schuster (1990). Recently the latter work was translated into Chinese and published for the Chinese HPS market in an anthology on the Scientific Revolution edited by Liu Dun and Wang Yangzong (2002), pp.835-869.

11 David C. Lindberg, for instance, asserts that "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." Lindberg (1992) p.212.

the early and mid seventeenth century.[12] Although specific concepts constitutive of Scholastic Aristotelianism were displaced during the seventeenth century, this occurred inside the continuing, contested life of the larger field or tradition of natural philosophising.

A Scholastic Aristotelian education taught that nature has a coherent, systematic unity; that nature not only can be studied by specific means but that correspondingly systematic knowledge of it can be obtained.[13] This template for natural philosophising also applied to all jostling species of natural philosophical challengers to Aristotelianism. Additionally, Scholastic Aristotelianism framed the way in which other disciplines were conceived, and related to each other, and to natural philosophising. The positioning of natural philosophical claims in relation to other enterprises always involved two routine manoeuvres: the drawing and redrawing of boundaries and the making of linkages.[14] This created the 'objective field of possible moves' in which natural philosophers carried out their own specific systematising and linking strategies—claiming new linkages or defending older ones—depending upon their respective aims and skills.[15]

One may think of the subordinate disciplines as an *entourage* of more narrow traditions of science-like practice: **[Figure 2]** These included the subordinate mixed mathematical sciences, as well as the bio-medical domains, such as anatomy, medical theorising and proto-physiology in the manner of Galen. The members of this entourage changed over time. In the seventeenth century, some were disputed; some were created; all changed; new or revamped entourage members evolved.

12 Concerning late scholastic education at the turn of the seventeenth century see Maclean (2007) and Des Chene (1996): Following their work, I hold that most of what we conceive of as the process and the products of the 'Scientific Revolution' took place within patterns of change, internal contestation and contextual shaping in this evolving field or culture of natural philosophising.

13 Schuster (1990, 1995, 2002), Schuster and Watchirs (1990); Schuster and Taylor (1997)

14 Cf. Anstey and Schuster, 'Introduction' to Anstey and Schuster (2005). We shall refine the concept of boundary-work, including how we think about players' contestation about it, below in Section 4.5.

15 This manner of conceptualising a competitive creative 'field' of course derives originally from the seminal and suggestive work of Bourdieu (1971a, 1971b, 1975). Cf. below Notes 26 and 69.

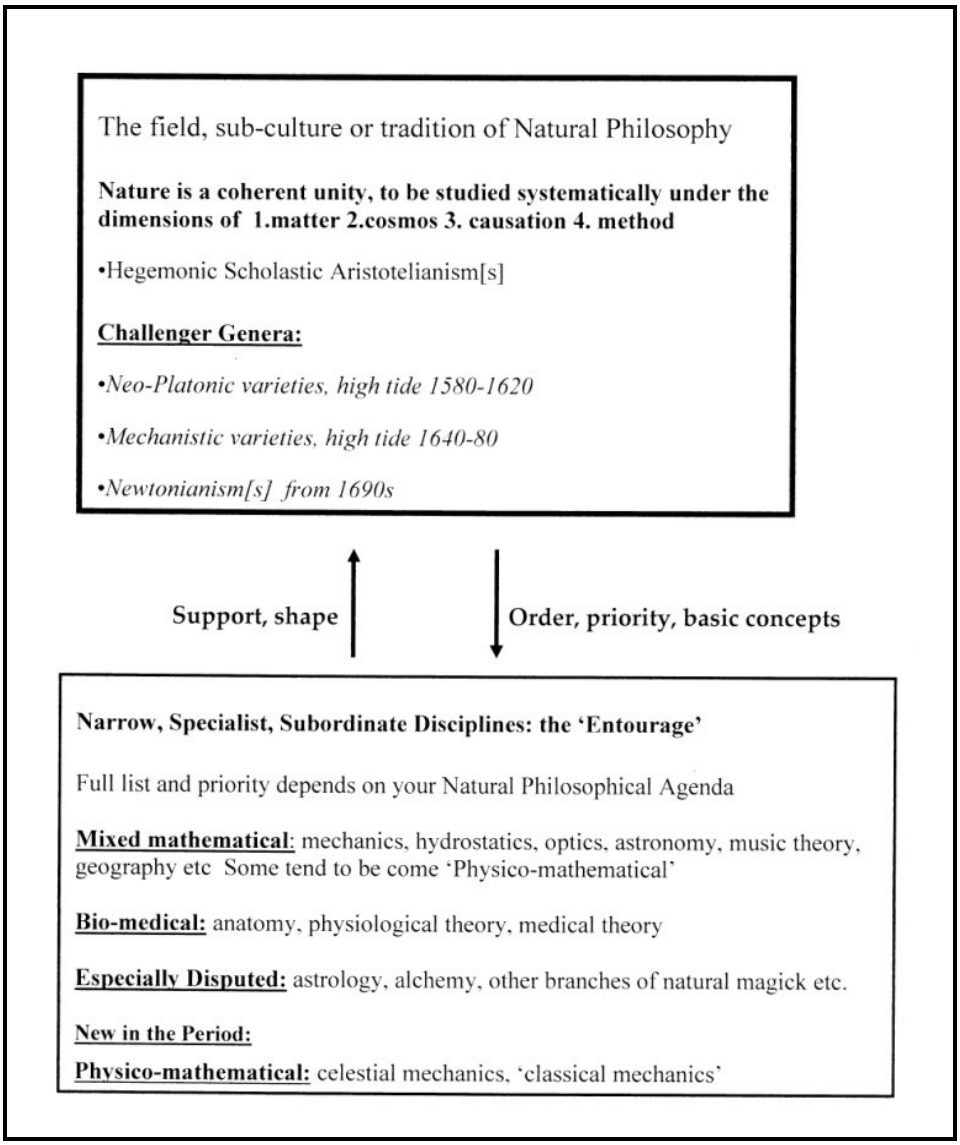

Figure 2: Generic Structure of Natural Philosophy and Possible Entourage of Sub-ordinate Fields:

In a given system of natural philosophy: (1) the particular entourage of subordinate disciplines lends support to and can even shape the system; while (2) the system determines the selection of and priority amongst entourage members, and imposes core concepts deployed within them.

Limitations of space prevent my detailing the five elements of theorising making up my model of the structure and dynamics of natural philosophy.[16] However, one dimension of the model, dealing with natural philosophy as a *dynamic and evolving sub-culture* needs to be mentioned. To explicate this notion, I invoke Marshall Sahlins' way of analysing cultures as dynamic historical entities in terms of their mechanisms of change and adaptation over time to exogenous and endogenous challenges. Developing an historical category of culture in anthropology, he argues that cultures display specificity of response to outside impingement; they are not simply imprinted upon or pushed around. The dynamics of response, over time, characterises the culture.[17]

Similarly my model of natural philosophising includes conceptualising it as a sub-culture, tradition or field in dynamic process—defined over time by the resultant of its players' combats over claims, where some claims involve attempts to respond culturally to variously perceived, and represented, contextual structures and forces, threats and opportunities. These moves are not determined by a universal logic, may express considerable novelty, but remain specific to the (evolving) culture. [18]

3. Phases and Stages in the 'Scientific Revolution' Seen as an Unfolding Process in the Field of Natural Philosophising

Let us consider a sketch periodisation of the flow and dynamics of natural philosophising. It marks out the central plot of the Scientific Revolution and will allow us to assess its relations with the Baroque.

The periodisation categories are: [19]

1. The Scientific Renaissance, 1500-1600.

16 The five theoretical dimensions of the model, are: [i] natural philosophy as intellectual tradition in the manner of post-Kuhnian science dynamics with a dash of Skinner; [ii] as competitive creative field (Bourdieu); [iii] as an evolving field of claims governed by rules of utterance, (Foucault); [iv] as an historically dynamic sub-culture of the larger culture (Marshall Sahlins); [v] and as a network of institutions, (Mertonian sociology as refracted through my work with Alan Taylor on the 'organisation of the experimental life' at the early Royal Society: (Schuster and Taylor 1996, 1997). These are developed in my current work in progress on "A Guide to Historiographical Technique and Pitfalls: The Scientific Revolution and Beyond".

17 Sahlins (1993) esp. pp. 25,15. "[Cultural orders] reveal their properties by the way they respond to diverse circumstances, organising those circumstances in specific forms and in the event changing their forms in specific ways. Here, then, in a historical ethnography—an ethnography that extends, say, over a couple of centuries—here is a method for reconciling form and function in a logic of meaning, for discovering the relatively invariant and mutable dimensions of structures….the currently fashionable idea that there is nothing usefully called 'a culture'—no such reified entity—since the limits of the supposed 'cultures' are indeterminate and permeable...paradoxically...misreads a cultural power of inclusion as the inability to maintain a boundary. It is based on an underestimate of the scope and systematicity of cultures, which are always universal in compass and thereby able to subsume alien objects and persons in logically coherent relationships." Shapin (1992) speaks of sciences as cultures in process in analogous ways.

18 On internalism/externalism, Schuster (2000a).

19 For more details, and somewhat varying emphases, see Schuster (1990, 2002) and Schuster and Watchirs (1990).

2. The Critical Period (or Natural Philosophical Crisis inside a Larger Crisis), 1590-1660.

3. The Period of Relative Consensus, Muting of Systemic Conflict, New Institutionalisation, and Incipient Fragmentation of the Field, 1660-1720. (Abbreviated as CMF Period below.)

The Scientific Renaissance displays in the subordinate sciences of the 'entourage', as well as in natural philosophy, many of the scholarly aims and practices which already characterized the treatment of classical literature, history and languages in earlier stages of the Renaissance. Established humanist practices of textual recovery, editing, translation, commentary and printing increasingly focused on the scientific, mathematical and natural philosophical heritage of classical antiquity.[20] These developments mark the first stage and essential pre-condition for the further process of the Scientific Revolution. There was a marked increase in the recovery, reconstruction and extension of the existing subordinate entourage sciences, the timing of which differed from field to field.[21] This took place amid the catalyzing influence of the pedagogical and philosophical assault on Scholastic philosophy; the reassertion of Platonising modes of thought which helped revalue mathematics as the key to knowledge; and the more general trend toward recasting the ideal of knowledge in the image of practice, use and progress, rather than contemplation, commentary and conservation.

In natural philosophy a wide and confusing array of non- or anti-Aristotelian approaches was made available through the recovery, assimilation and publication of alternatives. Outside of the universities, in princely courts, print house and workshops of master artisans, the literate practitioner and the practical intellectual could be set at odds with School philosophy and reach for rhetorical tools against it. 'Orthodox' Scholastic Aristotelianism, however, remained central to the education of all men, and even enjoyed renewed vigor throughout the sixteenth century.

