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Science in the Twentieth Century and Beyond

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It is 50 years since Thomas Kuhn published the million-selling *Structure of Scientific Revolutions*, and the work reviewed here rightly acknowledges Kuhn's to be 'by far' the most cited and discussed 20th-century book about science (pp. 415–16). What has the history of science come to in the intervening half century? Judging by the majestic scope of Jon Agar's new volume, we still have fertile big-picture approaches to guide us through the untidily evolving and multiplying plurality of the natural sciences. Certainly an awful lot of science has happened since 1900 (certainly far more than in any previous century) so it quite an accomplishment to cover the requisite material in around 600 pages. More importantly than that, this work epitomizes how much we have learned from attempting to generalize about the mechanisms and meaning of scientific change since the long debates on such Kuhnian themes as 'paradigms', 'revolutions' and the alleged 'incommensurability' of successive scientific world-views. Revealingly, Agar mentions this Kuhnian lexicon only two thirds of the way in, and even then only in a single passing paragraph. So by this late point in the monograph's narrative, we realize that such terms are brought out by Agar only as historiographical relics from an outmoded past master.

Yet one Kuhnian term does still linger in Agar's analysis: the notion of 'normal science' as a core feature of productively organized and mundanely un-revolutionary collective research (p. 58). And this is the ancestral clue to Agar's big interpretive theme: he seeks to recover scientists 'working worlds' as a framework for empathetic historical reconstruction of their myriad intersecting daily endeavours. The great advantage of this approach is that, unlike Kuhn's depiction of scientific paradigms as solipsistic self-referential enquiry, Agar illustrates the many heterogeneous factors that have contingently moulded the agenda, resources and methods of the sciences. These include the domains of technology, business, medicine, healthcare, social

policy, politics and – above all – warfare. As we shall see there is much of value in this ‘working worlds’ approach, but also plenty to treat with caution.

In Agar’s synthesis we find ourselves a long way from the erudite but somewhat sterile and static taxonomies of science that featured in John Pickstone’s *Ways of Knowing*, and much nearer to the territory of David Edgerton’s *Warfare State: Britain, 1920–1970*.(1) Indeed, we see how far the sciences have learned to thrive in circumstances of ubiquitous conflict and economic competition, rather than eschewing these worldly concerns, as idealized and ideologically-loaded models of so-called ‘pure science’ would have us believe. Such a model of science as a socially detached enterprise is what lay at the heart of Kuhn’s book. Indeed, in ways which can still surprise the 21st-century reader, Kuhn barely reached into the 20th century, never strayed beyond the physical sciences, and never reflexively acknowledged the Cold War context of the thriving military-industrial complex in which the *Structure* was written. By contrast, Agar opens up the 20th century in ways not even conceived by Kuhn, and treats us to a range of sciences that reveal how by the end of the last century, the physical sciences had been eclipsed in their intellectual and political significance by a complex of disciplines focussed on genetics, mind and body. The sophistication of Agar’s management of all these points of reflexive and disciplinary rigour shows just how much historians of science have learned from other authors than Kuhn and other (sub)disciplines.

Thus, in his carefully crafted introduction, Agar lays out his vision of working worlds as ‘arenas of human projects that generate problems’. In this account the sciences are tasked to solve such problems – in implicit contrast to Kuhn’s vision, in which scientists freely chose which anomalies to study in their normal science. And, rather than trying to construct unworldly paradigms, science for Agar is the ‘making, manipulation, and contest of abstracted, simplified, representatives of working world problems’, with outcomes that were resulted as regularly in new kinds of knowledge as in new and useful products and machines. The four principal (albeit overlapping) categories of working worlds he lays out are: technological systems, the mobilization of fighting forces, civil administration and maintenance of the human body. It is in turn the task of the historian of science to reveal the larger connections between the sciences and these working worlds so that we can escape the thrall of localized case-studies that have informed yet stultified so much history of science (pp. 1–5).

The structure of *Science in the Twentieth Century* is revealing of how Agar conceives the relative importance of these four forms of working world. The work is framed by studies of novel scientific enterprises at each end of the century. New kinds of physics, life sciences and sciences of the self are covered in part one (‘Science after 1900’) while part four (‘Sciences of our world') addresses new environmental themes developing from the 1960s (in which Kuhn’s contemporaneous work is mentioned parenthetically), new kinds of very big networks in genomics, internet-based computing etc., and the challenge of connecting the miscellaneous ends at which the sciences had arrived by the turn of the 21st century. Part two is a study of ‘Sciences in a world of conflict' – the First World War and Nazi science – while part three covers the Second World War and the Cold War, studying the particular sciences that the latter comparatively non-lethal conflict generated. The Edgertonian themes of science co-evolving with warfare thus take up the preponderance of this monograph, cogently linking the rise of global warfare with the rise of global science. Not all readers will agree with this emphasis, but Agar undeniably offers us a refreshing change from the peaceable sequestered world of Kuhnian ‘normal’ science innocent of participation in, let alone profit from, the world’s darkest woes.

