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ESSAY REVIEW

What's Wrong with Talking About the Scientific Revolution? Applying Lessons from History of Science to Applied Fields of Science Studies

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Abstract Since the mid-twentieth century, the 'Scientific Revolution' has arguably occupied centre stage in most Westerners', and many non-Westerners', conceptions of science history. Yet among history of science specialists that position has been profoundly contested. Most radically, historians Andrew Cunningham and Perry Williams in 1993 proposed to demolish the prevailing 'big picture' which posited that the Scientific Revolution marked the origin of modern science. They proposed a new big picture in which science is seen as a distinctly modern, western phenomenon rather than a human universal, that it was invented in the Age of Revolutions 1760–1848, and that science be de-centred within the new big picture: treated as just one of many forms of human knowledge-seeking activity. Their paper is one of the most highly cited in the history of science field, and has the potential to transform the way that science educators, science communicators, science policy-makers and scientists view science. Yet the paper and historians' scholarly response to it are not well-known outside the history discipline. Here I attempt to bridge that disciplinary gap with a review of scholarly papers published 1994–2014 that cited Cunningham and Williams or otherwise discussed the Scientific Revolution, to gauge the extent of support for the old and new big pictures. I find that the old big picture is disintegrating and lacks active defenders, while many scholars support aspects of the new big picture. I discuss the significance of this for scholars in 'applied' fields of science studies such as education, communication and policy.

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Introduction

The concept of 'the Scientific Revolution' was developed by a small group of historians of science working before and after the Second World War, primarily Alexandre Koyré, Herbert Butterfield and A. Rupert Hall. Put simply, it suggests that the origins of modern science were to be found in the mathematical and natural philosophy works of people like Galileo, Descartes and Newton in 16th and 17th century Europe. It was then, the narrative suggests, that science burst into the world in all its light, having struggled for so long in shadows. Koyré, Butterfield and Hall successfully promoted the Scientific Revolution as supremely important in the history of science 'big picture.' As a result, it is arguably the only major history of science narrative that has currency with people outside that specialist field, including many science educators, science communicators and science policy specialists.

Since then, historians have challenged the Scientific Revolution concept on many grounds. Most radically, its centrality within the history of science has been questioned. One of the most influential such challenges came in 1993 from Andrew Cunningham and Perry Williams, who rejected the notion of a Scientific Revolution altogether. They sought to establish a new big picture for the history of science to replace it, and proposed that science was invented (their word) in the late 18th to early 19th century, during 'the Age of Revolutions,' 1760–1848. They argued that science be recognized as a distinctly modern, Western, cultural phenomenon—as bounded in time, space and culture—rather than seen, as per the old big picture, as a universal human endeavour that reached its zenith in the modern West. Specifically, they asserted that the name 'science' should only be used to refer to this modern, Western phenomenon, not to other knowledge-seeking activities. Ultimately, they argued that the Scientific Revolution big picture is not just a historically inaccurate story about science, but an ideologically loaded narrative about science's meanings for human beings and the world. Its development was, in their view, motivated by the war-era historians' desire to promote a particular scientific mode of thinking within society, by equating the emergence of Western science with the revelation of truth.

If this alternative thesis has any merit, it presents a profound challenge for scholars and practitioners working in what I here call applied fields of science studies, such as the science education, science communication and science policy domains. What workers in these domains have in common are that we are at the coal-face of debates about science's value and the appropriate place of science in society. We are variously concerned with influencing things such as scientific literacy, science funding, science jobs, enrolments in science subjects, public debate about science and technology, the incorporation of science into government policies, and, broadly speaking, the principle of making science a foundation-stone

of society. Whatever each individual's specific views about science are, some idea of *what science is* lies at the heart of them. It is likely that for many people this idea has been, to a significant extent, shaped by the Scientific Revolution big picture, given the latter's prominence within the public consciousness. That big picture's apparent basis in empirical historical research has in turn lent legitimacy to a raft of ideological baggage about science that may in fact have no credible historical foundation.

For some applied science studies workers this history may not matter, if their views about science are based on things other than the historical big picture, such as their own experiences with science, or other evidence of its impact on society. However, for those who have constructed their views at least in part on the Scientific Revolution big picture, with a sense of trust and faith in the truth of that historical narrative, an alternative history may prove critically transformative. For that reason it is important to bring that alternative perspective into the scholarly discourse of applied science studies domains. Some of its component arguments are already in circulation within these domains, in particular questions about Eurocentrism within the old big picture. But what is not currently available is a critical review of the level of support for the Cunningham and Williams alternative big picture, to enable applied science studies workers to evaluate its legitimacy as an alternative history of science and, conversely, the strength of support remaining for the old big picture. Making this body of work available outside of the history of science field will enable applied science studies workers to make more informed decisions about how to proceed when applying history in their work, or when considering how their idea of history has shaped their thoughts about science.

Accordingly, the format of this paper is a review of the post-1993 literature citing Cunningham and Williams or discussing the Scientific Revolution, highlighting key points of agreement or disagreement with the old or new big pictures. At the core of this I review works from the history of science field. I also include papers from other disciplines, to identify additional perspectives that have a bearing on the matter.

Methods

While elements of the Cunningham and Williams thesis have been argued elsewhere (e.g. in a 1988 paper by Cunningham), I use the 1993 paper as a focal point for the review because of the considerable influence it has exerted within its field. Quantitatively, it is the most highly cited paper published in its journal, *The British Journal for the History of Science*, and one of the most highly cited papers ever in the history of science field.[1] A more qualitative measure of its influence was its

[1] This was determined primarily with a citation search on the Web of Science database. Of the >27,000 papers Web of Science lists for the keyword 'science' within research areas 'history' and 'history and philosophy of science,' it ranks 75th highest by number of citations (searched 13 January 2015). Many of the papers ahead of it in that list are from disciplines other than history, such as philosophy of science or sociology of scientific knowledge. Web of Science lists 73 citations for the Cunningham and Williams paper; the next most cited paper in *The British Journal for the History of Science* has 58. A search for papers referencing 'the Scientific Revolution,' conducted for the second part of the review, yielded an

inclusion in a 2003 historical reader on the Scientific Revolution, despite editor Marcus Hellyer framing it as 'a dissenting view' that 'has not found universal favor' (Hellyer 2003: 14, 216). These factors make it a useful lens for examining current thinking about the Scientific Revolution and its alternatives.