The **Critical Period (or Phase of 'Crisis within a Crisis')** of the Scientific Revolution (roughly 1590-1650) saw a conjuncture unique in the history of pursuit of natural knowledge, whether in classical antiquity, medieval Islam or Renaissance Europe: On the one hand Kepler, Galileo, and Descartes led an accelerated conceptual transformation in the subordinate entourage sciences—optics, mechanics and astronomy as well as the cognate, mathematics. On the other hand, in natural philosophy the tendencies corrosive of Aristotelianism took on greater urgency. There was heightened, often desperate competition amongst systematic natural philosophies (some tied to utopian and irenic programs of religious, social and intellectual reform), issuing in the construction and initial successful dissemi-

20 Schuster 1990; Dear, 2001a, chap 2; Gaukroger, 2006, pp.139-48; Eisenstein, 1979, vol 1.

21 In mathematical astronomy the Renaissance phase is discernible from the late fifteenth century with the work of Peurbach and Regiomontanus, whilst in mathematics and geometrical optics the pace of the Renaissance phase only accelerates in the later sixteenth century In geometry this development included not only improved texts and commentaries on Euclid's Elements, but the recovery, translation and edition of the texts of higher Greek mathematics, of Apollonius, Archimedes, Pappus, and most importantly for the further maturation of algebraic thinking, the work of Diophantus, Anatomy and medical theory followed more closely upon astronomy, the programme of editing and publishing the complete body of Galen's works culminating in the 1520s and 30s. (Schuster 1990)

nation of the mechanical philosophy. The Renaissance themes of the re-evaluation of practical knowledge and the desire for domination of nature sounded now more urgently and in a new key, as figures such as Bacon and Descartes systematically assimilated them to natural philosophical programs.[22]

Out of this proliferation and climactic struggle amongst advocates of competing systems there emerged varieties of mechanical philosophy. By the mid-seventeenth century the cultural dominance of Aristotelianism collapsed (although it continued supreme in most universities for another generation). The mechanical philosophy, in several species, became the dominant genus. Hence my image of a 'civil war in natural philosophy', with multiple regime change: from Aristotelianism to mechanism, which had averted a threatened neo-Platonic take over.

This is precisely where the change in natural philosophy needs to be linked to the 'general crisis of the seventeenth century' and its heightened political, religious and intellectual turmoil. Following Maravall's strategy, we place the turbulence and contestation within the field of natural philosophising within the larger crisis. Educated men with natural philosophical interests recognised an imperative to find, and install, the 'proper' system of natural philosophy, because it was widely believed that the 'correct' program for natural knowledge would *ipso facto* provide needed support for 'correct' religion, as well as a set of directives for improvement of the moral and practical aspects of life. This powered the proliferation of alternative programs to Aristotelianism, and shaped the emergence of mechanism out of the competitive turbulence thus created. The stakes—political, moral and religious—inside the natural philosophical field were high.[23] That there was no consensus on 'correct' religion casts a poignant light on this struggle and explains its intensity, as well as, to some degree, its lack of closure.

The following **'CMF' Period** (1660-1720) is distinctive for the muting of public systematic contestation, especially in the new 'scientific' institutions; for the widespread acceptance of loosely held varieties of the mechanical philosophy; and for the endemic melding of these variants to Baconian rhetoric of method and ex-

22 Rossi (1970); Ravetz (1975); Schuster (1990). The latter two build on the richly suggestive early thesis of Lenoble (1943), while taking their cues about the turbulence in wider intellectual circles from Popkin (1964) and Rabb (1971). More recently, the idea of a crisis period in the gestation of modern science has been articulated in great detail by H. Floris Cohen (2010), pp. 403-440. His long awaited study offers a tightly argued diachronic model of multiple overlapping and interacting 'transformations' in European nature-knowledge, flowing forward from an initial set of crucial transformations in the generation of Galileo, Kepler, Bacon and the younger Gassendi and Descartes. This initial movement broke with a 'Renaissance' phase of development, which had not yet displayed strong indications of reaching beyond what similar recoveries of classical natural philosophy and mathematics had achieved in medieval Islam or late medieval Europe. A crisis of legitimacy immediately ensued, in the middle decades of the seventeen century. Cohen traces this crisis in several dimensions within the realms of natural philosophy and the subordinate fields, rather than seeing it, in the manner of Rabb and Popkin, as a larger cultural crisis with an epiphenomenal echo in 'Science'. According to Cohen's account, this crisis momentarily threatened to abort any significant further development. However, it was contingently if sufficiently overcome to permit Cohen's subsequent waves of transformation to eventuate. Thus, Cohen's new model of the Scientific Revolution, reflects and further articulates the idea of a pivotal moment of crisis in the process (as well as the conception of a 'Renaissance' phase in the process).

23 The founders of mechanism hoped to resolve the conflict of natural philosophies in a way which was to them cognitively progressive, but religiously and politically conservative. Accordingly, mechanism was neither the finest fruit of detached, rational 'modern' thought finally asserting itself to end 'the confusion', nor was it simply or directly, the reflection of some long rising merchant, administrative or craftsman-technologist groups, who for some contingent reason invented mechanism between 1630 and 1650. (Schuster 1990)

periment.[24] Under this new, looser umbrella of natural philosophical commitments a 'research' primacy was granted to new (rather than co-opted) experimentation. Natural philosophers found themselves doing some of their natural philosophising within the confines of new institutions in ways advantageous to them in institutional *and* natural philosophical terms. These institutions were additional nodes in the Europe wide field of natural philosophising, not the exclusive ones, and, they were not incubators of an essentially new, unified Science, replacing a natural philosophising supposedly barred from their precincts.[25]

The ironic upshot of the 'civil war in natural philosophising' was that, on the one hand, the entire field of natural philosophising became more autonomous of other cultural forms such as theology, as well as other branches of philosophy, whilst, on the other hand, it began a long process of fragmentation into a number of more modern looking, semi-autonomous, diverse and narrow special domains or disciplines of natural inquiry, which begin to look like sciences in our modern sense.

4. The Dynamics and Rules of Natural Philosophical Contestation During the 'Crisis within a Crisis' Phase

Our overview of the three phases has prepared us to anatomise the types of natural philosophical contestation and competition prevalent during the critical or crisis phase of the scientific revolution. This will allow us to focus on how some Baroque norms, modes of behaviour and identity formations may have been recruited into the natural philosophical struggle during the 'crisis within a crisis' phase.

We begin by noting what amounts to an objective condition of the field:[26] that virtually all natural philosophical utterance, by any player, was ultimately referred back to a template initially learned through neo-Scholastic training in Aristotelian natural philosophy. Superimposed upon this in the critical period was the fact that Scholastic Aristotelianism provided the target of strategies of displacement, whilst competition amongst members of different broad genera of natural philosophising—Aristotelian, neo-Platonic, Magnetic, qualitative atomistic, and finally

24 As to Newton, I hold that we misunderstand the rhythm of the development of early modern science by focusing too intently upon Newtonian celestial mechanics and physics. Our periodisation, focussing on the trials of natural philosophy, should take this into account, seeing the process in terms of three phases or moments, punctuated, contingently by Newton, rather than aiming for him. See Schuster and Watchirs (1990), Schuster (1990).

25 For the claims in the second half of this paragraph and their wider historiographical implications: Schuster (2002), Boschiero (2007), Schuster and Taylor (1997); Schuster and Watchirs (1990).

26 The term 'objective' is used here in the sense of Bourdieu (see above, Note 15 and below Note 69), whereby we denote the (model-derived) organisation and dynamics of a competitive field, existing above and beyond the immediate control, or even necessarily the understanding, of actors in the field, and not capable of being instantly or unilaterally modified by the actions of such players in their respective micro contexts. These notions may be related back to the 'iceberg' metaphor offered earlier.

mechanistic—also heated up.[27] We can model the dynamics of this increased contestation, thus elucidating the rules (negotiable of course) of such engagement.

4.1. Articulation on Subordinate Disciplines: Grammar and Specific Utterance

The existence of a field of natural philosophising and its entrenched Aristotelian templates was a 'grammatical' given. However, individual natural philosophers had differing interests and skills within the *entourage* of subordinate disciplines. Each natural philosopher, even Scholastic Aristotelians, had to set priorities amongst entourage members and link them conceptually to his natural philosophy, creating a characteristic linkage pattern. The practice of a subordinate discipline under the aegis of a particular genus of natural philosophy was colored by the nature of that conceptual linkage. The upshot was, metaphorically speaking, a dialectic of grammar and particular utterance, which becomes especially interesting to examine under conditions of heightened contestation amongst the players, as in our critical period.

Consider the mixed mathematical fields, under Aristotelianism, where they were considered to be intermediate between natural philosophy and mathematics and subordinate to both.[28] For example, for Aristotelians, the investigation of the physical nature of light would fall under natural philosophising, an issue of invoking appropriate principles of matter and cause. In contrast, the mixed mathematical science of geometrical optics studied ray diagrams, in which geometrical lines represented rays of light, and phenomena such as the reflection and refraction were dealt with in a descriptive, mathematical manner, which was, according to

27 It has been obvious since Lenoble's (1943) work that families of natural philosophies competed in respect of the values, aspirations and religious resonances they endorsed and condemned; see also Rattansi (1963. 1964) and Easlea (1980). The fact that natural philosophy had that entourage of subordinate, more narrow traditions of science-like practice however, resulted in a much fiercer competition and contestation than even the traditional literature suggests. The situation was actually more like every man for himself, as natural philosophers of similar genealogical stripe—neo-Platonic, proto or emerging mechanist, 'magnetic', or chemical—competed with each other as well: Kepler vs. Fludd; Descartes vs. Gassendi vs. Hobbes; Libavius and other latter day Paracelsians vs. the heritage of Paracelsus himself.

28 The term 'mixed mathematics' was used by Scholastic Aristotelians to refer to a group of disciplines intermediate between natural philosophy, which dealt with those things that change and exist independently of us, and mathematics, which deals with those things that do not change but have no existence independently of us, since numbers and geometrical figures have (contra Plato) an existence only in our minds. (Aristotle, Metaphysics Book E.) A physical account of something — such as why celestial bodies are spherical — is an explanation that works in terms of the fundamental principles of the subject matter of physics, that is, it captures the phenomena in terms of what is changing and has an independent existence, whereas a mathematical account of something — such as the relation between the surface area and the volume of a sphere — requires a wholly different kind of explanation, one that invokes principles commensurate with the kinds of things that mathematical entities are. (Aristotle Posterior Analytics, 75a28-38; Cf. 76a23ff and De caelo 306a9-12.) In the De caelo, 297a9ff, for example, we are offered a physical proof of the sphericity of the earth, not a mathematical one, because we are dealing with the properties of a physical object. In short, distinct subject matters require distinct principles, and natural philosophy and mathematics are distinct subject matters. However, Aristotle also recognises subordinate or mixed sciences, telling us in the Posterior Analytics, 75b14-16, that 'the theorem of one science cannot be demonstrated by means of another science, except where these theorems are related as subordinate to superior: for example, as optical theorems to geometry, or harmonic theorems to arithmetic.'

