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Chapter 13
The Structure of Scientific Revolutions and History and Philosophy of Science in Historical Perspective

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Introduction

My late teacher Gerry Geison used to say that *The Structure of Scientific Revolutions* is a book worth rereading once a year. With each new reading, one is bound to discover a new insight about science, and, I would add, one is also bound to raise new questions about the character of this revolutionary book. More than fifty years after its publication, *Structure* remains as intriguing and hard to categorize as it was when it first appeared. No less an authority on the book's character than its own author, even Kuhn himself had trouble classifying it: "Asked what field it [*Structure*] dealt with, I was often at a loss for response" (Kuhn 1993, xii). Recently, Ian Hacking again raised the question "is the book history or philosophy?" without addressing it directly (Hacking 2012, x). So, what kind of intellectual work is *Structure*, given that its ideas "are drawn from a variety of fields not normally treated together"?[1] Clarifying the book's interdisciplinary character may help us better understand and hopefully strengthen the troubled relationship between history and philosophy of science (HPS).

HPS as an integrated discipline goes back to the nineteenth century, when major philosophers and historians of science, from Comte and Whewell to Mach and Duhem, amalgamated historical study and philosophical reflection, imposing a "shape" on the scientific past.[2] During the first half of the twentieth century, however, as philosophy of history on a grand scale became suspect and philosophy of science focused on science as a static body of knowledge, issues about the pattern of scientific development receded into the margins of philosophical discussion. Kuhn's work brought those issues back to the forefront of philosophy of science, thereby reviving a nineteenth-century tradition of viewing science from a historical-cum-philosophical perspective. Since *Structure* offered a grand narra-

[1] The quotation is from Kuhn's application for a Guggenheim fellowship, dated 22 October 1953. See Hufbauer (2012, 459).

[2] I borrow the term from Graham (1997).

tive of scientific change in terms of long periods of normal science punctuated by scientific revolutions, it can be plausibly read as a contribution to the philosophy of history of science.[3]

Furthermore, *Structure*, more than any other recent work, opened up space for HPS as an integrated project, notwithstanding Kuhn's later claim that there is no such thing (Kuhn 1977, 4; 1980, 183). *Structure* raised novel questions (e.g., about the nature of scientific discovery or the character of scientific practice) that required an interdisciplinary approach. Neither historical research nor armchair philosophical reflection, by themselves, sufficed to address those questions. Rather, they could be tackled only through a combination of historical interpretation and philosophical analysis. Historical scholarship and philosophical argumentation had to be brought under the same roof.

In what follows, I will do four things. First, I will discuss some ways in which history and philosophy of science are intertwined in *Structure*. Second, I will briefly outline the history of HPS after *Structure*. Third, I will point out some possibilities for HPS opened up by *Structure* which, however, were not sufficiently explored in the subsequent career of HPS. Finally, I will reflect further upon one of those possibilities, namely philosophical history of science.

HPS in *Structure*

Structure was a rich blend of "something resembling philosophy" (Kuhn 1977, 8) and history. The relationship between philosophy and history of science in Kuhn's work has been extensively discussed and remains a controversial issue.[4] The focus of the discussion has been on whether Kuhn's extensive use of historical examples provides evidence for his philosophical claims or whether those claims were meant to stand on their own. While this is an important issue, my concern here is rather different; I plan namely to look at how Kuhn brought his philosophical acumen to bear on the historiography of science.

Before I discuss this, however, let me mention two uncontroversial points in the literature on Kuhn and HPS. First, it is widely agreed upon that Kuhn's philosophical reflections on scientific practice were elucidated and made plausible by discussions of historical cases, such as the Copernican Revolution or the discovery of oxygen. Conversely, on the basis of Kuhn's philosophical insights, such as the incommensurability of competing paradigms or the extended character of scientific discovery, those episodes were seen in a new light.

[3] Jardine (2009); Skinner (1990); Hollinger (1973, 370); Gordon (2012).

[4] See, e.g., Caneva (2000); Hoyningen-Huene (1992); Kindi (2005); Mladenović (2007); Sharrock and Read (2002).