My review is in two parts, following a brief re-visitation of Cunningham and Williams' paper. In the first part I review 68 of the 74 works published between 1994 and 2014 inclusive that are indexed on the Web of Science database as having cited Cunningham and Williams.[2] These 68 comprise a comprehensive survey of the scholarly response to their work. I review them to assess whether Cunningham and Williams' premises have been broadly accepted or disputed by scholars and on what grounds.

In the second part I review journal papers published between 1994 and 2014 inclusive that engaged with the concept of the Scientific Revolution but did not cite Cunningham and Williams. In this part I sought to identify how the authors of those papers used the term 'Scientific Revolution' compared to the objections Cunningham and Williams raise to it, and what, if any, historiographical issues they raised about the concept or about the 'big picture' in the history of science. The papers for this second section were identified by a key word search for 'the scientific revolution' in the Web of Science and Historical Abstracts databases, restricting the results to English language journal papers, including review essays and proceedings papers published in journals. I manually checked those I could access (approximately 90% of returned hits) and excluded those that only mentioned 'the scientific revolution' in the abstract but not in the body of the paper, or those using the term to mean some other event (such as the 'revolution' in biotechnology). This search strategy yielded a set of 110 papers available for analysis, in addition to the 68 works citing Cunningham and Williams. Following this second part of the review, I offer some synthetic conclusions, focusing on the results' significance for applied science studies fields.

To fully cite 178 sources would take several thousand words in itself, so some of the bibliographic evidence underlying this paper is referenced in an online resource file. There are 20 instances in the review where I summarize the perspectives of multiple works without citing all directly in the text; for each such instance, I provide the full bibliographic substantiation in a section of the online resource file. I refer to the appropriate section using a bracketed formulation with the letters OR and numbers 1 through 20. For example, to refer readers to the third section of the online resource file, I would follow a statement with (OR3). The file also contains a complete bibliography of the 178 works.

A methodological limitation of this survey is its restriction mainly to journal papers, and therefore its exclusion of the many books published since 1994 that

Footnote 1 continued
additional citing paper that was mistakenly not listed among the 73, taking the total to 74. A search using the disciplinary specialist Historical Abstracts database did not add any further citations to those listed by Web of Science.

[2] See footnote 1 for search details. The six works listed as citing Cunningham and Williams that were not included in the review were either not in English, were inaccessible, or appear to have been erroneously listed by Web of Science.

have included the term 'Scientific Revolution' somewhere in their title—possibly over a hundred, judging by listings on worldcat.org. Several of these books continue to exert a strong influence on scholars, particularly in the book-oriented discipline of history, but no doubt also beyond that field because of books' general accessibility, and so should rightly be considered part of the body of scholarly works. I excluded them for pragmatic reasons. First, the sheer volume of books was prohibitive, considering the journal papers on the topic were numerous enough to comprise a substantial review. Second, it is near impossible to discern where the boundary lies between scholarly and popular works on this topic, and so a survey of books would bleed into a study of popular discourse about the Scientific Revolution. That would be a fascinating study in itself, and informative for understanding the dynamics of these ideas within the applied science studies fields of concern. But such a study would be a departure from the present aim, which was primarily to review scholars' engagement with challenges to the Scientific Revolution big picture, and so restricting the reviewed texts to journal papers was a logical choice. Should future researchers take on the challenge of studying popular discourse on this topic, the present study will hopefully provide a useful point of comparison.

The Cunningham and Williams Thesis

Cunningham and Williams built their thesis on three premises: that the 'old big picture' could no longer be sustained in light of more recent scholarship; that the evidence suggests 'science' as we currently conceive of it was invented in the Age of Revolutions; and that a new big picture should de-centre science as 'just one amongst a plurality of ways-of-knowing the world' (Cunningham and Williams 1993: 429). The last point provides a theoretical framework for the whole, with Cunningham and Williams disputing the tendency under the old big picture for historians to appropriate 'all ways-of-knowing-the-world…to a single, unitary "history of science"' (p. 409). The influence of postcolonial theory is evident here—we could substitute Dipesh Chakrabarty's (2000) term 'provincialize' for Cunningham and Williams' term 'de-centre'—and indeed, Cunningham and Williams rejected the Eurocentrism (and presentism) inherent in the notion that science 'could act as a neutral framework on which to organize ways-of-knowing across the whole span of human history and human cultures' (Cunningham and Williams 1993: 410).

If taken literally, one implication of this is that applied science studies workers seeking to apply the label 'science' to non-modern or non-Western ways-of-knowing should not do so; and nor should such ways-of-knowing be seen as inferior or superior to science. This would then exclude a whole range of knowledges and practices from the purview of science communication, education and policy. It would also confine the latter disciplines to a narrowly modern, Western epistemological frame, potentially pitted against the many alternative ways-of-knowing. In this sense, the Cunningham and Williams thesis would frame applied science studies activities that promote science as attempts at intellectual

imperialism, undermining any view that they are more innocently a neutral, universal good.

Cunningham and Williams argued that the old big picture emerged from an ideological imperative to promote science in particular, now familiar ways: certainly as a universal human enterprise, but also as a specific method of inquiry, and as 'the embodiment of basic values of freedom and rationality, truth and goodness, and the motor of social and material progress' (p. 411). Drawing on existing scholarship, they contended that none of these ways of characterizing science are robust: that it cannot be equated with all human knowledge-building activities, is not methodologically consistent, and is often not morally good nor intellectually free nor a positive contributor to 'progress.' They argued that a new big picture must be built to accommodate this profound shift in beliefs about the nature of science, starting with what was now believed and known, rather than tweaking the old model. They felt that the old big picture would continue to haunt their discipline if it was not replaced by a new one.