Aristotle, incapable of providing causal explanations.[29] Thus the grammatically hegemonic Scholastic viewpoint dominated the question of the relation of mixed mathematical fields to natural philosophising. However, as the competition amongst differing approaches to natural philosophy heated up in the early seventeenth century, some natural philosophers hostile to Aristotelianism proposed a more central explanatory role for mathematics in natural philosophy, and some sophisticated Scholastic Aristotelians began to loosen the Aristotelian marginalisation of mathematics as non-explanatory. A competitive dynamics eventuated around attempts to bend the template, or 'declaratory', rules of subordination of the mixed sciences to Aristotelian natural philosophy.[30]

Similarly, in geometrical astronomy, the fine details and elaborate geometrical tools of Ptolemaic astronomy eluded plausible realistic interpretation, offering merely appearance-saving geometrical models, rather than natural philosophical explanations in terms of matter and cause. However, at a deeper grammatical level the fundamental concepts of Ptolemaic astronomy were shaped by Aristotelian natural philosophy: the finite earth-centered cosmos, the distinction between the celestial and the terrestrial realms, the primacy of uniform circular motion. Hence, there were some, albeit thin, linkages of a causal and matter theoretical nature that grounded Ptolemaic astronomy and linked it to its 'parental' Aristotelian natural philosophy. But, when Copernican astronomy became hotly debated in the later sixteenth and early seventeenth centuries, it was not as an instrumental predictive device, but as a system with realistic claims about the cosmos, implying the need for a non-Aristotelian natural philosophy, able to explain its physical workings.[31] This illustrates how the articulation of a subordinate field to one's brand of natural philosophy involved acceptance or bending of the template Aristotelian rules, and also dictated that the discipline in question be conceptually flavored in terms of matter and cause explanations derived from that favored natural philosophy.[32]

But, there was a more radical gambit in articulating a natural philosophy to a putatively subordinate field. An entire natural philosophy could be launched, or differentiated off from a broader genus, by borrowing its core conceptual and normative resources from a now privileged more narrow discipline.[33] Articulating

29 Cf Aristotle Physics, 194a10: geometrical optics 'investigates mathematical lines, but qua physical, not qua mathematical.'

30 The point of introducing the unusual term 'declaratory' will be become more clear in Section 4.3 below, where we see how certain natural philosophical rebels tried to renegotiate, rather than destroy, the formulations of these rules as they received them through their Scholastic Aristotelian educations into natural philosophy.

31 However, the articulation of a natural philosophy to a mixed science could be much looser than the Copernican example implies. As just noted, under Aristotelianism geometrical optics, virtually any natural philosophical theory of matter could have been used to provide an explanatory 'voice over' for this science. Only during the critical phase of the Scientific Revolution, in the optical work of Johannes Kepler and René Descartes, was there sought a closer interaction between optical theorising and problem solving, on the one hand, and natural philosophical explanations, on the other.

32 This operated at an individual basis, but over time, such moves could themselves aggregate and form patterns of largely unintended change in the subordinate disciplines in question.

33 What were constructed were still natural philosophies, within the common field of natural philosophising, but the Aristotelian limitations on the rules or terms of construction were being radically challenged and shifted. Beeckman's corpuscular mechanism keyed to a reading and amplification of dynamical interpretations of mechanics, as in the pseudo Aristotelian Mechanical Questions. Descartes' cor-

one's natural philosophy to a favoured interpretation of a favoured discipline invited counter moves, because natural philosophical opponents were stimulated to co-opt and 'sanitise' (of opposing natural philosophical valencies) the domain in question. In such strategic natural philosophical battles entire subordinate disciplines and their value structures were at stake.[34]

4.2. Find or Steal Discoveries, Novelties or Facts, including Experimental Ones

In the critical period there was competitive production of novel experiments and facts, accompanied by scrambles to co-opt and reinterpret others' claims, whether amongst nominal members of the same natural philosophical genus, or across such families. Note first of all that any given natural philosophy, was capable of stimulating new developments—discoveries of fact, production of new instruments or experiments—conditioned and shaped by the natural philosophy in question. Aristotelians continued to contend about experimental discoveries and instruments well into the middle of the seventeenth century. The novelties in Gilbert's work heavily conditioned by, and in turn affecting the shape of, his neo-Platonic natural philosophy are well known.[35] Similarly, Kepler's, optical, astronomical and celestial mechanical discoveries were shaped by his version of a neo-Platonic philosophy of nature.

The increasing imperative to pursue novelties and embed them within one's own natural philosophical agenda did not simply involve filling cabinets of curiosities. *To be important in the history and dynamics of natural philosophising, novelties had to be pursued and coveted within and for natural philosophical purposes.* Moreover, appropriation or negation was tactical: If a discovery or claim

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puscular-mechanism, surprisingly was keyed in part to the purely static mechanics and hydrostatics of Stevin (and Archimedes) much overlayed as it developed with material from his own 'physical' optics. (Gaukroger and Schuster, 2002; Schuster 2000; Schuster 2005)

34 So, versions of the Chemical philosophy depended for both technical and value orientation on the notion of a spiritualised yet practically productive alchemy, thus powerfully expressing moral-psychological aspirations—a search for redemption through esoteric knowledge and successful practice. These powerful sentiments were partially shared, and certainly co-opted in the programs of Bacon, Descartes and their later seventeenth century followers, for whom the nature and 'control' of alchemy was therefore a particularly strategic issue: The values and aims which Paracelsianism and later the Chemical philosophy invested in alchemy were co-opted, sanitised of radical political and religious resonances and made acceptable to intellectually progressive but socially conservative elites, a ready audience for the mechanical philosophy. Chemical phenomena were de-spiritualised and reduced to applied mechanistic matter theory, whilst the search for personal justification and social benefit would now be achieved through proper method and well grounded results, rather than esoteric insight and wisdom.

35 William Gilbert (1544-1603) in his On the Magnet (1600) suggested a new natural philosophical agenda and content, built on exploiting and metaphorically extending important experimental work he had done on the magnet and magnetic compass. Adopting neo-platonic notions such as the Earth's magnetic soul as an all-pervading spiritual power, he reinterpreted the craft knowledge and lore of miners and metallurgists, to argue that lodestone is the true elemental nature of the earth; that the earth is a gigantic spherical magnet; and that, since magnetic force is an immaterial force, the magnetic nature of the entire earth amounts to a cosmic soul or intelligence—capable of moving, or at least spinning the earth. Similarly, he insisted that his knowledge was productive of useful results, most notably improving the understanding and use of the magnetic compass in navigation.

was particularly significant in the architecture of a competing system, it had to be appropriated, down played, reinterpreted or neutralised.

For example, Harvey's ultra significant claims about the motion of the heart and blood became a target in an extended game of inter-systemic competitive football: Descartes was happy to appropriate Harvey's epochal, yet clearly Aristotelian based claims to the discovery of the circulation of the blood and motions of the heart, radically altering the latter (to the point of arguably contradicting it) to fit his mechanistic program in physiology. Within his radical Chemical natural philosophy Fludd endorsed the discovery of his friend Harvey, but invested it with mystical connotations that only aficionados of his natural philosophy could appreciate. The tactical cross fire thickened when Gassendi, a mechanist competing with Descartes, tried to refute Fludd's interpretation of the circulation, before going on to reaffirm, against Harvey (and Descartes) the Galenic pores in the septum of the heart on the basis of claimed first hand witnessing of anatomical facts! For Gassendi this *Galenic claim* vindicated the identity of venous and arterial blood, one of Harvey's central claims. Hence, with Harvey, Gassendi endorsed the 'anatomists' way' of firsthand experience, yet also preserved a key tenet of Galen, the 'physiology expert', whom both Harvey and Descartes were determined to displace.

In the critical period the players were happy to co-opt, and reinterpret, each others' claims. Symbolic capital was not assigned only to new matters of fact.[36] Borrowing and renegotiating facts and discoveries were endemic, because, and this is crucial, the contest was about systematic natural philosophical advantage, not the toting up unique, novel discoveries.[37]

4.3. Bend or Brake Aristotle's Rules about Mathematics and Natural Philosophy: The Gambit of 'Physico-mathematics'

It is often said that Kepler, Galileo, Descartes and others tried to 'mathematicise science'. These developments are better understood as products of contestation and renegotiation in one corner of the natural philosophical field, involving chal-

36 For example, Gassendi's observational claim only confirms Galen, and is subservient to the larger natural philosophical contestation in which he is involved.

37 Descartes' extended strategic encounter with Gilbert's work on magnetism illustrates all the above points. What was novel in Gilbert's experimentation was co-opted by Descartes without the addition of a single new experiment. For Descartes the nub of the encounter lay elsewhere. Gilbert's natural philosophical exploitation of the magnet was dictated by his concern to establish a novel system of Magnetic natural philosophy of distinctly neo-Platonic flavour and embodying and supporting a modified Tychonic cosmology. This was the 'significance' of the magnet work that had to be appropriated, reframed, and tamed to the imperatives of Descartes' program. Gilbert's natural philosophising of the magnet was too important and impressive a gambit in the natural philosophical field to be ignored by his natural philosophical competitors. Descartes' efforts were directed at re-glossing Gilbert's experimental work in mechanistic terms, rather than at extending the number and type of magnetic experiments.. He replaced Gilbert's story of the cosmos making and binding role of the spiritual magnetic force with a mechanist's story of an equally cosmic magnetism which was now the purely mechanical effect of a species of corpuscle of particular, and peculiar, shape and size, moving in and through suitably configured aggregations of ordinary 'third matter'.

lenges to the dominant Aristotelian template rules about how the mixed sciences should relate to natural philosophy. This problem involves our making use of the category 'physico-mathematics', which, like natural philosophy, is both an actors' term from the time, and a category to be historiographically fleshed out. Recall the examples we have seen in Section 4.1 of attempts to articulate geometrical astronomy and optics much more closely to anti-Aristotelian natural philosophies, bringing the matter and cause dimensions of the natural philosophy into play inside the target discipline. This is what one means by players attempting to render the mixed mathematical disciplines more physico-mathematical. It is not the *mathematisation* of natural philosophy, but the *physicalisation* (tighter natural 'philosophication') of disciplines Aristotelianism held to be merely instrumental and non-explanatory.