Another uncontroversial point is that there was a direct link between Kuhn's experience as a historian and his philosophy of science. The notion of incommensurability, for instance, was motivated by Kuhn's difficulties in interpreting historical sources. "Incommensurability is a notion that for me emerged from attempts to understand apparently nonsensical passages encountered in old scientific texts. Ordinarily they had been taken as evidence of the author's confused or mistaken beliefs."[5]

Kuhn's realization that there was a conceptual gap between older modes of thought and contemporary science was in tune with the "new historiography of science," which ruled out anachronisms and retrospective evaluations of past scientific practice. These historiographical maxims were particularly prominent in the work of Alexandre Koyré, whom Kuhn deeply admired. *Structure* was put forward as an articulation of the image of science that was implicit in Koyré's innovative historiography.[6] Kuhn's account of scientific development provided, in turn, a powerful philosophical explication and defense of Koyré's non-presentist historiographical approach. In particular, the notion of incommensurability captured the conceptual and axiological distance between older paradigms and their contemporary descendants. Thus, it lent philosophical support on the resolve of historians to avoid contemporary concepts and values when interpreting past scientific beliefs and practices.

Thus, Kuhn's philosophical work has to be examined and appraised in close connection with his practice as a historian of science.[7] Despite his later ambivalence towards integrated HPS, there was an underlying unity in Kuhn's historical and philosophical work. He wore both hats (the historian's and the philosopher's) all the time.[8]

The new historiography of science was enriched further by Kuhn's philosophical vision. Philosophical theses, such as the theory-ladenness of observation and the importance of epistemic values in theory-choice, shed new light on previously puzzling features of scientific life, such as the existence of protracted disagreements among scientists. Kuhn did not just draw upon historical scholarship to score philosophical points. Rather, he employed the philosophical tools he had fashioned in order to illuminate key episodes from the history of science.[9]

[5] Kuhn (2000, 91); cf. also Caneva (2000, 98).

[6] Kuhn (1970, 3). Kuhn's indebtedness to the "new internal historiography of science" has been emphasized by Paul Hoyningen-Huene (1993). Cf. also Larvor (2003).

[7] Cf. Sharrock and Read (2002, 2).

[8] Cf. Kuhn (2000, 85, 91); Marcum (2015, 109–111, 115–116).

[9] It should be noted that Kuhn stressed the philosophical, rather than historiographical, ambitions of *Structure* (see, e.g., Kuhn (2000, 276)). As I will suggest below, however, the significance of that book lies equally in its fruitful historiography.

For instance, on the basis of his philosophical analysis of scientific discovery, Kuhn developed a novel approach to the discovery of oxygen. In the older historiography of the chemical revolution, which dated back to the nineteenth century, the discovery of oxygen was attributed either to Joseph Priestley or to Antoine Lavoisier, depending on the national loyalties of the chemist-historian. In either case, those attributions presupposed that scientific discoveries are precisely datable events that can be credited to particular scientists. Kuhn argued that this presupposition blocked the historical understanding of the emergence and consolidation of the oxygen theory of combustion, by raising unanswerable and misleading questions about the date of the discovery of oxygen and the identity of its discoverer.

Kuhn suggested instead that scientific discovery is an extended process, involving the development of a novel theoretical framework, which inevitably spans a prolonged period and is a collective achievement. This explains why many scientific discoveries cannot be exactly dated or exclusively associated with individual scientists. Thus, Kuhn's meta-historical conception of discovery gave rise to a more sophisticated understanding of the discovery of oxygen. This could now be seen as the outcome of an extended and controversial process of experimentation and theorizing that involved the isolation of a constituent of atmospheric air and its conceptualization as a chemical element with distinct properties. Incidentally, the question of who discovered oxygen, Priestley or Lavoisier, now lost any appeal it might have originally held.

HPS after *Structure*

In post-*Structure* developments, we can discern two main strands of HPS: historical philosophy of science and philosophical history of science. The former addresses general epistemological and metaphysical issues about science in light of its historical development. The latter explores particular historical episodes while taking into account philosophical considerations about, e.g., the dynamics of scientific theories or the processes of conceptual change.

If we look at the history of HPS with this distinction in mind, we immediately realize that HPS has been dominated by the first strand, historical philosophy of science. To begin with, history of science has been used as a source of "data" for generating and evaluating philosophical accounts of scientific development. In *Structure*, Kuhn suggested that "theories about knowledge" should be subjected "to the same scrutiny regularly applied to theories in other fields" (Kuhn 1970, 9). In that spirit, he drew upon historical scholarship on the Copernican and the Chemical Revolutions to motivate and support his model of scientific development. Other philosophers of science, most notably Imre Lakatos

and Larry Laudan, took up the challenge of developing alternative accounts of scientific change that could capture its rational and progressive character (purportedly undermined by *Structure*). In that "confrontation model" of the relationship between history and philosophy of science, history of science was seen as a repository of facts for testing theories of scientific change (Schickore 2011). This approach to historical philosophy of science is now passé, primarily because there are grave doubts that historical evidence can be sufficiently detached from philosophical theories so as to be used in their evaluation (Nickles 1986). Rather, it has been plausibly suggested that philosophy of science should be seen as a hermeneutic enterprise that interprets the historical record in terms of its analytic concepts, which in the process of interpretation may be refined or modified.[10]