Cunningham and Williams built their new big picture on the historiographic principle that science does not derive from a transcendent realm, so therefore requires a conventional historical explanation. In other words, any definition of science developed on the basis of philosophical reasoning or descriptions of the present nature of science (for any given 'present') is inadequate, because it creates an impression that the concept 'science' transcends temporal, geographic, material, political and cultural boundaries. Cunningham and Williams argued to the contrary that, like everything else, the idea of science has a very grounded, situated history—it came from somewhere. Accordingly, they established the second premise of their thesis by reference to empirical historical research that identified the timings of things important to the identity of science: the first use of the word 'science' in its current sense; the creation and/or consolidation, and differentiation, of disciplines such as physics, biology, chemistry and geology; the professionalization of 'scientific' labour; the laboratory being seen as basic to research; and the shift in the investigation of nature from a godly pursuit to a secular one. Since all of these things had been dated to the Age of Revolutions, they chose that era as the basis for their new periodization. They argued that science of the late 18th to 20th centuries was not the same kind of activity as natural philosophy and mathematics in 17th or 16th century Europe. They also dated the roots of the Scientific Revolution creation story to the same point in time as science itself was invented: with early 19th century 'men of science,' under the influence of the Enlightenment *philosophes* and the Romantics, locating science's origins in the 17th century and, before that, in ancient Greece. Therefore, Cunningham and Williams concluded, the events of the so-called 'Scientific Revolution'—though perhaps important to the history of European natural philosophy and mathematics—were not properly considered the origins of modern science. Indeed, they considered the qualifier 'modern' redundant, as the origins of science were *only* modern.

In other words, Cunningham and Williams emphasized an *institutional* identity for science over and above an identification with science's *subject matter*—ostensibly, the study of the natural world. While the study of the natural world may indeed be a human universal, it has been carried out in diverse ways across the

world and throughout history, and that diversity is governed and shaped by institutional factors—social, cultural, political, economic, ideological factors. It is in this institutional respect that modern, Western science—or simply 'science'—is unique, and different from the ways-of-knowing dominant in 17th century Europe, for example. A potential implication of this for applied science studies workers is that our primary allegiance, as manifest in our use of the label 'science,' appears to be with the institutional aspects of science, rather than with a more universal interest in studying the natural world. At the very least, Cunningham and Williams' differentiation between these ways of thinking about science must give us pause for thought about where our allegiances do lie.

A key question this review seeks to address, however, is how other historians of science have received this thesis or otherwise negotiated its ideas, to help us evaluate how seriously we should take it. In the next two sections I address this, beginning with the 68 available papers that cite Cunningham and Williams. It is noteworthy that 22 (32%) of these works only included relatively trivial citations of the paper, using it to assert minor and uncontroversial points in this context, for example, that science is the West's dominant way of knowing, that there is a big picture in science history, that the big picture is Butterfield's, and so on (OR1). These works do not contradict Cunningham and Williams' thesis, but their authors only tacitly support it by, in essence, admitting that they are aware of it and not arguing against it. It is not possible to analyze these 22 papers in greater depth than this, therefore I will not engage with them further. This reduces the body of available literature that has critically and/or deeply engaged with Cunningham and Williams' thesis to 46 papers, which I review next.

Works Citing Cunningham and Williams

This first part of the review is divided into three sections, following Cunningham and Williams' three premises. I begin with the first premise: to what extent have scholars accepted the argument that the Scientific Revolution is an unsustainable concept that should be rejected? I continue with the paper's second premise, asking: has the proposed new periodization of the origins of science been accepted? Finally, I examine whether scholars agree that (modern, Western) science should be de-centred within the history of human knowledge making.

Is 'the Scientific Revolution' an Unsustainable Concept?

Of the three premises, the first is the least widely endorsed in the literature citing Cunningham and Williams, primarily because few scholars have engaged directly with the crucial proposition that the Scientific Revolution should be written off. Those who have engaged with it seemed to agree with it. Diederick Raven expressed the view that 'the seventeenth century events' were not 'that significant' when viewed 'from a comparative and civilizational point of view' (Raven 2011: 450–451). David Wade Chambers and Richard Gillespie agreed that the institutionalization of science as a 'polycentric communications network' in the

19th and 20th centuries 'represented a revolution in knowledge making more significant for both science and society than the theoretical advances of the seventeenth century, traditionally known as the Scientific Revolution' (Chambers and Gillespie 2000: 223). Soraya de Chadarevian (2009: 15) generally acknowledged that 'There seems to be agreement that the overarching accounts as produced in the past are not viable anymore.' Adrian Johns argued that the Scientific Revolution framework had hindered historians, whereas recasting the 17th century events as part of 'natural philosophy' rather than 'science' had enabled them to identify continuities with the pre-Renaissance era (Johns 1999; see also Osler 1998). Johns in essence argued that this more sensitive attention to continuities, breaks and periodization enables better history to be done.

Support for Cunningham and Williams' analysis of the problem has come more commonly in another form. A number of scholars have elaborated on the view that the old big picture was ideologically driven by a transcendent view of science, critiquing the lack of a historicist approach to put science in its social, cultural and political context (OR2). This body of work includes some detailed empirical archival substantiation, particularly by Anna-K. Mayer (2004). Most have not commented on the proposition of rejecting the Scientific Revolution concept outright, but have recognized the concept as a historiographical product, one of the 'fundamental experiments in narrating the history of science' (Findlen 1998: 244). These authors have thus kept the question of rejecting it open.

Others, mostly not historians of science, have more passively perpetuated the Scientific Revolution concept, sometimes adding scare quotes to its name, but otherwise carrying on as normal (OR3). Some read the Cunningham and Williams thesis as a mere 'revision' or 'redefinition' of the concept, or a 'second scientific revolution,' not acknowledging the stated extent of their challenge (OR4). This seems to support Cunningham and Williams' contention that a strong new big picture is required if we are to de-centre the old one.