Outcroppings of 'physico-mathematical' initiatives began to appear in the sixteenth century, for example, regarding the natural philosophical status of mechanics.[38] The heightened natural philosophical contestation of the early seventeenth century intensified the proliferation, and competition amongst, physico-mathematical gambits, a number of which can be identified.[39] Physico-mathematicians (Galileo, Kepler, Descartes, Gilbert, Mersenne and Beeckman to name the usual suspects) hostile to Aristotelianism claimed that mathematics could play an explanatory role in natural philosophy. This demanded further articulated accommodation, between their respective innovations in the mixed mathematical sciences and their respectively favoured natural philosophies.

Consider how the traditional mixed mathematical field of geometrical optics developed 'physico-mathematically' inside the natural philosophical turbulence in the early seventeenth century: In their optical work Kepler (1604) and Descartes (1637) each sought closer articulation between optical innovation on the one hand and natural philosophical explanation on the other. New natural philosophical theories of matter and cause were taken more intimately to control technical details in geometrical optics, and in turn, technical details in geometrical optics exerted pressure on the exact nature of those natural philosophical claims about matter and cause.[40] Under such pressures geometrical optics evolved into a much

38 Hattab (2005), following Liard (1986), Rose and Drake (1971).

39 There were competing varieties of physico-mathematics, running from the conservative version of some leading Jesuits mathematicians [Peter Dear (1995)]; the more radical reading of the classical texts in mechanics — such as the statics and hydrostatics of Archimedes, or the pseudo-Aristotelian Mechanical Problems as part of or relevant to natural philosophy; through to the more innovative schemes of Kepler's celestial physics, a new physico-mathematical domain; Beeckman's linking of an emergent corpuscular mechanism to dynamical interpretations of the simple machines; Descartes' very radical attempts to ground a corpuscular-mechanism and determine the principles of its doctrine of causation (laws controlling force and determination of motion) through exploitation of hydrostatical and optical inquires of a physico-mathematical character; [Gaukroger and Schuster (2002), Schuster (2000, 2005)] and Galileo's sui generis new science of motion as well as his more piecemeal physico-mathematical excursions, identified by Dear.

40 Kepler practised geometrical optics under, a neo-Platonic natural philosophy and conception of light. (Lindberg, 1976) He got brilliant results in the theory of the camera obscura, theory of vision, and, to some degree, the theory of refraction and the telescope. Descartes emulated Kepler's technical optical achievements but abandoned the underlying neo-Platonic natural philosophical program. Instead he practised geometrical optics under his version of a mechanical conception of light. He achieved a simple and workable version

more 'physico-mathematical' discipline, in which innovating natural philosophers extracted natural philosophical capital out of optical work, whilst unintentionally there emerged at each turn a denser, relatively more independent domain of physico-mathematical optics—*a disciplinary area was crystallising as a function of being batted around in the natural philosophical ruck.*

Finally, it is useful to ask what it means to talk about players within the field of natural philosophy obeying, or bending 'rules'. The physico-mathematicians were rebels, but not in the sense of intending the destruction of natural philosophising, but rather attempting to renegotiate the rules of the natural philosophical game. So, by the first third of the seventeenth century, the given, template-derived rules about the status of the mixed mathematical sciences were the subject of an unprecedentedly vexed debate and a turbulent state of play.

4.4. "Hot Spots" of Articulation Contest: Additional Causes and Effects of a Field in Crisis

Just as the overall intensity and 'spatial' extent of contestation increased in the 'crisis within a crisis' phase of the Scientific Revolution, so new sites of inflammation of contestation appeared, which may be termed 'hot spots' in the field of natural philosophising. A dual process of change took place, involving, on the one hand, the target—the subordinate science, theory, instrument, novelty or discovery in question[41]—and, on the other hand, the natural philosophies contending to exploit the target. One example of a hot spot involved the claims of Harvey discussed above. Not only were they contested, and revised, by natural philosophical combatants for natural philosophical ends; but, over the next two generations, a domain of experimental physiological inquiry emerged at this site. Thus later seventeenth century English experimental natural philosophers investigated issues about 'cardiology', the functions of respiration, the blood, the lungs and the atmosphere.[42] A new, relatively autonomous domain of inquiry started to crystallise, as often happened from hot spots, although in this case it suffered a foreshortened and ultimately abortive trajectory.

The most important hot spot was located where astronomers and natural philosophers tried to articulate realist Copernicanism to natural philosophical claims. Copernicus himself, with his realist claims for his astronomical theory, had been *de facto* attempting what we can now discern as a 'physico-mathematical' move. His theory of astronomy had natural philosophical implications contradicting the

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of the law of refraction and a general theory of lenses. Conversely, as I have shown, essential details of Descartes' mechanistic system were shaped by his optical successes. Schuster (2000); Schuster (2005). See also Gal and Chen-Morris (2010)

41 Hence the salience of significant novelties and discoveries, immediately up for first time contestation in the field. As interesting novelties emerged across increasingly dynamic and interrelating subordinate fields, the struggles over them increased. Merely gazing at, or hording or collecting curious new facts may have been a popular pastime, but it was not central to the natural philosophical agon—contention about curiosities was!

42 Frank (1900), Anstey (2000).

prevailing Aristotelianism, and in effect demanding a systematic replacement of major components of astronomical practices and conceptual structures, although Copernicus himself offered nothing substantial along these lines. A hot spot developed in the natural philosophical field, between systematic natural philosophical theorising and the formerly relatively tame sub-ordinate mixed science of geometrical astronomy, only when some later players took Copernican realism more seriously for their own reasons and agendas.

Supporters of realist Copernicanism needed to adduce a framework of non-Aristotelian natural philosophy, a new theory of matter and cause, adequate to explaining the heliocentric cosmos. They bid to radicalise the grammar of relation between mixed mathematics and natural philosophical explanation. The entire late sixteenth and early seventeenth century debate over realist Copernicanism (culminating in Kepler's and Descartes' discourse of 'celestial physics') constituted an inflamed site within the natural philosophical field—no realist Copernicanism, no inflammation. But why be a realist Copernican unless you intend a quite radical overhaul of Aristotelian natural philosophy as such?[43] Furthermore, it was only in articulations of natural philosophy onto realist Copernicanism that the possibility of a 'physico-mathematical' astronomy arose, in the form of the emergence of a new domain, celestial mechanics, with Kepler and Descartes, [44] and the physicalisation of certain astronomical questions.[45] Not only was the old mixed mathematical science of Ptolemaic astronomy passing, but the very genus 'astronomy as mixed mathematics' was giving way to physico-mathematical problematics in astronomy and celestial mechanics.

43 The rhythm of this process is fascinating, and important. Copernicus staked his claims upon the truth value of 'cosmic harmonies' Copernicus himself was either too timid, or unprepared, to recast his astronomical theories in natural philosophical terms of cosmic matter and cause. Instead it was Tycho Brahe, who, toward the end of the century kicked off the eventual crisis of natural philosophy/astronomy articulation by linking his favoured version of quasi Copernican astronomy to significantly altered (Aristotelian) claims in natural philosophy. Gilbert weighed into the contest with arguably the most innovative natural philosophical vision of his generation. Then in short order Kepler subsumed his brand of Copernicanism within physico-mathematical explanations which in turn resided at the centre of his neo-Platonic natural philosophy. The situation was similar with Descartes, for in Le Monde he staked the truth of his natural philosophy on the truth of his version of a physically explained Copernicanism. (Schuster, 2005; Gaukroger 1995)

44 As I have shown elsewhere Schuster (2005), in his Le Monde, Descartes had a complex articulation strategy spanning astronomy, optics and a new challenging utterance in natural philosophy.

45 Such as: What is the nature of the earth as a planet— what can be gathered about the earth, for example, about its structure, its magnetism (Gilbert), its tides (Galileo and Descartes), the nature of local fall, that might support its construal as a planet amongst planets and allow for the motions Copernicanism required of it; what causes the celestial motions; what physical role does the sun (and all stars in multiple planet system versions of Copernicanism) play in those motions; does the nature and behaviour of comets throw any light on these problems, and so on. Jacqueline Biro has recently shown how sixteenth century technical developments in mathematical geography, which potentially had implications for such questions, were only grudgingly granted by the Scholastic Aristotelians, but eagerly seized as a resource by natural philosophers advocating Copernican cosmology, such as Copernicus, Gilbert, Bruno, Galileo and Descartes. (Jacqueline Biro, 2009).

4.5. The Mechanics of Responding to 'Outside' Challenges and Opportunities

We have focussed upon the critical or crisis phase in natural philosophising so that we can link it to the larger crisis of the age. Maravall constructed a model of Baroque culture, as a concerted elite response to the relevantly perceived aspects of the 'general crisis of the seventeenth century'. We, in turn, ask how the natural philosophical turmoil of the early and mid seventeenth century was shaped by players' responses to that same general crisis, and whether, in the process, elements of the then crystallising Baroque culture also were recruited into play in natural philosophy.

It is easy to cite testimony about the cultural, political, religious and identity desperation of the day as signs of a general crisis. [46] But, without a clear sense of how our object of study, natural philosophy, was affected by these larger circumstances, we have not illuminated the possible collateral shaping of 'natural philosophy in crisis' by the supervening Baroque culture. In modelling terms, that is, in terms of constructing historical categories and interpretative structures, this problem runs as follows: How should we think through the causal role[s] of features of a larger socio-political-religious crisis of the sort posited by Rabb and Maravall?

After two generations of development of methodological criticism from both the school of Quentin Skinner and the school of post-Kuhnian sociology of scientific knowledge, we cannot appeal to the 'influence' of ideas upon other ideas; nor can we revisit vulgar Marxism, wherein social and economic structures imprint corresponding constellations of ideas upon leading thinkers, who just happen to be cultural dopes.[47] However, our model of natural philosophising offers a solution. The way to deal with 'contextual drivers, shapers or causes of thought' is built into our model of a dynamic agonistic field or tradition, in which competing players deploy resources, and follow (or attempt to revise) rules of engagement, in order to construct claims. The modelling here follows Sahlins' conception of the historicity of cultural dynamics discussed above in Section 2, by extending the idea of natural philosophical players competing over articulations of their preferred natural philosophy onto subordinate fields. The players in the natural philosophical tradition responded to 'outside' or 'contextual' challenges and forces by deciding to bring them into play, inside the field, in the form of new claims, skills, material practices or values. The 'things' being brought in had to be represented by

46 Writing long ago, and dealing with opposite chronological ends of the period, Henri Pirenne (1936,—actually written whilst detained by the Germans 1916-17, Eng trans 1939) and Paul Hazard (1935, English trans. 1963) each captured poignantly the religiously centered critical desperation and life or death imperative to choice. Compare, for example, Pirenne p.583 on the later sixteenth century and Hazard p.221 on the later seventeenth; that is depictions respectively from early on in the presumed general crisis and near to its supposed close.