Furthermore, history of science has been brought to bear on salient philosophical issues, such as rationality, relativism and realism. In the 1960s and 1970s, historical episodes of theory change (e.g., about the transition from ether-based electromagnetic theory to the special theory of relativity) were discussed in connection with the rationality of scientific development. The philosophers who contributed to that literature were for the most part interested in retrospectively justifying the outcome of past scientific episodes in light of philosophical accounts of scientific change, such as Lakatos' methodology of scientific research programs (Howson 1976).

Kuhn complained that philosophical case studies of that nature confused *ex post facto* philosophical justification with historical explanation (Kuhn 1980). It is no wonder that historians of science remained indifferent to HPS so conceived. They didn't see any added value in that enterprise and were repelled by its normative character. Thus, they stayed clear of the debates over HPS.[11]

In the 1980s, history of science entered forcefully into the realism debate. Historical cases of entities that have dropped out of the ontology of science (e.g., phlogiston and caloric) were used to throw doubt on "convergent realism," the view that science has been progressing towards the truth about nature (Laudan 1981). Ever since, history of science has occupied a central stage in philosophical discussions on scientific realism (Vickers 2013). In this area too, even though history and philosophy of science were brought closer together, all the action was on the philosophical side. Historians of science kept a safe distance from those debates, perhaps because they had already distanced themselves from the image of science associated with "convergent realism." The realist tendency to view older scientific theories as imperfect versions of contemporary ones was (and still is) anathema to most historians (Arabatzis 2001).

[10] See Schickore (2011); Nersessian (1995) made the same point earlier in connection with cognitive history of science.

[11] As can be glimpsed from Zammito's comprehensive survey (2004, chap. 4).

Proceeding to the second strand of HPS, philosophical history of science, we can see that it has been a relatively neglected endeavor. Whereas Kuhn's *Structure* made evident the philosophical stakes in the history of science, the historiographical relevance of philosophy of science has remained rather obscure. To many historians of science, philosophy of science still lacks "pragmatic value" (Buchwald 1992, 39).

Furthermore, Kuhn's grand narrative of scientific development was not well received by historians of science, who have been skeptical of his generalizations and have not adopted his terminology and conceptual apparatus (paradigm, normal science, crisis, revolutions, etc.) to describe and explain how the sciences have developed.[12] It is indicative of the historians' continuing indifference to Kuhn that only one major history of science journal, *Historical Studies in the Natural Sciences* (42:5, 2012), has devoted a special section on the 50th anniversary of *Structure*. Sociologists of science and intellectual historians, on the other hand, have been more receptive to Kuhn's message.[13]

Nevertheless, it would be fair to say that Kuhn's book has influenced substantially, if indirectly, historiographical practice.[14] Historians of science have learned from Kuhn, among other things, to appreciate the "losers" in scientific revolutions and see them as rational agents that resisted the new paradigm, often for good reasons. Furthermore, Kuhn's approach to science as a practice shaped by tradition, involving tacit knowledge and depending on rigid forms of training has stimulated historical research and has been substantiated by several historical and sociological studies.[15]

Structure and Philosophical History of Science

What morals about HPS can we draw from *Structure* and its early reception among historians and philosophers of science? Kuhn's classic work offers a spectrum of possibilities for integrating HPS, each possibility blending philosophical analysis and historical interpretation in a distinct manner.[16] On the philosophical side, there is little doubt that history of science can cultivate philosophical intuitions and function as a source of insights about the epistemology and the ontology of

[12] Cf. Hollinger (1973).

[13] See the special issues of *Social Studies of Science* (42:3, 2012) and *Modern Intellectual History* (9:1, 2012), respectively.

[14] Jan Golinski (2011) has plausibly argued that Kuhn's impact on history of science was mediated by the sociology of scientific knowledge and the Edinburgh School.

[15] See, e.g., Kaiser (2005). For a recent, rather critical assessment of Kuhn's impact on history of science, see Cohen (2012).