Few scholars, though, have explicitly defended the Scientific Revolution concept. Hellyer is an exception, but offered an argument based on institutional convenience rather than empirical evidence: 'The Scientific Revolution does retain considerable usefulness as a shorthand name for the field, and it certainly shows no signs of simply disappearing' (Hellyer 2003: 14). This may have been a defensive move, but perhaps with good reason. Markku Peltonen wrote as early as 1999 that a coherent Scientific Revolution 'has become increasingly difficult to sustain and is, in fact, seldom defended anymore' (Peltonen 1999: 325). Peltonen quietly asserted that this 'historiographic programme' against the Scientific Revolution had become not only dominant, but also hegemonic. He invoked as evidence the fact that Steven Shapin's popular book on the Scientific Revolution had paid extensive lip service to the challenges, but essentially covered the same content as John Henry's less apologetic book on the subject, seemingly demonstrating a degree of political correctness on Shapin's part (Shapin 1996; Henry 1997). The historian most heavily engaged in this debate, Peter Dear, made a similar point in 1998:

> The 'Scientific Revolution' is nowadays, as a category, much less attractive to historians than it once was…. Nonetheless, as our historiographic heritage, it

> continues to set agendas and direct us to particular problem areas. (Dear 1998: 173)

Dear used that as a starting point for querying whether the idea was 'nothing but an ideological construct' (Dear 1998: 173). He went on to defend a renovated version of the Scientific Revolution, while also acknowledging Cunningham and Williams' Age of Revolutions periodization. As a reconciliation, Dear proposed 'two interconnected stories': a 17th century story 'best told in a sociologized idiom of intellectual/cultural history' and a 19th century story 'told in the predominant idiom of social/institutional history' (Dear 1998: 192; for some support of this idea, see Szmrecsányi 2009). Since, as he stated, 'any historical story…is situationally determined,' in his view it was premature to completely reject the events associated with the 'Scientific Revolution' as important—their value depends upon the question being asked. By 2012, however, the discussion had substantially moved on. That year Dear concluded that while 'Grand overviews survive in the pedagogically necessary genre of the textbook…the days of the large scale historical account of the Scientific Revolution seem to be almost gone' (Dear 2012a: 207). This may signal a warning to science educators that the history we are teaching, based on such textbooks, is no longer recognized by historians as an appropriate way of reading history.

The safest general conclusion to draw about Cunningham and Williams' first premise is that historians largely agree on the problem: that the Scientific Revolution of Koyré, Butterfield and Hall was formulated using ideologically-driven rather than socio-culturally contextualized approaches to historical study, and a flawed, ahistorical concept of science. For this reason, the Scientific Revolution concept and the big picture centred on it have fallen out of favour, at least among most history of science specialists.

Historians, however, have not loudly reached a consensus on Cunningham and Williams' proposed solution, to abandon the Scientific Revolution altogether. It seems that to do so would result in an identity crisis for the history of science field. This, of course, need not particularly concern those in the science education, communication and policy domains, and so seems an inadequate reason to perpetuate an outmoded model of history there. In any case, Cunningham and Williams proposed a solution to that problem, too: to replace the old big picture with a new one, 'to give identity and meaning to our specialism' (Cunningham and Williams 1993: 407). The next question is, then, how have scholars of the past two decades received this second premise, that science was invented in the Age of Revolutions?

Has Cunningham and Williams' Proposed Periodization been Accepted?

The most obvious answer to this question is that almost all of the many scholars who mention questions of periodization agree with Cunningham and Williams about the date of origin of science, and about the appropriate measures to use to distinguish it from pursuits such as natural philosophy, including secularism, professionalization and disciplinary identities (OR5). This is easily the least contentious aspect of their

thesis, and does seem to have become accepted as a commonplace within the history of science, including by scholars who wish to retain the Scientific Revolution concept, or who have objected to other aspects of the thesis. Even Hellyer admitted that Cunningham and Williams 'may well be correct in arguing that the origins of MODERN (sic) science lie in the age of revolutions,' but downplayed the significance of this, saying that the other authors in his reader 'do not insist that early modern science was identical to modern science' (Hellyer 2003: 217). Understanding this period's significance for science would thus seem to be an important task for anyone in an applied field of science studies who talks about the history of science in their work.

The strength of commitment to the second premise in its entirety may be reasonably low though. For example, the terminology of 'invention' of science has not been taken up widely; only three authors whose work is reviewed here adopted it without scare quotes or other qualifiers (OR6). Some scholars also harbour a lingering concern that the recognition of the new periodization has made little actual difference to historiography. As Dear put it:

> The practical consequence is that whenever we think about 'science' for that time and place [early modern Europe], we can simply substitute the term 'natural philosophy' and carry on exactly as before — while feeling pleased at having avoided the pitfalls of present-centredness. (Dear 2001: 377; see also Pickstone 2007)

Dear asserted that Cunningham and Williams' periodization has been largely accepted without much interrogation, and that more detailed study of the proposal is warranted (Dear 2012a). Tamás Szmrecsányi agreed, stating, 'The only question which remains open is that of defining when, why and how the transition occurred' (Szmrecsányi 2009: 51). Nonetheless, some works (including those of Dear and Szmrecsányi) have added further elaboration and evidentiary weight to Cunningham and Williams' argument (OR7).

Two main points of concern about the second premise have been raised, both disputing Cunningham and Williams' seemingly sharp differentiation between the 'early modern' era of natural philosophy and the 'modern' era of science. The first is a practical matter: too sharp a division seems to isolate these eras from each other, suggesting that any studies of continuity across them are somehow problematic. A number of scholars have argued that they agree with the periodization but want to study these two 'eras' in conjunction, because both are important to understanding the story of science (OR8). The second concern is related but more philosophical, and therefore perhaps of more importance to applied fields of science studies: that Cunningham and Williams have overly essentialized both 'science' and 'natural philosophy.' Dear, in particular, made the point that both categories are heterogeneous, underwent change, and are not neat, for example, '"science" in the nineteenth century that…involved God rather centrally' would not neatly fall into either 'science' or 'natural philosophy' (Dear 2001: 381).

Early on, Dear (1995) identified Cunningham and Williams' view as a minority one for these reasons. Although this designation of 'minority view' did not last, the concerns do identify an ambiguity in Cunningham and Williams' paper. It is unclear

how they conceptualized legitimate approaches to the history of knowledge across the break between 'natural philosophy' and 'science.' This ambiguity—Dear (2001: 385) called it a 'tactical error'—left the door open for some writers to make overblown assertions about their thesis. For example, Nick Tosh filled the ambiguity with the (probable) overstatement that Cunningham and Williams believed topics like 'Newton's work on gravity…should not be studied as part of the history of science' (Tosh 2003: 648). Such apparent attacks on the identity of their field may remain an obstacle to a fuller embrace of the proposed new big picture by some historians, and presumably also by some applied science studies workers.