47 Nor do we want to follow intellectual history practice, for example, Popkin (1964) with his hypostatised, growing then resolved 'sceptical crisis', and simply give thick enough, untheorised descriptions so that a de facto and largely tacit explanation emerges something along the psychologistic lines of 'great thinkers somehow get it into their heads to address the great challenges hanging about in the cultural atmosphere, and hence their intellectual output somehow reflects or is shaped by them'.

actors in appropriate form—the arguably objective existence of contextual structures and processes that we model and explain did not cause, imprint or 'influence' thoughts about natural philosophy by natural philosophers. Rather, appropriately thinkable/writable representations of things about contextual structures and features were mobilised, used, reshaped and deployed in natural philosophical claims by players of the natural philosophical game.[48] I term these actions by actors 'the articulation of natural philosophical claims upon things at the boundary of the field' and I envision the process as described by Sahlins.[49]

Hence we are now talking about the shifting ways in which players accounted, acted upon, and competed over what they took to be the boundaries of the field at any given moment.[50] There were no fixed, essential boundaries of the field of natural philosophising; no permanent, consensual actors' account of what was inside natural philosophy and what was outside: what was relevant to natural philosophising and what was not. Rather, [1] the utterances of dominant figures and groups tended to create, and recreate, a 'leading or hegemonic picture' of those boundaries and how to articulate natural philosophy onto them, whilst [2] articulation upon boundaries was an essential part of the competitive dynamics of the field. The university neo-Scholastic Aristotelians' possession of dominant institutions was crucial; but, competitors challenged the way dominant players articulated utterances to boundaries in order to [re-]define the field. The dominant utterances in the field carried a particular *selection, weighting and thematisation* of articulations on boundaries. Challengers could reorder these selections, weightings and contents, and also modify existing articulations, or bring in new ones.

For example, in the university teaching of Aristotelianism, a virtual articulation was present to whatever version of orthodox religion dominated that particular polity and university. However, the traditional exclusion of discussion of theology in the undergraduate course meant that this articulation was tacit, not thematised

48 That is, we historians can model, by evidence based conceptual construction, macro entities such as social, economic and political structures and processes. We may attribute objective existence in the past to such models if they are well formed, grounded, and consensually agreed by expert modellers. But these [models of] macro entities should not be granted direct causal efficacy over the thoughts of historical actors by influence or imprinting. And, they should be taken as having been known by actors, if at all, only in terms of their own discourses and representations, which also need to be studied, and modelled by historians. For example, there undoubtedly was a rise in the import and scope of the practical arts in the sixteenth century, which itself had needs explanation through macroscopic drivers, economic, military and political, and which contemporaries partially represented in their own terms and for their own reasons. We only know about these macro forces and structures through our own evidence based modelling; actors only knew parts of them through their own representations. So, our models of the drivers will not directly explain the discourse of, say, a Bacon: its occurrence in time, content, form or motives. For that we need to start by modelling the field of contention in which the actor was moving, as in our study of natural philosophy, and the particular actor's likely trajectory through it, and finally his gambits in articulating upon boundaries, where, to complete this circle of interpretation, we understand what underlay the boundaries in terms of our own contextual modelling.

49 The term articulation is used here to deal with 'external' forces or drivers in partial emulation of the young Foucault, as in The Archaeology of Knowledge. All my modelling obviously grants much more reality to individual actors and their intentions than doctrinaire Foucauldianism would. That is because a wider range of resources are invoked in my model building. Cf above Note 16.

50 To this end, I have also benefited from post-Kuhnian sociology of scientific knowledge scholars' concept of 'boundary work' in disciplines or professions (Gieryn, 1983), but, as some readers will sense, my conceptions of boundary maintenance and work upon field or disciplinary boundaries are wider, more historical and very much tempered by a much modified 'Foucault' passed through the filter of Bourdieuian sociology of agonistic fields.

in the body of undergraduate natural philosophical teaching. In effect a rule existed about not explicitly articulating natural philosophy to theology from the natural philosophers' side of the fence. But, competing utterances from non- and anti-Aristotelian challengers could mobilise explicit and deeply developed articulations onto religion. To bring in religion explicitly involved devising new utterances, new articulations in depth and degree of thematisation in accord with favoured religious and theological commitments, claims and agendas.[51] This gives a more precise meaning to a Maravall-type formula that *'some natural philosophers responded to a perceived crisis with cultural moves inside natural philosophy'*.[52] Contending players, with differing agendas, were always making out the boundaries and relations of the field, by articulating utterances upon (their selection and weighting of) boundary structures and discourses. If outside entities and forces seemed to some to be particularly threatening and challenging (if, hence, a crisis was in progress), the variety, intensity and scope of competing articulations would rise, and it did.

To recur the stage of 'crisis within a crisis', we can say the following: A genuine sub-culture of natural philosophy existed, in which systems of nature had significant and contested articulations to religious, political and social discourses. The equally really existing contextual problems and tensions (labelled the 'general crisis') were interpreted by players through the filter of natural philosophising, thus suggesting that the problems of the age had some of their basis in natural philosophical contention and dissensus. This raised the stakes in finding and enforcing the 'true' philosophy of nature, since natural philosophy was arguably part of these problems and part of their solutions. Hence the proliferation of desperate and daring initiatives in neo-Platonic, alchemical, magical and Hermetically tinged natural philosophy, which in turn, elicited the equally sweeping, desperate as well as sudden invention of corpuscular-mechanism. Hence, also, a sense of a crisis of natural philosophising, within a larger general crisis.[53]

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51 This is what we mean by challenging the choice, depth and weighting of an articulation. Similar points attach to politics, or more particularly to issues about the nature and role of 'the state', and the contemporary tortured issues of sovereignty, Church governance vis à vis the state, and issues of civil order and legitimate rebellion (all of which could count as elements in a larger 'crisis' perceived and responded to by some natural philosophical players). Most Aristotelian teachers of natural philosophy in the university environment would have left largely unsaid within natural philosophy its linkages to the local political status quo, and to the institutional arrangements that supported the very existence of that particular university and its natural philosophical functions. A Bacon or Hobbes, however, articulated natural philosophical utterance in part upon such particular evaluations and agendas of these political issues. But this is not to say that politics or political doctrines or agendas 'influenced' the natural philosophical utterances of Bacon or Hobbes. Rather, it is to say in the first instance that within the field of natural philosophy they saw fit to mobilise and deploy such articulations in an effort to win the natural philosophical agon, and through it, partially to support their properly political aims, now recursively expressed, amongst other ways, through natural philosophy.

52 Similarly it can be argued that the practical arts and their practitioners did not influence natural philosophers, but rather that certain natural philosophers articulated their natural philosophical utterances in part upon resources from and about the domain of practical arts.

53 Cf. Schuster (1990) pp. 237-38, which can now be reframed using the more developed model of natural philosophical competition presented in this section of the present paper.

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5. Recruitment of Baroque Behaviours, Norms and Identities?

Following Maravall we now ask: *'Were elements of Baroque culture, identity and behaviour templates recruited into the field of natural philosophy; were there phenomena inside natural philosophising in its critical phase that make sense as normal cultural mores of otherwise 'Baroque-ified' intellectuals'?* That is, we look for Baroqueness in the very weave of the processes of the game of natural philosophising.[54] The answers fall under overlapping categories of 'challenges to Scholasticism'; 'bending and breaking of rules'; 'the politics of heroic identity and honour', and 'shifting images and self-understandings of reason'.

Trying to run rings around Scholastic institutions and thinkers was a Baroque proclivity, although not a new pastime.[55] But unlike Renaissance humanism, early and mid seventeenth century natural philosophising displayed specific forms of anti-Aristotelianism focussed on *strategies of displacement of hegemonic Aristotelianism within a continuing and contested game of natural philosophy*. Many desired regime-change within the culture of natural philosophising, not the destruction of the game as such. These are the players Stephen Toulmin picked out as the anti-Renaissance, self-proclaimed heroes of intellectual and cultural salvation.[56] The culture of Renaissance humanism would have to go, as well as the institutional hegemony of neo-Scholastic Aristotelianism. But one did not have to be Descartes, Hobbes or Bacon to be involved in Baroque-looking rule breaking and bending. The vogue of seeking out novelty and discovery, not a salient feature of Scholastic commentary and disputation,[57] meant that natural philosophers were under pressure to change as the entire field became more contested and turbulent. Neo-Scholasticism taught 'don't change the mixed mathematical sciences and their relation to natural philosophy'. But some bold innovators tried to do so, fomenting and exploring the domain of physico-mathematics. Neo-Scholasticism said 'don't explicitly articulate natural philosophical claims on religious/political challenges, agendas and debates'. But some innovators tried to do so. Neo-Scholasticism held *de facto*, but strongly, 'don't bring in "inappropriate" values, aims or players, particularly anything related to practical arts, material practice, instruments, and images and rhetoric concerning the status and value of same'. But many bold and aggressive, hence Baroque-looking, innovators did.

Entrenched rules, norms and practices, reproduced from generation to generation, were under threat of reformation, deformation or rejection. The self image, self-understanding, and public posturing of the rebels and challengers was one of

54: Friedrich and others who have studied the Baroque as a culture stress that the Baroque was about rule bending and rule breaking, as well as about especially self-regarding and anguished matters of identity and honour. Friedrich (1962) especially chapter 2 ; Maravall (1973); Rabb (1975) who treats these phenomena under his category of rising 'crisis';

55 Clark (1992)

56 In his Cosmopolis: The Hidden Agenda of Modernity. (Toulmin, 1990)

57 Which of course is not to say that none went on in Scholastic circles, teaching and textbooks, only that it was not the leading edge of these phenomena, rather the reluctant follower. (Gascoigne, 1990; Reif, 1969; Schmitt, 1973; Brockliss 1981)

isolated, heroic, honour seeking, black and white decisive decision-making and action-taking. We easily label as 'Baroque personalities' the political and military figures of the age—Richelieu, Wallenstein, Gustavus Adophus, Maurice of Nassau, and Olivares—who, engaging their particular businesses in the general crisis, displayed these cultural identity garments whilst forging new or revised concretions of power (and its legitimations). The highest stakes natural philosophical players similarly displayed these traits.[58] To contest for systemic hegemony meant that one stood against the rest, including the massed ranks of neo-Scholasticism. Heroic effort was required, perhaps poignantly (Baroquely?) overlaid with intimations of tragic failure. We cannot know the delicate biographical cum psychological channels through which the Baroque identity and protocols came to be lived and expressed. But, for many players the situation in natural philosophising seemed to demand such self-understandings and public imaging, and the presence of such personalities further enflamed the field.[59]

In sum to comport oneself in a Baroque manner involved a striving to test and remould styles and norms, entangled with a search for identity and agenda in line with images of heroic struggle and individual honour and fame. The more radical the breaking with available styles and norms, and the more daring and honour/fame seeking the intended identity, the more Baroque the performance. If you were a natural philosopher in the 'crisis within a crisis' phase, numerous avenues were open to you to pursue and express such traits, whilst natural philosophising: *Is natural philosophy to become mathematical? Is good and true natural philosophy to be decided more in terms of co-opting and explaining novel discoveries? Can natural philosophy articulate to political theory, medicine, theology or not,*

58 With the exception of the gentle, genial Gassendi, a man for that reason well recognised by historians as interestingly generationally displaced (too late for the scientific renaissance, too early for the age of consensus, muting and fragmentation). (Brundell, 1987) I thank my colleague Dr Barry Brundell, MSC, for enlightening informally expressed insights about the personality and likely outlook of Gassendi.