Agar’s strategy is to develop the interpretive theme of ‘working worlds’ through chronological progression through examples in these four main sections. Rather than overburdening with theoretical exegesis, he returns to the theme at over 20 points in the text – although (surprisingly) it is not the subject of a substantial synthetic overview in the book’s conclusion, being mentioned only at the start and finish. That being said, the notion of ‘working worlds’ is left so open-ended and (arguably) protean that it could be made to fit almost any historical scenario. And as the phrase ‘working worlds’ has been used before in sociology and healthcare, one would hope that Agar would have more explicitly contrasted his usage of the term with theirs.

It must be said that the effective deployment of the 'working worlds' theme is more evident in some parts in

the book's first section than others. This material might all too easily be read as a conventional account centred upon some familiar 'discovery' pairings intruding from the 19th century: J. J. Thomson and the electron, Gregor Mendel and the gene (although Agar does not emphasize that the attribution of the electron's discovery to Thomson was as retrospectively contrived as the attribution of the discover of the gene to Mendel). The principal force of the working worlds thesis in this early section is that the universalizing projects of communication, power and lighting (especially the electrical varieties), along with patents for these, actively generated demands for new knowledge that both furnished physics laboratories with equipment, and motivated a train of theoretical investigation (primarily in Germany) that led to the founding of quantum theory. To be specific, Agar characterises the origins of that theory as the result of a 'collision between sciences relevant to the working world of steam engines and empirical measurements extracted from the working world of electrical light and power' (pp. 26–39). This is not quite the working worlds thesis as laid out in the introduction, but it is at least coherently drawn from the solid scholarship of David Cahan on research c. 1900 at the Physikalische Technische Reichsanstalt in Berlin.(2) Agar certainly avoids the cliché of associating Sigmund Freud in any facile fashion with the discovery of the unconscious; instead our author works hard to bring the late 19th-century understanding of electric currents in terms of fluid flow in lighting circuits (but oddly not in telegraph wires) to explain Freud's modelling of the human mind in terms of fluid flow (p. 67). This is not quite the thorough reconstruction of Freud's working world of that we might have anticipated, but we do at least see here the benefits of Agar's attempt to make connections between different domains of the increasingly diverse early 20th-century physical and psychological sciences, which are rarely ever connected by historians.

The 'working worlds' thesis acquires a stronger purchase when it is deployed in the context of the 'Big Science' that emerged in the contexts of military conflict that dominate discussions in the mid-part of the book. After all, it was in the making of a whole new industrial mode of science that scientists were first obliged (but not unwillingly) to turn to state/military and commercial sponsorship to supply resources on the scale needed to conduct the new kinds of enquiry initiated in the 20th century, whether these be the initiation of radar, atomic bombs or biotechnology. Most spectacular in this regard is the arrival of high-speed computing during the Second World War and its aftermath – computer scientists getting their problems, agendas and expense accounts from the military who were both sponsor and customer. From this project emerged radio-astronomy, the control theory of cybernetics, artificial intelligence and genomics. Without the power of electronic computing made possible by several decades worth of US military budgets, and the kinds of project favoured by the US military in this period, it is hard to see how scientists' working worlds would have led them to these particular projects and outcomes (pp. 367–99). Indeed, it is not surprising that it is in this discussion that Agar devotes most effort to re-articulating the working worlds thesis – in ways that might make the sceptical reader wonder if it is only in this context that Agar's thesis can be effectively applied.

As already indicated the book's conclusion does not substantially rearticulate the working worlds theme, except to say that 'much good science' was done by measuring, comparing and contesting simplified and abstracted 'representative models of working world situations.' Thus does the author deftly concede that there may have been at least some 'good science' that was not accomplished by such means. One such candidate is the 'black holes' identified by Robert Oppenheimer and his students in the late 1930s as an extreme result of the application of Einstein's General Theory of Relativity Theory to stellar collapse. This *topos* is mentioned by Agar (p. 241) without any indication of how black holes came into the world under the pressure of anything except theoretical physicists' exploration of their own esoteric mathematical tools and complex theories – just the kind of explanation that a traditional Kuhnian account of paradigms would have cherished. Doubtless there are other examples that readers (or their students) might wish to explore to find the parts of science that do not so readily fit into Agar's thesis, or might even be framed as counter-evidence to it.

Whatever might be said of the working worlds thesis (and we can but hope that Agar will further elucidate this theme in a future publication) his conclusion does build on what has emerged in the main core of the book to present a bigger picture. Three big themes emerge: in addition to the pre-eminence of warfare in

supporting (directly or indirectly) the development of many sciences, he notes the rise of the USA as the predominant power in the sciences by the end of the century, and the rise of the biomedical sciences to eclipse the mid-century prestige and efficacy of the physical sciences that emerged from atomic warfare. These are surely sound – if unsurprising – conclusions. It remains for the reader to consider whether the best historical explanation of these can be found in some formulation of the 'working worlds' thesis or in more conventional socio-political analysis.