As a final point on the second premise it is worth noting that not all historians like big pictures, as Cunningham and Williams themselves noted. De Chadarevian discussed this in her review of the question of 'microstudies' versus big picture accounts in the history of science, acknowledging the historians who 'argue that big pictures of that sort are obsolete,' and the fact that a move by a critical mass of historians towards microstudies was motivated by 'uneasiness about overarching explanatory systems' (de Chadarevian 2009: 14–15; see also Pickstone 2007). This, or a self-conscious awareness of this dominant tendency, may at least partially explain the relative dearth of defenders of Cunningham and Williams' new big picture *in toto*. In addition, both de Chadarevian and Pamela Smith noted the difficulty of trying to construct a new big picture on a pluralist premise. In Smith's words, the 'many components of a new narrative…just do not cohere in the seductive way that the triumphalist story did' (Smith 2009: 373). This may also prove an obstacle to applied science studies people embracing the new big picture, if the weave of science is made up of so many threads as to render it a meaningless concept. This pluralism throws down a significant gauntlet to applied fields of science studies: a challenge to consider which threads have meaning for us.

Should Science be De-centred Within Historical Study?

This brings us to the third and final premise of Cunningham and Williams' thesis: de-centring (modern, Western) science within the broad field of the study of human knowledge making. A much smaller number of scholars have engaged with this premise than with the first or second, but most of those who did agreed with it whole-heartedly (OR9). Some but not all study non-Western science and/or the history of science at a global level. Their grounds for support are clearly based on postcolonial and related approaches to history, including opposition to the Eurocentrism implicit in the old big picture, and a desire for a more pluralist, more historicist, more localized, less universalist picture of science. This seems to have been tacitly supported more broadly. Of the works reviewed here, only Tosh (2003), a non-historian, cut against it to defend the notion that science is 'timeless' and has unique explanatory power.

Nonetheless, there are sticking points in this premise too. Most notable is the widespread retention of the word 'science' to refer to non-Western science, by scholars advocating the de-centring of modern, Western science. This is in stark contrast to scholars of early modern Europe, who have generally embraced a shift in language away from 'science' when referring to things like 17th century natural

philosophy. The reason for the difference is the cultural prestige of the label 'science' in the current academic (and non-academic) landscape. Scholars of early modern Europe are acutely aware of anachronism, but other things come into play elsewhere, primarily the denigration or lack of recognition of non-Western knowledge. Najmal-Din Yousefi (2008: 560, fn.1) has asserted the importance of the term 'science' for studies of medieval Islam, because of 'the continuity of many scientific methods and practices'—a continuity often elided in a Eurocentric history of science. Francesca Rochberg has argued that denying the use of 'science' for ancient Babylonian knowledge can lead to anachronism of a more serious sort than a mere problem of terminology:

> To limit the discussion of what the nature of ancient Babylonian divination is by erasing the term science from our discourse about it leads back to the predicament of binaries, to science and pseudo-science, science and religion, rationalism and irrationalism, and even science and superstition…. the category 'pseudo-science', in projecting a modern demarcation between legitimate and illegitimate sciences, miscategorizes ancient investigations of phenomena and ancient bodies of 'natural' knowledge as unjustified or wrong belief, and perpetuates anachronistic ideas about what the nature of Mesopotamian science was. (Rochberg 2010: 262)

The problem is that which Dear identified in 1998, discussed above: there are many dimensions to science. Not only are there cultural, intellectual, social and institutional dimensions, there is also a persistent ideological dimension. The latter is at the core of much of the heated debate about the place of science in society: regardless of how much some scholars challenge science's claims on truth and universality, others continue to uphold and defend the claims. As such, in the present landscape it would not be a politically astute move for everyone to restrict the term 'science' to the narrow place, time and culture Cunningham and Williams strictly associate it with, irrespective of how historically accurate that would be.

In 2012 Dear suggested a radical shift to accommodate the different issues at stake in these debates, at least for historians: to shift the focus of the history of science field from 'a history of science' towards 'a history of "science,"' in other words towards 'the history of the idea, or ideology, of "science" that has so possessed modern culture' (Dear 2012b: 37; see also Golinski 2012). Part of his argument was that a broadly ecumenical history of science, where 'science' includes 'any sort of knowledge or human activity to do with the world that we regard as serious, formally organized, and respectable,' would, in his view, 'have little real coherence' (p. 37). Further:

> An adequate, integrated history of science needs to confront many preconceptions about what science is and is not: whether it is one or many (methodologically or otherwise), or, indeed, whether it is nothing more than a culturally prestigious label to be attached to absolutely anything whenever one can get away with it. (Dear 2012b: 45)

This insistence on perpetual inquiry into the meaning of 'science' seems a reasonable caveat for a field of research based on something whose definition is

fundamentally contested, and the same must be said of applied science studies fields. Of course, philosophers of science have always engaged in such inquiry, but the critical point historians have added to the conversation is the notion that *the idea of science* itself has a history. Taking that seriously, we can see that 'science' is not a transcendent phenomenon whose nature we have as yet failed to define well. Rather, it is partly a rhetorical phenomenon, which has at times been presented in the guise of a transcendent door to truth. To be conscious of the history of this ideological framework is to remind oneself that advocating for change around science's place in society is an ideological act.

Dear's suggestion is thus perhaps the most fruitful contribution yet to emerge from Cunningham and Williams' legacy, both for historians and for applied science studies fields. He takes their program to a more sophisticated level, creatively interrogating the ideological scaffolding left by Koyré, Butterfield and Hall and their 19th century antecedents—the scaffolding upon which 'science' itself is built—rather than trying to pretend it is not there at all and was just an embarrassing historian's fabrication.

The works citing Cunningham and Williams directly are of course not the only materials published in the past two decades that have engaged with the old big picture of the history of science. To paint a full portrait of that picture's currency, we turn now to the 110 papers for which 'the scientific revolution' was identified as a key word, but which did not cite Cunningham and Williams.