59 Importantly, acting Baroquely inside the natural philosophical crisis, did not mean one's writings have to be notably Baroque by the standards of later literary classification. Descartes, particularly the young Descartes whom I have been studying, is a fine example of all this. From 1618 and age twenty-two Descartes, operating at first under his similarly inclined mentor, Beeckman, was a thrusting rebel against the official university rules about the scope and application of mathematics, without an as yet well defined, maturely expressed, cause in the game of natural philosophy. Beeckman and Descartes were thumbing their noses at scholastic natural philosophical rules about the status and role of mixed mathematics, and even the ideal of systematisation. Correlatively, they were willing to take on board the vague, but trendy concept of physico–mathematics, and in Descartes' case, his home cooked version of the already circulating idea of a 'universal mathematics', as well, inflating them with aspiration and bravado. Descartes soon went even further, to a putatively world–beating new analytical method. At each stage Descartes was well pleased. To fancy himself a 'physico-mathematician', then a 'universal mathematician', gave him firm placement in a cultural debate, and provided a sense of who he was intellectually (and particularly as some special specimen of a mathematicising natural philosopher). After ten years of these endeavours, and self-inflations; that is, after several notable little technical successes and a sequence of ever more grandiose fantasy agendas: 'physico-mathematics', 'universal mathematics', and, 'the method', it all blew up with the unfinished later portions of the Regulae in 1628-9, at which point he realised he was actually meant to be a radical version of his own Jesuit scholastic mentors in systemic natural philosophy, leading to an equally rebellious agenda along these more customary lines of systemic natural philosophising. That makes a rather Baroque looking story line through the natural philosophical currents of the day, without anything Descartes produced in those years, or in the Discourse which retails an ideal version of his life story to that point, being particularly Baroque in the literary sense.

on whose terms? Is natural philosophy meant to produce useful results? What then in relation to these questions is the role and identity of the natural philosopher? All these channels were potentially open, and various gambits available within them. Hence the overall goal of replacing Aristotelianism by producing the really best and truest natural philosophy became supercharged, with Baroque culture elements in play. The 'crisis within a crisis' phase was lived through and played out, thus, by men inside natural philosophising who often acted, expressed and understood themselves in Baroque cultural terms.

Finally, it's possible that part of the self-understanding and public imaging of competitive players in the 'crisis within a crisis' phase had to do with shifting notions of reason relatable to the Baroque. Consider Bernier and Boileau in 1671, cited in Hazard,[60]

Whereas for some years past an obscure person, who goes by the name of Reason, has been attempting to make forcible entry into the schools of our University; and whereas said person, aided and abetted by certain comical quidnuncs calling themselves Gassendists, Cartesians, Malebranchists, vagabonds all of them, designs to arraign, and then expel Aristotle…

This has nothing to do with nineteenth century characterisations of rationalists (Descartes/Malebranche) and empiricists (Hobbes, Gassendi). 'Reason' here denotes an active, competitive, anti-Scholastic and (in the later seventeenth century sense) 'critical' reason—anti-authority, anti-credulity and anti-self illusion. All these terms can be imputed to the self-understandings of our earlier crisis players. This kind of 'reason', as a self-understanding and public stance, was arguably older than Hazard made out, and not totally opposed to everything Baroque. Rather, it was the obverse side of that self-aggrandising, often desperate competition in natural philosophising, which was partly Baroque in temper and cultural garb. The identity struggles and comportment of our natural philosophical players, their competitive plays and their understandings of reason are hence arguably all of a cloth which had Baroque culture threads running through it. Perhaps Baroque culture was not all about emotion and manipulation of the senses. When recruited into core of natural philosophical conflict—by specific intention, or through the

60 Hazard (1963) p.119. Hazard's conception of a late seventeenth century 'crisis of the European mind' ushering in the Enlightenment may seem contrary to later crisis theories, such as those of Rabb (1975) and Popkin (1964), and similarly averse to the position put in this paper. The resolution, is this: there was an historical hysteresis (in the Sartreian sense, Sartre,1963, pp. 64, 75 and part III passim) between natural philosophical crisis (which paralleled the hot state structural and religious-political-military turbulence of the early and mid seventeenth century) and the later, wider 'Hazard cultural intellectual crisis'. The latter was marked by the prior changes in natural philosophy, and played out largely in the new pan-European literary and cultural media as a density of quarrels and controversies, not as a set of life and death social, civil and inter-state confrontations and conflicts. The Hazard crisis, marked by the rise of deism, 'criticism' and sceptical rationalism; the proto-Enlightenment 'war' on tradition, superstition and unreasonable authority; and the quarrel of ancients and moderns, would not have occurred had not, amongst other things, the trajectory of natural philosophy already unfolded as it had earlier in the century; or if state structures and the inter state-system had not crystallised into their post 'general crisis' forms. Perhaps it was not a crisis at all, just the opening phases and rapidly ramifying crystallisation of new, wider cultural forms, the emergence of the 'Republic of Letters' as it were, with a widened reading public and enlarged (open or clandestine) publishing domains. The third, or 'CMF', phase natural philosophy, attendant sciences and new organisations were part of the furniture in the salons in which Hazard's crisis was argued out, for these developments had been forged by prior 'crisis inside a crisis' if you will.

already formed personalities of the players—'the Baroque' was also about 'reason' in new senses of critical, competitive, and against the existing rules and authorities. Within the context of natural philosophical contestation delineated in Section 4, this type of 'reason' maps onto the image of the lonely, heroic combatant, wielding 'reason' (according to some method of his own devising) as a weapon to win the natural philosophical game, thus closing down the perceived 'crisis within a crisis'.

6. An Additional, Surprising, Conjectural Finding

At this point our inquiry yields a surprising speculation: What if one could link the culture and dynamics of the modern sciences to key elements of the structure and dynamics of natural philosophising, including some of Baroque provenance? Perhaps certain traits of the modern sciences express competitive, cognitive and rhetorical genes first implanted in European thought during the 'natural philosophical crisis within a general crisis', and which are partially Baroque in tenor. This corresponds to the third type of result envisioned by the Baroque Science problematic discussed in Section 1.

Consider an ideal typical model of the agonal dynamics of modern scientific disciplines, grounded in reflection on findings in contemporary history and philosophy of science, and sociology of scientific knowledge (SSK).[61] A more nuanced reading of Thomas Kuhn's model of science dynamics is a good entry point.[62] In simplistic readings of Kuhn, one has rigid—frozen—paradigms facilitating puzzle solving research, until dysfunction, crisis and revolution install a new puzzle solving paradigm, equally rigid. Against this, post-Kuhnians have explicated "normal science" dynamics using micro-sociological tools.[63] In this approach the cultural resources in play in a tradition of research, are constantly subject to re-negotiation and modification. Suppose a problem is solved by advocating a shift in some aspect of 'the paradigm', however so slight. This means

61 The model presented below is ideal typical. It is not meant to capture the precise social and cognitive dynamics of any particular modern (that is, post early nineteenth century) scientific discipline. As an ideal model, it invites complexification on a case by case basis by considering variants and emerging long term shifts affecting the sciences as a whole. One suspects that the sorts of ideal models arising from post-Kuhnian thinking in HPS and SSK are better attuned to what Ravetz (1971) called the classical academic science of the late nineteenth and early twentieth century, rather than the industrial/military science of the mid and late 20th century or the emerging post-modern transdisciplinary sciences of today.

62 Kuhn, properly understood, was fully committed to the idea that the sciences are many, not one Science, and that his theorising was aimed at providing an ideal typical account of how any given mature science functions, the motor of tradition dynamics in any given science as it were. He also aimed to provide a broad, macroscopic mapping of the trajectories of the sciences over time. Cf. Schuster, 1995b, chapters 15 and 16; 1995a, chapter 8.

63 Ravetz (1971); Schuster (1979); Barnes (1982); M. Mulkay (1979). Latour and Woolgar (1979); Knorr-Cetina (1981); Collins (1985).

the problem solution involves feed-back alterations to the paradigm—conceptual, instrumental, normative. Such alterations—if negotiated into place by the expert community[64]—carry over into subsequent rounds of problem-solving, where further alterations may be negotiated. Post-Kuhnian historians and sociologists of science call such negotiated alterations of the paradigm 'discoveries', when they involve the conceptual/theoretical 'objects of inquiry' in the discipline[65], rather than, say, its instrumental techniques and standards, or norms of adequate procedure and argument.[66] Modern scientific disciplines thus display historically unique, and peculiar, tradition dynamics. They are defined by the fact that tradition modifying alterations are constantly sought, and fought over. This modelling also highlights the rhetoric that players use in self-understanding their roles and moves, and in representing them to each other, and to wider publics. Such 'method-talk' concerning isolated, non-tradition bound heroic discoveries does not accurately represent how the sciences work as agonal, novelty producing traditions. Rather, it is an accounting rhetoric used within the sciences as part of the mechanisms of contestation and accounting for change. [67]

Whilst most SSK research involves case studies, Pierre Bourdieu offered a general model of the social and organisational processes in the sciences, relating them to their knowledge-making, knowledge-breaking dialectic.[68] Bourdieu places members of a scientific tradition as players in a 'field', in a peculiar agonistic relation, involving an economy of material and symbolic resources, strategies and positions. Bourdieuian players seek a monopoly of the cognitive and social power at stake in particular field: They have certain amounts of symbolic and material resources (or capital) which they can deploy, strategically, in attempts to secure more resources and more power over the determination of the social and cognitive stakes at risk in the field in the next rounds of play. Given their different positions, resources and hence strategies, players attempt to produce claims that are both achievable within the limits of their symbolic capital and likely to prove significant and attractive to their competitors. These peers accredit such work by taking it up and redeploying it in their own construction of bids. What Bourdieuian players play for—the production of non-trivial, new claims that might be taken up and used by peer-competitors—maps directly onto the post-Kuhnian conception of ongoing negotiation into place of 'discoveries' which shift

64 Of course the form of the discovery claim negotiated into place, and accounted back to the presumed individual discoverer, can differ greatly from that originally published, let alone imagined, by the first inventor[s] of the claim.