Indeed, the scientist-centred assumptions of the working worlds thesis can make parts of this book a rather provocative read. Take, for example, Agar's analysis of the recent rise of nanotechnology which cites Langdon Winner's 2003 criticism of the United States' forays into that novel field . Winner sees these forays as the opportunistic creation of pseudo-goals to suit nano-technological means, with little attempt to ask what social needs of Americans those means might have been harnessed to meet. Although sympathetic, Agar suggests that Winner misses the point here by failing to observe that the particular working worlds that have generated nano-technology are those of scientists, not the wider society that interests Winner. This presumptive prioritization of the scientists' working worlds over that of society in Agar's account certainly differentiates it from historical sociologies of science that have naïvely presumed the public has had some kind of *de facto* sovereignty over the trajectory of recent science. Yet it also reveals that Agar's commitment to the working worlds thesis is at the expense of understanding how far the new sciences he writes about have become more socially accountable in the post-Cold War era, or whether the sciences still exist in a neo-Kuhnian world in which scientists are still free to set up and resolve their problems irrespective of wider social issues (p. 496). It is interesting therefore that Agar does not explore the limits and possible contestation of the working worlds approach: we are simply left to infer the uncongenial point that scientists have not in general welcomed the views of the public on their work, whereas (to put the matter in Agar's terms) the public has often sought to become part of the working world of scientists by constraining what they do with some kind of social contract – tax-payers' money to be spent only for public benefit. This apparent limitation of Agar's formulation of the 'working worlds' approach that privileges scientists perspectives over those of others might well be a fertile theme for further work.

There are also weaknesses to which the author himself honourably and candidly admits (p. 507). One of these is the heavy reliance on secondary sources – although this is a problem endemic to all synthetic 'big picture' volumes. At least in contrast to Kuhn and even Pickstone the range of secondary literature in the history of science that Agar draws upon is substantial, even polymathic in scope. Fortunately it is only occasionally the case that his choice of secondary sources leads to a distortion of emphasis, for example on the electron where the story is still more British- (and indeed Cambridge-) focussed than state of the art literature would have us believe.(3) He notes that his attempt to study all of the sciences for the entire 20th century in a single volume is necessarily going to be selective in ways that understate the significance of some potentially very important issues. These include key episodes of non-Euro-American science (notably in Japan), also sciences that were discredited and then only later revived ('Is history of science a history of the undead?' Agar asks rhetorically), and also those stories lost to posterity by being the subject of strategically managed secrecy. In effect Agar invites readers to consider these 'missing stories' as potential future research topics. Perhaps a wiki related to the book might be set up on these grounds for students to (attempt to) complete the project in the decades to come.

On the plus side, this book, like Kuhn's (but unlike Pickstone's), opens up new avenues and projects for enquiry. This reviewer believes that the provocations and gaps in this volume will inspire research and teaching in the subject, taking longer overviews of topics, and reconstructing the contingencies of scientists own working worlds rather than imposing on their lives boiler-plate templates from political or cultural theory. Generations of students might take great pride in fill in the gaps and critiquing the basic assumptions and terminology of the book, just as scholars have done for fifty years with Kuhn's (in)famously challenging monograph.

To give one example of the fertile territory here, at the close of this often fascinating book we find Agar sticking his futurological neck out in a manner untypical of the epistemically modest historian. In looking

forward to contemplate what forces might shape the sciences of the 21st century, he pinpoints as key factors: the conflicts between the working worlds of energy intensive societies, international environmental governance and global commerce (p. 530). This is an interesting shift of emphasis from his analysis of the 20th century: either warfare will disappear as an independent force from his menagerie of working worlds, or – a much more chilling prospect – armed conflict will become integral to competing efforts to secure each of these areas of energy, power, profit and sustainability. Let us hope that, on reading this book, those responsible for the generations to come might see the usefully prognosticatory wisdom that Agar lays out and steer us away from an Armageddon that might prevent a comparably ambitious book being written about 21st-century science.

Notes

1. John Pickstone, *Ways of Knowing: a new history of science, technology and medicine* (Chicago, IL, 2001); David Edgerton, *Warfare State: Britain, 1920–1970* (Cambridge, 2005)Back to (1)
2. David Cahan, *An Institute for an Empire The Psysikalisch-Technische Reichsanstalt, 1871-1918* (Cambridge, 1988)Back to (2)
3. Jed Buchwald and Andrew Warwick, *Histories of the Electron: the Birth of Microphysics* (2nd. ed., Cambridge, MA, 2004).Back to (3)

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