Other Papers Engaging the Concept of 'the Scientific Revolution'

Of the 110 papers, 39 (35%) used the term 'Scientific Revolution' only cursorily and as a mundane name to identify a particular historical period, without qualification or comment on the term's historiographical implications (OR10). None of these focused on defining or debating the features of the period in question, so I did not analyze them further. But as with the 'trivial' citations of Cunningham and Williams, they are not without significance. It is worth noting their prevalence as an indication of the continuing currency of the term 'Scientific Revolution' within the literature, including history of science journals. It is not true to state that the notion of the Scientific Revolution has outlived its usefulness entirely. These sources affirm Hellyer's assertion noted above that it is a useful shorthand for referring to a particular set of events. However, we cannot tell from such cursory citations whether the term 'Scientific Revolution' still takes centre stage in these scholars' 'big picture' views of the history of science. There is a difference between using the term as shorthand for a set of events as these 39 papers do, and using it as shorthand for *a set of ideas about the significance of those events*. An additional seven papers (6%) help establish the importance of this distinction. These still used the term cursorily, but qualified it as 'the *so-called* Scientific Revolution,' or placed the phrase in scare quotes (OR11)—usages that undermine the significance implied by the convention of capitalizing the name and calling it a 'revolution.' Such qualifications are ambiguous but may constitute an acknowledgment of its contested nature.

Excluding these 46 papers from deeper analysis, we are left with 64 papers that discussed the Scientific Revolution in more detail, which provide the basis of the second part of the review. It is worth noting that approximately 50% of these papers (32 of the 64) were authored by scholars whose primary disciplinary identification (where it could be discerned) is something other than history, including the sciences, philosophy, religious studies, archaeology and anthropology, or language and communication studies. By comparison, only 20% of the 46 works citing Cunningham and Williams non-trivially (reviewed above) were authored by non-historians (and only 28% of all 68 works citing Cunningham and Williams). Those authors were also restricted to a narrower set of disciplines (mostly philosophy or science and technology studies) than non-historians in this second part of the review. This in itself demonstrates the relative lack of awareness of Cunningham and Williams' work beyond the discipline of history.

The most striking thing to note about these 64 papers is that, with a few exceptions, the authors tacitly accepted the historical existence of the Scientific Revolution in some sense. At the farthest extreme, 14 papers accepted the concept and large or small elements of the old big picture unquestioningly and without qualification (OR12). Non-historians authored the vast majority of these. In a few cases these authors acknowledged that something else important happened to science in the 19th century, lending some credence to Cunningham and Williams' proposed alternative big picture (OR13). But in all cases it was the Scientific Revolution that remained at centre stage, and the 19th century developments were secondary or only relevant in a reduced context.

That approach, however, is in a minority. Much more commonly, authors have sought to challenge the received view of the Scientific Revolution, though mostly without rejecting it altogether. The kinds of arguments such authors have put forward include: disputes over its definition and timing, or what it was that made it special or revolutionary (OR14); questions about what role was played in the Scientific Revolution by particular technical concepts, epistemological positions, or bodies of literature (OR15); critiques of ideological rhetoric that has emerged about science in the wake of the Scientific Revolution (OR16); a desire to see particular disciplines or practices included in the Scientific Revolution story (OR17); or a desire to radically revisit the Scientific Revolution story with a greater incorporation of the global, cultural, economic or social contexts in which it took place (OR18). The point for these authors is not to ask whether the Scientific Revolution happened, but how it happened, why, where, exactly when, and with whom. As such, they individually provide evidence that the concept is alive and well in the literature, and considered robust enough for its terms to be debated. Taken as a whole, though, these papers strongly suggest that the Scientific Revolution concept is vague, unwieldy and tattered, and can no longer be read as a neat and coherent moment in history. The sheer variety of challenges mentioned demonstrates the range of potential problems with the concept, a point noted by Cunningham and Williams in their decision to reject it entirely.

Only a small subset of the 110 papers engaged directly and/or deeply with the kinds of questions raised by Cunningham and Williams without citing them, so are worth discussing in more depth. H. Floris Cohen (1999) provided the most

uncompromising defence of the Scientific Revolution published in journals in this period, but his article was a transcribed lecture, so lacked the scholarly rigour expected of a journal paper. Cohen stated that he had 'good reasons' for persisting with the Scientific Revolution name and concept, but did not explain them (p. 107), relying instead upon a denigration of critical historians and of 'forlorn, postmodern angst' to make his point (pp. 108, 112). His article therefore adds little to the present debate, though this is an instance where his book might have shed more light.

A far more rigorous defence of the concept—and the most comprehensive and convincing defence in either part of this review—was mounted by economic historian Patrick O'Brien (2013). O'Brien evaluated the merits of the Scientific Revolution concept from a global history perspective in order to understand the impact of its events on the West, and thence on the rest of the world via Western expansion and imperialism. O'Brien's perspective was persuasively moderate: he accepted potential problems with the term 'Scientific Revolution'; acknowledged that related events developed gradually between 1500 and 1800 rather than transforming all of a sudden in a truly revolutionary manner; placed the Scientific Revolution in an economic and global context rather than fixating on its usual heroes; and unequivocally rejected any Eurocentrism or valorization of reason that may accompany the concept. He concluded with a statement that the Scientific Revolution's 'deeper intellectual origins have been properly located in Indian, Chinese, Arab, and Persian thought' (p. 24). As such, O'Brien demonstrated a mixture of acceptance and rejection of Cunningham and Williams' thesis. He acknowledged that something like the Scientific Revolution took place, and asserted that this something was inextricably related to our current concept of science, but he also de-centred those events in the history of the world by contextualizing them on a global stage. An essential part of his critique of academic debates about the Scientific Revolution was that they are parochial in focusing on the European story. In this, his view has some elements in common with that put forward by scholars like Rochberg, discussed above, that completely limiting the boundaries of 'science' to the modern West denies the political nature of the idea of science. O'Brien's argument was focused more on material links and influences and less on the terminology, but his interest was similarly in the politics of science.