65 The expression "(intellectually constructed) objects of inquiry" is Ravetz's (1971) term of art in his own early and brilliant sophistication of Kuhn's original model of 'normal science'.

66 This post-Kuhnifies the partially separate development of the so-called attributional model of scientific discovery. (Brannigan 1980, 1981; Schaffer 1986); For a textbook level exposition of a case study of these issues of post-Kuhnian notions of discovery and 'revolution' see Schuster (1995a) chap 4 and 5.

67 On the politics and rhetoric of method see: Schuster (1984, 1986, 1993); Schuster and R. Yeo (1986b), pp.ix-xxxvii.; Richards and Schuster (1989). Method-talk is flexibly used by players inside science to account for achievements, failures and allocate credit. It is part of the self-identity of many practicing scientists and an important part of the public imaging of science and its constituent disciplines.

68 Bourdieu (1975, 1971a, 1971b). Needless to say his model is an ideal type to which empirical fields approximate.

the terms of practice in subsequent rounds of research. But it is crucial to understand that for Bourdieu a 'system of objective relations' exists at any given moment amongst the positions already won and occupied in the field, via previous rounds of struggle. Bourdieu insists that the system of relations should not be reduced to or conflated with the micro-interactions and moment to moment strategies 'which it in fact determines'.[69]

Melding the post-Kuhnian and Bourdieuian models, we can see modern natural sciences as agonistic traditions, manufacturing and negotiating novel shifts of tradition practice, and awarding credit for these shifts, using a rhetoric of individual methodologically based heroic discovery. But where did this come from? I conjecture that the crisis phase in natural philosophising (itself partaking variously and diffusely of Baroque culture) left in the dynamics and culture of the field certain competitive practices and accounting rhetorics that survived in the ultimate descendants of early modern natural philosophy, the modern sciences, partially shaping their uniqueness as traditions

In Section 3, we noted that an ironic upshot of the 'civil war in natural philosophising' was that natural philosophising as a whole became more autonomous of other cultural forms, whilst it also began a process of fragmentation into a number of diverse and narrow special domains or disciplines of natural inquiry. The formerly more coherent, if internally contested, domain of natural philosophising began to fragment into, and *débouche* onto, a suite of successor, more narrow domains. Over the course of the next century natural philosophy faded and died, and these modern sciences emerged.[70]

Perhaps this slow but powerful process toward fragmentation of natural philosophy into successor disciplines, first unleashed during the crisis within a crisis, carried the élan of continuous competition and contestation from the earlier period right into the structure and dynamics of the successor fields, along with the heroic methodological accounting rhetoric.[71] Perhaps transcribed into the successor fields

69 By the "objective" systematic state of the field at any moment of play, we take Bourdieu to mean that the field exists as an analyst's model, a historian's model of the internal political economy of the field at a given moment in the style of historiographical category construction alluded to above. As in any model in historiography—for example my model of natural philosophy, or Maravall's model ('structure') for Baroque culture, or the post-Kuhnian model of research dynamics in a scientific tradition—it is an intellectual construct, category, constellation of concepts, constructed using social theory, bits of other historical findings, and appeals to evidence about the field or discipline in question. It then functions, as Bourdieu (and Maravall) suggest, as the ultimate object of study and as an explanatory resource for understanding particular plays and processes in the field.

70 On this Schuster and Watchirs (1990); Schuster (1990, 2002); Schuster and Taylor (1996, 1997). The domains that emerged in this process included: the complexly evolving master science, classical mechanics; new versions of the old mixed mathematical fields, now crystallised as more experimental and 'physico-mathematical'; and a host of emergent experimental fields which solidified further in the eighteenth century.

71 An important dimension of this result was the fact that as this process continued, actors' legitimatory and packaging rhetorics (typically rhetorics of method) evolved to meet the needs of players with these new sorts of aims and agendas. For example a method–discourse concerning 'speculative' vs. 'experimental' (natural) philosophy flourished in late seventeenth century England and was deployed, mainly by self-styled advocates of the latter, against real or imagined adversaries of the former stripe as a way of positioning themselves and their work in a field still inhabited not only by themselves, but by others, including a few players and texts of overtly theoretical, systematic and contentious natures. (Anstey 2005)

were the peculiar agonal dynamics according to which the a scientific tradition exists for the purpose of producing accredited novelty, a gene first expressed, in confused and desperate form, during the heated contestation of the critical phase.

7. Conclusion

This inquiry has taken two paths: On the one hand, viewing the Baroque as a cultural epoch in European history, we have tried to understand early modern natural philosophy, its dynamics and phases, in relation to the picture of Baroque culture and the general crisis painted by Maravall. On the other hand, we have found an intriguing hint that the modern natural sciences, as such, bear distinct cultural genes descending, ultimately, from the culture of the Baroque and the period of 'civil war in natural philosophy'. Modern sciences are by historical standards very odd beasts. They are continuously reproduced expert traditions whose very dynamics, and *raison d'être* in rhetoric and in practical activity, consists in the unremitting, competitive and concerted struggle to construct, and have re-implanted into the tradition, *significantly tradition-altering achievements*, which are proffered on a contested basis, and only have effect after being revised and negotiated into place by peer competitors of the initial proponents. In other words, both the actual, messy, competitive and political 'mangle of practice' inside scientific traditions, and the channels of crisp method rhetoric through which they are understood and accounted for, seem, on close inspection, to bear just legible hallmarks that say—"*forged by somewhat rebellious master practitioners in the white heat of the early to mid seventeenth century natural philosophical crisis, with some ingredients in part borrowed at that time from the supervening Baroque culture*".

References

Anstey, Peter. 2000. 'Descartes' Cardiology and its Reception in English Physiology' in Gaukroger, Schuster and Sutton (2000), pp.420-444.

Anstey, Peter. 2005 "Experimental versus Speculative Natural Philosophy" in Anstey and Schuster (2005) pp. 215-42

Anstey, Peter. and John. Schuster. (eds.), 2005. *The Science of Nature: Patterns of Change in the Culture of Natural Philosophy in the Seventeenth Century* Dordrecht: Springer. *(Studies in History and Philosophy of Science*, vol 19).

Aston, Trevor. 1967. *Crisis in Europe 1560-1660* Garden City: Doubleday

Bachelard, Gaston. 1949. *Le rationalisme appliqué*. Paris: Presses Universitaires de France.

Barnes, Barry. 1982. *T.S.Kuhn and Social Science*. London: MacMillan.

Biro, Jacqueline. 2009. *On Earth as in Heaven: Cosmography and the Shape of the Earth from Copernicus to Descartes*. Saarbrucken: VDM Verlag.

Bourdieu, Pierre. 1971a. "Intellectual Field and Creative Project." in M.F.D. Young (ed.) *Knowledge and Control: New Directions for the Sociology of Education*, pp.161-188. London: Collier-MacMillan.

Bourdieu, Pierre. 1971b."Systems of Education and Systems of Thought." in M.F.D. Young (ed.) *Knowledge and Control: New Directions for the Sociology of Education*, pp.189-207. London: Collier-MacMillan.

Bourdieu, Pierre. 1975. "The Specificity of the Scientific Field and the Social Conditions of the Progress of Reason." *Social science information* 14: 19-47.

Boschiero, Luciano. 2007. *Experiment and Natural Philosophy in Seventeenth-Century Tuscany*. Dordrecht: Springer (*Studies in History and Philosophy of Science 21*).

Brannigan, Augustine. 1980. "Naturalistic and sociological models of the problem of scientific discovery", *British Journal of Sociology* 31: 559-573.

Brannigan, Augustine. 1981. *The Social Basis of Scientific Discoveries.* Cambridge: Cambridge University Press.

Brockliss, Laurence. 1981. "Aristotle, Descartes and the New Science: Natural Philosophy at the University of Paris, 1600-1740". Annals of Science 38: 33-69.

Brundell, Barry. 1987. *Pierre Gassendi.* Dordrecht: Reidel.

Clark, William. 1992. 'The Scientific revolution in the German nations' in Roy Porter and Mikulas Teich (eds.) *The Scientific Revolution in National Context* Cambridge: CUP. pp.90-114.

Cohen, H. Floris. 1994. *The Scientific Revolution: A Historiographical Inquiry*. Chicago: University of Chicago Press.

Cohen, H. Floris. 2010. *How Modern Science Came into the World: Four Civilizations, One 17th Century Breakthrough*. Amsterdam: Amsterdam University Press.

Collins, Harry. 1985. *Changing Order*. London: Sage

Cunningham, Andrew. 1988. 'Getting the game right: some plain words on the identity and invention of science', *Studies in History and Philosophy of Science*, 19, pp. 365–89.

Cunningham, Andrew. 1991. 'How the *Principia* got its name; or, taking natural philosophy seriously', *History of Science*, 24, pp. 377–392.

Cunningham, A. and Williams, P. 1993. 'De-centring the "big picture": *The Origins of Modern Science* and the modern origins of science', *British Journal for the History of Science*, 26, pp. 407–432.

Dear, Peter. 1991. 'The church and the new philosophy' in S. Pumfrey, P. L. Rossi and M. Slawinski. Eds. *Science, Culture and Popular Belief in Renaissance Europe* Manchester: Manchester University Press, pp. 119–139.

Dear, Peter. 1995. *Discipline and Experience: The Mathematical Way in the Scientific Revolution*. Chicago: Chicago University Press.

Dear, Peter. 2001. 'Religion, science and natural philosophy: thoughts on Cunningham's thesis', *Studies in History and Philosophy of Science*, 32, pp. 377–386.

Dear, Peter. 2001a. *Revolutionizing the Sciences: European Knowledge and its Ambitions 1500-1700*. Princeton: Princeton University Press.

Des Chene, Dennis. 1996. *Physiologia. Natural Philosophy in Late Aristotelian and Cartesian Thought.* Ithaca: Cornell University Press.

Easlea, Brian. 1980. *Witch-Hunting, Magic and the New Philosophy: An Introduction to the Debates of the Scientific Revolution 1450-1750.* Sussex: Harvester Press.

Eisenstein, Elizabeth. 1979. The Printing Press as an Agent of Change: Communications and Cultural Transformations in Early-Modern Europe, vol 1. Cambridge: CUP.

Feyerabend, P.K. 1975. *Against Method*. London: New Left Books.

Foucault, Michel. 1969 [1972]. *The Archaeology of Knowledge*. trans. Alan Sheridan, London: Tavistock.