[16] Some possibilities for HPS, although not necessarily in a Kuhnian spirit, are suggested in Arabatzis and Schickore (2012).

science.[17] An engagement with history of science can also cultivate a sensibility to the complexity and variability of scientific practice, which have to be accommodated within an adequate philosophical account of science.[18] On the historiographical side, philosophy of science can stimulate and enrich historical work. In the subsequent history of HPS, only some of those possibilities have been explored in depth, mostly those related to historical philosophy of science. HPS has been, for the most part, a philosopher's game, where internal history of science is put in the service of philosophical theorizing. I think it's high time to redress this imbalance and further develop philosophical history of science by exploring how philosophy of science can be involved in historical interpretation.[19]

Philosophical history of science, as I conceive it, aims at understanding the scientific life in terms of philosophically articulated meta-scientific concepts, such as discovery, objects, models, epistemic values, the relationship between theory and experiment, etc. By actively drawing upon the philosophical literature on, say, scientific modeling, philosophically inclined historians of science may shed new light on familiar scientific episodes and in the process refine and modify the philosophical tools that they use.

I see Kuhn's *Structure* as the founding work for philosophical history of science in the above sense. In that respect, its importance did not lie in Kuhn's grand narrative of scientific development. As I already pointed out, although this narrative may fit some historical cases, it has not been taken seriously by historians of science, who, for the most part, have moved away from big pictures of scientific development and towards small-scale analyses of particular developments.[20]

Rather, the significance of *Structure* for philosophical history of science rests on some of Kuhn's insights into scientific practice, such as the role of epistemic values in theory-choice. Furthermore, his liberal conception of scientific rationality led to a more sympathetic understanding of the "losers" of scientific controversies, who can no longer be seen as irrational holdouts obstinately resisting scientific proof. Despite the fact that "there is no Kuhnian school of history" (Andersen, Barker, and Chen 2006, 1), several philosophically inclined historians of science have enlisted aspects of Kuhn's philosophy of science in the service of historical analysis and interpretation.

To begin with, incommensurability, a key Kuhnian notion, has been deployed to interpret various debates, from the wave theory of light (Buchwald 1992) to recent particle physics (Pickering 2001). Jed Buchwald, for instance, employed Kuhn's taxonomic approach to incommensurability to conceptualize

[17] Cf. McMullin (1974); Schindler (2013).
[18] Cf. Kindi (2005).
[19] For systematic reflections in this direction see Kuukkanen (2013).
[20] Cf. Golinski (2011, 25); Hollinger (1973, 370); Gordon (2012, 73).

the development of nineteenth century optics and electromagnetism, and argued that Kuhn's philosophical framework can deepen our understanding of the developments in those fields. More recently, Hasok Chang has also made use of incommensurability to interpret the late eighteenth century transition from a phlogiston-based to an oxygen-based chemistry. Chang argued that the proponents and the opponents of phlogiston had incommensurable methods, epistemic values and problems. One can thereby understand why the controversies around phlogiston were so difficult to resolve and why phlogiston chemistry persisted well into the nineteenth century. Thus, Chang's work shows the historiographical fruitfulness of incommensurability, a notion which Kuhn considered his main contribution to philosophy of science.[21] Conversely, Chang's engagement with late eighteenth and early nineteenth century chemistry has revealed some limitations of Kuhn's original understanding of incommensurability. In particular, Kuhn's overstated emphasis in *Structure* on conceptual incommensurability cannot accommodate the substantial continuity, at the level of chemical observations and manipulations, across the divide separating the phlogiston-based and the oxygen-based theories of combustion.[22]

Kuhn's approach to scientific discovery has also proved historiographically fruitful. As I pointed out above, Kuhn criticized the conception of scientific discoveries as temporally and spatially non-extended events and argued that it hindered historical understanding. Taking Kuhn's analysis as its point of departure, recent scholarship has further documented the complexity and extended character of particular scientific discoveries.[23] For instance, my own work on the discovery of the electron has been inspired by Kuhn's account of scientific discoveries as extended processes, involving the detection and most importantly, the gradual conceptualization of novel entities. This has led me to question the simple-minded attribution of the discovery of the electron exclusively to J. J. Thomson. As I have come to realize, Thomson's work must be situated within a complex landscape of converging developments, spanning from electrochemistry to spectroscopy, which collectively comprise the discovery of the electron.

To conclude, Kuhn's *Structure* got philosophical history of science off the ground by suggesting a rich repertoire of meta-scientific concepts for describing and interpreting the scientific past. Philosophically inclined historians of science have fruitfully framed their narratives and analyses of particular historical episodes in terms of those concepts. In my mind, this aspect of *Structure*'s legacy

[21] Chang (2012); cf. Collins, in this volume.
[22] According to Kuhn's later taxonomic approach to incommensurability, locally incommensurable "lexicons" may share a common observational ground.
[23] Arabatzis (2006); Caneva (2005); Dick (2013).

has outlasted Kuhn's famous grand narrative of scientific development and will continue to enrich the historiography of science for years to come.

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