Carolyn Merchant made an argument along similarly political lines, defending the use of the Scientific Revolution concept from a narratological perspective:

> the notion of a 'Scientific Revolution' in the sixteenth and seventeenth centuries is part of a larger mainstream narrative of Western culture that has propelled science, technology, and capitalism's efforts to 'master' nature — *a narrative into which most Westerners have unconsciously been socialized and within which we ourselves have become actors in a storyline of upward progress*. Demoting the 'Scientific Revolution' to the mere nomer of 'early modern science' obscures the power of the dominant narratives of colonialism and imperialism that have helped to shape Western culture since the seventeenth century at the expense of nature, women, minorities, and indigenous peoples. (Merchant 2006: 517; emphasis mine)

Merchant thus made a point critical to applied fields of science studies, that when we think about the Scientific Revolution and the history of science, we must do so with a reflexive awareness of its highly charged political nature. In other words she defended its discursive currency, though not necessarily its positivist legitimacy. In this sense her stance, and to a lesser extent O'Brien's, corresponds with Dear's idea for a reorientation towards a history of 'science,' or in the case of applied science studies, a perpetual reflexivity about science *being an idea supported by a narrative framework*, and the critical importance of actively interrogating that framework. These narrative elements of the Scientific Revolution were discussed in detail by Rivka Feldhay (1994), who identified the fictive narrative structures and techniques used by historians who engaged with the concept, including Koyré.

An essay review by Stephen Gaukroger (2002) would also fit Dear's reconceptualization of the history of science field. Gaukroger compared the Scientific Revolution to 'boom/bust' periods of scientific activity that occurred elsewhere in the world and in other historical periods to identify anything that made it unique—reasons why its 'boom' never went 'bust.' He concluded that it was the subsequent consolidation and legitimation of the scientific enterprise that made it different. Significantly for Cunningham and Williams' thesis, Gaukroger identified the end of the 18th century as the beginning of the period of consolidation and legitimation, which echoes their idea that this was the period of institutionalization for science. Further, Gaukroger identified a transition at that point from defending science 'in terms of its usefulness' to defending science 'in terms of its truth' (p. 282). This chronology and interpretation dovetails neatly with Cunningham and Williams' new big picture. It de-centres the Scientific Revolution in a new way, by casting it as one of many 'mini-scientific revolutions' (p. 280), and identifying historical rather than philosophical or jingoistic reasons why it did not end in a 'bust' like the others.

Several other papers also commented on the place of the Scientific Revolution within a global perspective, signalling an ambivalence about the old big picture and new ways forward. Harold J. Cook argued that while greater knowledge of how local cultures have shaped science has been a positive result of 'the decentering of stories about "the rise of the West,"' what is now needed is 'to discern the relationships among local knowledges' and 'to understand the apparent universalism of scientific knowledge' (Cook 2011: 108). On a slightly different track, Ting Xu and Khodadad Rezakhani (2012) criticized Eurocentric assumptions about the specialness of the Scientific Revolution and, like O'Brien, sought to establish that it was the outcome of a dialogue between civilizations. Roddam Narasimha (2003) went still further in an article responding to Joseph Needham's famous question of why the Scientific Revolution did not happen in India or China. He argued that many of the 'discoveries' attributed to the Scientific Revolution had in fact already occurred previously in India, as had some of the ideological battles such as clashes between science and religion. All three papers thus rejected the element of Eurocentric triumphalism they saw as present in the old big picture, and indeed that element seems to have been almost universally rejected, including in other papers reviewed here (OR19).

Finally, two papers written in the period provide support for Cunningham and Williams' thesis while acknowledging the pragmatic reasons the Scientific Revolution occupied such a central place in the history of science field. One, a

posthumously published paper by B. J. T. Dobbs, presented views similar to those published by Cunningham and Williams regarding the origins of the Scientific Revolution concept (Dobbs 1994). She agreed that Koyré, Butterfield and Hall's vision was an ideologically motivated, whiggish history, shaped by the political environment in which they were working. As such she criticized that history, while also acknowledging its strategic usefulness for the field. She presents as a natural ally of Cunningham and Williams, and one imagines she would have engaged deeply with their work had their papers not 'crossed in the night.' In the final paper, Mario Biagioli (1998) treated as a given the fact that the Scientific Revolution has fallen out of favour with historians, a perspective backed up by three other historians of science in review essays who characterized an unambivalent acceptance of the Scientific Revolution as outdated (OR20). But Biagioli discussed the fact that it continues to be used in titles of university courses on the history of science, essentially for marketing reasons. Like Cunningham and Williams and Dobbs, Biagioli identified the Scientific Revolution as the 'myth of origin' for the history of science field. But like Hellyer, he identified that it continued to have important practical value, because 'it is such a well established myth of origin that [historians] can get academic credit even by criticizing it' (Biagioli 1998: 145–146).

In sum, the authors engaging with the Scientific Revolution concept between 1994 and 2014 who did not cite Cunningham and Williams were, with a few notable exceptions, uninterested in critically questioning the concept altogether, though many sought to pick small holes in it. Most continued to use the term to reference a particular set of historical events, granting it continuing currency, but often stripped of its former ideological weight. Those few scholars who overtly defended it generally offered one of two arguments: first, that *the idea of the Scientific Revolution* has had ideological and narratological potency in global history that should not be ignored; or second, that it carries institutional benefits for the history of science field. Those few who explicitly criticized the concept did so along lines largely consistent with the Cunningham and Williams thesis.

All of this suggests that, with the exception of on-going debates about the uses of the terms 'science' and 'Scientific Revolution,' the historical tide is predominantly with Cunningham and Williams. Historians and historically minded others wish to paint a new empirical big picture of the history of science that does not have the Scientific Revolution at its centre. But discursively they seek to recognize the rhetorical power of the old big picture in shaping our thoughts about science for the past 70, or even 250, years.

Conclusions

This review has shown that, among historians and some other scholars, there has been a profound move against the old big picture of the history of science in the past 20 years. The events of the so-called 'Scientific Revolution' are no longer seen as the single or primary origin point for modern, Western science in the way they once were. Nor are they universally seen as the most centrally important events in the global history of science. The Scientific Revolution is no longer seen to be so clearly

defined, so revolutionary nor so special. Many historians continue to be interested in studying knowledge-making and technologies in 16th and 17th century Europe, but the triumphalist tale of human beings finally alighting on the truth in that time and place is no longer seen as empirically supportable, when viewed from a global, *longue durée* perspective.