Frank, Robert, G. 1980. *Harvey and the English Physiologists: Scientific Ideas and Social Interaction*. Berkeley: University of California Press.

Friedrich, Carl J. 1962. *The Age of the Baroque: 1610–1660* 1st ed 1952, , New York, Harper & Row.

Gal, Ofer and Raz Chen-Morris. 2010. "Baroque Optics and the Disappearance of the Observer: From Kepler's Optics to Descartes' Doubt", *Journal of the History of Ideas* 71: 191-217.

Gascoigne, John. 1990. "A Reappraisal of the Role of the Universities in the Scientific Revolution", in David Lindberg and Robert Westman. Eds. *Reappraisals of the Scientific Revolution*. pp. 207-260. Cambridge: CUP.

Gaukroger, Stephen. 1995. *Descartes: An Intellectual Biography* Oxford: Oxford University Press.

Gaukroger, Stephen. 2006. *The Emergence of A Scientific Culture*. Oxford: Clarendon Press.

Gaukroger Stephen W. and John A. Schuster. 2002. "The hydrostatic paradox and the origins of Cartesian dynamics.", *Studies in History and Philosophy of Science* 33 535–572.

Gaukroger, S. W., Schuster, J. A. and Sutton, J. (eds.) (2000) *Descartes' Natural Philosophy*, London: Routledge.

Gieryn, Thomas. 1983. 'Boundary-Work and the Demarcation of Science from Non-science: Strains and Interests in Professional Ideologies of Scientists', *Amer. Sociological Review* 48, pp.781-795

Hattab, Helen. 2005. "From Mechanics to Mechanism: The *Quaestiones Mechanicae* and Descartes' Physics." In Peter Anstey and John Schuster eds. *The Science of Nature in the Seventeenth Century: Changing Patterns of Early Modern Natural Philosophy.*, pp.99-129. Dordrecht: Springer.

Harrison, Peter. 2000. 'The influence of Cartesian cosmology in England' in *Descartes' Natural Philosophy*, eds S. W. Gaukroger, J. A. Schuster and J. Sutton, London: Routledge, pp. 168–192.

Harrison, Peter. 2002. 'Voluntarism and early modern science', *History of Science*, 40, pp. 63–89.

Harrison, Peter. 2005. "Physico-Theology and the Mixed Sciences: The Role of Theology in Early Modern Natural Philosophy", in P. Anstey and J. Schuster eds. *The Science of Nature: Patterns of Change in the Culture of Natural Philosophy in the Seventeenth Century* pp.165-183

Hazard, Paul. 1935. (Eng trans 1952, 1963) *The European Mind 1680-1715* (*La Crise de la conscience Européenne*) New York: World Publishing Co.

Henry, John. 2002. *The Scientific Revolution and the Origins of Modern Science*. 2nd ed. London: MacMillan.

Knorr-Cetina, Karin. 1981. *The Manufacture of Knowledge: An Essay on the Constructivist and Conventional Character of Knowledge and Cognition.* Oxford: Pergamon.

Kuhn, Thomas S. 1970. *The Structure of Scientific Revolutions*. 2nd ed. Chicago: University of Chicago Press.

Latour, Bruno and Steve Woolgar. 1979. *Laboratory Life, The Social Construction of Scientific Facts* London: Sage

Lenoble, Robert. 1943. *Mersenne ou la naissance du mécanisme*. Paris: J.Vrin.
Laird, W. R. 1986. "The Scope of Renaissance Mechanics." *Osiris* 2 : 43-68.
Lindberg, David. 1976. Theories of Vision: From Al-Kindi to Kepler. Chicago: University of Chicago Press
Lindberg, David. 1992. *The Beginnings of Western Science* Chicago: University of Chicago Press
Liu Dun and Wang Yangzong (eds.) 2002. *Chinese Science and the Scientific Revolution: Selected Writings on the Needham Problem and Related Issues*, Shenyang, Liaoning Education Publishing House
Maclean, Ian. 2007. *Logic, Signs and Nature in the Renaissance* Cambridge: Cambridge University Press.
Maravall, José Antonio. 1973. *The Culture of the Baroque: Analysis of a Historical Structure.* (Eng Trans, 1986) Minneapolis: Univ of Minnesota Press.
Mulkay, Michael. 1979. *Science and the Sociology of Knowledge*. London: George Allen & Unwin.
Olby, R. C., Cantor, G. N., Christie, J. R. R. and Hodge, M. J. S. (eds.) 1990. *Companion to the History of Modern Science*. London: Routledge.
Pinch, Trevor. 1985. 'Towards an analysis of scientific observation: the externality and evidential significance of observational reports in physics', *Social Studies of Science* 15: pp.3-36.
Pirenne, Henri. 1936. (Eng trans 1939) *A History of Europe from the Invasions to the XVI Century*. London: George Allen & Unwin.
Popkin, Richard. 1964. *The History of Scepticism from Erasmus to Descartes*. New York
Rabb, Theodore K. 1975. *The Struggle for Stability in Early Modern Europe*. New York: Oxford University Press.
Rabb, Theordore K 2006. *The Last Days of the Renaissance & the March to Modernity*. New York: Basic Books
Rattansi, P.M. 1963. "Paracelsus and the Puritan Revolution." *Ambix* 11: 24-34.
Rattansi, P.M. 1964. "The Helmontian-Galenist Controversy in Seventeenth Century England" *Ambix* 12 : 1-23.
Ravetz, J.R. 1971. *Scientific Knowledge and Its Social Problems*. Oxford: Clarendon Press.
Ravetz, J.R. 1975. 'Science, History of', *Encyclopaedia Britannica*. vol 16, pp.366-72
Reif, Patricia. 1969. "The Textbook Tradition in Natural Philosophy, 1600-1650", *Journal of the History of Ideas* 30: 17-32.
Richards, Evelleen, and John. A. Schuster. 1989. "The Myth of Feminine Method: A Challenge for Gender Studies and The Social Studies of Science." *Social Studies of Science* 19: 697-720.
Rossi, Paolo. 1970. *Philosophy, Technology and the Arts in the Early Modern Era* New York: Harper and Row.
Rose, Paul Lawrence and Stillman Drake. 1971. "The Pseudo-Aristotelian *Questions of Mechanics* in Renaissance Culture", *Studies in the Renaissance* 18 : 65-104.
Sahlins, Marshall. 1993. "Goodbye to *Tristes Tropes:* Ethnography in the Context of Modern World History." *Journal of Modern History* 65:1-25.
Sartre, Jean-Paul. 1963. *Search for a Method.* New York: Alfred Knopf, Inc.
Schaffer, Simon. 1986. 'Scientific Discoveries and the End of Natural Philosophy', *Social Studies of Science* , 16 ,387–420.
Schmitt, Charles. 1973. "Towards a Reassessment of Renaissance Aristotelianism", *History of Science* 11:159-93.
Schuster, John. A. 1979. "Kuhn and Lakatos Revisited." *British Journal for the History of Science,* 12 : 301-17.
Schuster, John A. 1984. "Methodologies as Mythic Structures: A Preface to the Future Historiography of Method." *Metascience* 1-2: 15-36.
Schuster, John A. 1986. " Cartesian Method as Mythic Speech : A Diachronic and Structural Analysis." in Schuster and Yeo 1986a, pp. .33-95;

Schuster, John A. 1990. "The Scientific Revolution." in R. Olby et al (eds.), *The Companion to the History of Modern Science*. pp.217-242. London: Croom Helm.

Schuster, John A. 1993."Whatever Should We Do with Cartesian Method: Reclaiming Descartes for the History of Science." in S. Voss (ed.) *Essays on the Philosophy and Science of René Descartes*, pp. 195-223. Oxford: Oxford University Press .

Schuster, John A. 1995. "Descartes *Agonistes* New Tales of Cartesian Mechanism." *Perspectives on Science* 3 : 99-145.

Schuster, John A. 1995a. *An Introduction to the History and Social Studies of Science.* (Open Learning Australia, 1995). On open access at *http://descartes-agonistes.com*

Schuster, John A. 1995b. *The Scientific Revolution: An Introduction to the History and Philosophy of Science.* (Open Learning Australia,1995). On open access at *http://descartes-agonistes.com*

Schuster, John A. 1997. 'Saving the Revolution', *Isis*, 88 (1) , 118-121

Schuster, John A. 2000. "Descartes 'Opticien': The Construction of the Law of Refraction and the Manufacture of its Physical Rationales, 1618-29". In *Descartes' Natural Philosophy*. Edited by Stephen Gaukroger, John Schuster and John Sutton, pp.258-312. Routledge: London.

Schuster, John A. 2000a. 'Internalist and Externalist Historiographies of the Scientific Revolution', in W. Applebaum (ed.) *Encyclopedia of the Scientific Revolution*, , New York: Garland Publishing

Schuster, John A. 2002. 'L'Aristotelismo e le sue Alternative', in D. Garber [ed] *La Rivoluzione Scientifica.* Rome: Instituto della Enciclopedia Italiana pp. 337-357. English translation available at *http://descartes-agonistes.com*

Schuster, John A. 2005. 'Waterworld: Descartes Vortical Celestial Mechanics and Cosmological Optics—A Gambit in the Natural Philosophical Agon of the Early seventeenth Century', in J.A.Schuster and P. Anstey [eds.] *The Science of Nature in the seventeenth Century: Patterns of Change in Early Modern Natural* Philosophy [Kluwer/Springer,], pp. 35-79.

Schuster, John A. and Alan B. H. Taylor. 1996. 'Seized by the Spirit of Modern Science', *MetaScience*, 9, 9-26.

Schuster, John A. and Alan B. H. Taylor. 1997. "Blind Trust: the Gentlemanly Origins of Experimental Science". *Social Studies of Science* 27: 503-36.

Schuster, John A. and Richard R. Yeo, (eds.), 1986a. *The Politics and Rhetoric of Scientific Method: Historical Studies*. Dordrecht: Reidel.

Schuster, John A. and Richard R. Yeo. 1986b. "Introduction" to Schuster and Yeo 1986, pp.ix-xxxvii.

Schuster, John A. and Graeme Watchirs. 1990. "Natural Philosophy, Experiment and Discourse in the Eighteenth century: Beyond the Kuhn/Bachelard Problematic." in H. E. LeGrand (ed.) *Experimental Inquiries: Historical, Philosophical and Social Studies of Experiment.* pp.1-48. Dordrecht: Reidel .

Shapin, Steven. 1992. "Discipline and Bounding: The History and Sociology of Science As Seen Through the Externalism-Internalism Debate." *History of Science* 30:333-369.

Toulmin, Stephen 1990. *Cosmopolis. The Hidden Agenda of Modernity*. New York: The Free Press.