The consensus alternative big picture presented in the reviewed works seems to be that the Scientific Revolution came to be seen as unique because of events that happened afterward. It did become the symbolic core of a global knowledge movement, while other developments in knowledge across the world did not. But this was not primarily because the understandings it offered were of particularly unusual quality. It was primarily because powerful intellectual forces during the 17th and 18th centuries successfully promoted some elements of Scientific Revolution-era knowledge as useful and/or as the path to truth. Consequently, these elements were consolidated during the Age of Revolutions, both institutionally and ideologically, as 'science.' The old big picture is now seen as the product of a particular reading of this story by some historians, who were inclined to frame it as the Revolutionary triumph of truth over ignorance, rather than framing it as the victory of a socio-cultural movement that championed the new philosophy and in doing so created 'science.'

It is notable that this 'new new big picture' version of the story differs from Cunningham and Williams' thesis in some respects. Cunningham and Williams sought to separate natural philosophy from science rather than identifying continuities between them, and so sought to paint science as a rather isolated phenomenon that is simply one among many approaches to the organisation of knowledge. Modern, Western science, however, is a long way from being de-centred in the new new big picture, and the Scientific Revolution still has a role to play in its story, so Cunningham and Williams' first and third premises are only supported halfway. Scholars largely agree that natural philosophy in early modern Europe and science in the modern West are different entities, and that understanding them as different has enhanced historical studies of natural philosophy. They largely agree that there was a problem with the old big picture, and that neither modern, Western science nor the Scientific Revolution were the only interesting things to happen to human understanding. But they remain fascinated by how we arrived at that picture and by its power in the modern world.

The work of scholars like Dear, Gaukroger, Merchant and O'Brien suggests that trying to decouple the 'Scientific Revolution' from the invention of 'science' is not sensible, since one was the narratological and ideological product of the other. Indeed, it may be more accurate to say that both ideas were created simultaneously and mutually support each other. In addition, some authors argue that the economic and political reality of Western science's power in the world today cannot and should not be ignored in our big pictures of the history of science. Rather, it is of interest to understand, in Dear's words quoted earlier, 'the history of the idea, or ideology, of "science" that has so possessed modern culture.' Thus, while few of the reviewed scholars privilege modern, Western science as the best way of understanding the world, many remain interested in how it came to be seen by so many people as the best way of understanding the world. They are therefore interested in how discourse about the Scientific Revolution influenced that history.

However, this does not mean scholars have generally rejected Cunningham and Williams' thesis. Its second premise—that 'science' was invented in the Age of Revolutions—is extensively supported within the literature, with almost nothing presented to contradict it. This is undoubtedly the clearest, most widely accepted shift in the big picture of the history of science since the 1990s. If a new new big picture does exist, it has the invention or consolidation of 'science' around 1800 as one of its most prominent features.

This has some significant implications for those working in applied fields of science studies. The thoughts I offer here are tentative though, and exactly what impact this new knowledge might have remains to be seen.

Most obviously, this review may prompt those involved in teaching or communicating about science history to reconsider the way they approach that task. This is most relevant to science teachers who are obliged to incorporate history of science elements into their curricula, and to the senior science education managers who write those curricula. It will also impact on science communicators, and perhaps even science policy-makers, who employ elements of science history when they write or talk about science.

Of more widespread relevance, this body of literature challenges us to reconsider the ways we define 'science.' It is clear from Cunningham and Williams' work that using the word too loosely, without specifying which particular body of knowledge we are referring to (from which time, place and culture) is inaccurate and unhelpfully reinforces old big picture thinking. On the other hand, restricting the word's application solely to modern, Western science, as Cunningham and Williams suggest, is not universally endorsed. Rochberg in particular raised pertinent objections to doing so, because of the negative judgments that might be implied about a knowledge system if we refuse to allow it to be labelled with the term. There seems to be no easy solution to this quandary. The best compromise may be qualifying the term with situating adjectives such as 'modern' and 'Western' where possible. But for practitioners in fields like science communication or science education this would quickly become untenable—it is not realistic to expect every news article or lesson about science to carry such qualifications. Nonetheless this issue is worth bearing in mind, and being continuously re-interrogated, because of its importance. This is particularly so when questions about the nature, authority or legitimacy of particular knowledge systems, including modern, Western science, are under discussion.

The new new big picture also, then, challenges us to reconsider how we think about the relationship between modern, Western science and other forms of knowledge making. None of the scholars reviewed here suggest that scientific ways of knowing are methodologically flawed and result in factual inaccuracies, but the literature does strongly undermine any idea that science has a monopoly on truth and understanding. The suggestion that modern, Western science succeeded as a global knowledge movement because of historically situated social, cultural and political factors, rather than inherent epistemological superiority, may be challenging for people working in disciplines primarily devoted to promoting science. For example, science communicators, policy-makers or educators whose job entails debating, regulating or teaching controversies that pit science against other sources of knowledge, such as climate change, creationism, vaccination or HIV denialism, may feel the scientific position is undermined by a more historicist view of science.

Certainly, public opinion about such issues is often swayed more by *ethos*-style rhetoric appealing to the established reputation of science (or its alternatives) than by the details of *logos*-style arguments, so historical work that appears to challenge the foundations of science's established reputation may change the rhetorical landscape in adversarial situations.

On a more positive note, a view of science as historically situated may enhance the quality of dialogue between representatives of science and representatives of other knowledge systems. For example, conversations about natural resource management on indigenous lands between indigenous traditional owners, on the one hand, and Western-trained scientists, on the other, may be more productive if there is a shared understanding about the geo-temporal and cultural situatedness of Western science. This would place Western science on a par with indigenous knowledge systems the world over, which are generally understood to be geo-temporally and culturally situated. For science communicators and science policy-makers involved in facilitating such discussions and translating them into law, again this will change the rhetorical landscape. But such changes may prove more empowering for all, and enable a more 'honest broker' approach to arriving at decisions.

Finally, the work reviewed here also paints a picture that has science's advocates playing a more central role in science history than appeared to be the case in the old big picture. The late-18th and early-19th century equivalents to today's science communicators, policy lobbyists and educators were surely those who first developed 'the idea, or ideology, of "science" that has so possessed modern culture.' A new history of science, then, would likely also be a history of the disciplines that have become applied fields of science studies. Historical work specifically examining these intertwined histories could radically alter our ideas about what the history of science looks like, away from the 'struggling lone genius' model of the old big picture. Perhaps applied science studies workers' ideas about the history of science will become less dependent on that old big picture if we can see the antecedents of ourselves alongside the geniuses, actively creating this thing called 'science' that is at the centre of our work.

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