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INTRODUCTION

The history of science, the 'big picture' and the politics of scale

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Abstract

What does it mean to write the history of science and the 'big picture'? In this introduction, I argue that 'scale' is a crucial but relatively underutilized concept for addressing this question. Rather than taking 'big' as a transparent category, I develop a detailed theoretical account of scale in the history and historiography of science. Following work in political geography, I argue that there is a 'politics of scale', one that the sciences have played a key role in shaping. Following work in the philosophy of history, I argue that scale should be thought of in its temporal dimension as well as its more traditional spatial dimension. And following work in cultural anthropology, I argue that scale should be understood as an actor's category just as much as an analytic category. The sciences, it turns out, have been one of the principal means through which scale is made and contested. More broadly, this volume of *BJHS Themes* encourages a creative and open-ended approach to scale in the history of science.

> The microscope is a marvellous instrument for research: but a pile of microscope slides does not make a work of science.
>
> Marc Bloch[1]

The history of science lacks a sense of the 'big picture'. Three decades ago, James A. Secord identified this problem in an influential special issue of the *British Journal for the History of Science*.[2] At the time, the history of science was dominated by localized case studies – quantum mechanics in Weimar Germany, phrenology in 1830s Edinburgh, experimental philosophy in seventeenth-century London, and so on. These case studies, localized in time as well as in space, were important for challenging the post-war consensus that modern science was universal. However, as Secord noted, this proliferation of case studies also undermined any sense of the 'big picture' – how and why science changed over the *longue durée*, and how science moved between different parts of the world. 'The striking lessons of recent research need to be applied to longer time spans, a broader range of participants, and wider regional and global perspectives', argued Secord in 1993.[3]

1 Marc Bloch, 'Regions naturelles et groupes sociaux', *Annales d'histoire économique et sociale* (1932) 4, pp. 489–510, 505, translation my own.

2 James A. Secord, 'Introduction', *BJHS* 1993 (26), pp. 387–9.

3 Secord, op. cit. (2), p. 387.

Looking at the discipline today, it is fair to say that not much has changed. The history of science is still dominated by localized case studies, especially when it comes to journal articles. It still lacks a sense of the big picture. True, in recent years the field has started to move beyond its traditional Eurocentric focus. There are now many excellent national and regional studies of the history of science in Latin America, Asia, Africa, the Middle East and the Pacific. Yet it remains a challenge to connect these disparate local case studies together. And whilst a number of more generalist books on the history of science have been written since 1993, these too have struggled to make an impact on the wider field.[4] For now, the big picture remains stubbornly elusive.

This is worrying for many reasons, not least because the need for big-picture histories of science is more urgent than ever. Whether it is climate change or artificial intelligence, the contested place of science in society is at the heart of major contemporary political debates. Happily, there has been a move towards writing for broader publics on these and related issues, as exemplified by the work of Naomi Oreskes and Erik M. Conway.[5] Public engagement is also something well supported by the British Society for the History of Science through the Hughes Prize (formerly the Dingle Prize).[6] However, the impact of such work has yet to feed back into the writing of journal articles or postgraduate training. Historians of science, in my view, have a public duty to share our knowledge and engage with a variety of disciplines and audiences.[7] This should be a core feature of postgraduate training. It should be a value reflected in the pages of our leading academic journals. It is not enough to simply insist that the history of science is 'complex', 'contested' or 'contextual'. Such an approach is characteristic of what Steven Shapin once wonderfully called 'hyperprofessionalization', in which 'professional success is indexed by insularity'. If we don't write for wider audiences, both academic and public, the history of science risks 'death by purification'.[8]

This volume therefore invites historians of science to re-engage with the problem of the big picture. It brings together scholars at different career stages working on a variety of regions and drawing on a range of approaches. The volume also features a round table conversation with six of the contributors to the original 1993 special issue of the *British Journal for the History of Science* on *The Big Picture*. As with that original special issue, authors in this volume were 'invited to be speculative, sketchy, polemical and provocative'.[9] The idea was to push beyond the typical localized case study, to say something more general about content, theme, method or perspective in the history of science. But beyond that, there was no set expectation, and contributors have approached the task in a diversity of ways: some more empirical, some more theoretical, some located within particular regional histories, others expansive in geography or chronology. In writing this introduction, I have therefore made the somewhat unconventional decision not to explicitly summarize each of the articles. Instead, I am going to ask you, the reader, to do something a bit unusual: read the whole volume. Yes, all the articles, in order, front to

4 For a more detailed discussion of the various 'big pictures' which have been published since 1993, see Michael Bycroft's contribution to this volume.

5 Naomi Oreskes and Erik M. Conway, *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*, London: Bloomsbury Publishing, 2012.

6 'Hughes Prize', British Society for the History of Science, at www.bshs.org.uk/prizes/hughes-prize (accessed 17 November 2023).

7 I share the view that 'large-scale questions' are 'what makes history a public discipline'. Marshall G.S. Hodgson, *Rethinking World History: Essays on Europe, Islam and World History*, Cambridge: Cambridge University Press, 1993, p. 255.

8 Steven Shapin, 'Hyperprofessionalism and the crisis of readership in the history of science', *Isis* (2005) 96, pp. 238–43, 239.

9 Secord, op. cit. (2), p. 387.

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back. Don't simply skip to the one that sounds closest to your specialist area of expertise. You might not find all of the articles as convincing or as relevant. That's fine. But if you do read them all, you will have got a good sense of what the big picture could be, and what work remains to be done.

With all that said, I want to use this introduction to provide a frame for the big picture you're about to examine, something to mull over as you work your way through the volume. There are, of course, reasons to be pessimistic about the big picture. Secord, after all, was neither the first nor the last to identify the problem. Writing in 1991, the Dutch historian of science Caspar Hakfoort published an article titled 'The missing syntheses in the historiography of science'. Hakfoort similarly lamented the lack of 'general, synthetic surveys of the history of the natural sciences'.[10] He even complained that the *Cambridge History of Science* series of monographs amounted to 'no more than a coloured patchwork quilt'.[11] Another decade passed, but little changed. Writing in the introduction to a 'Focus' section of the journal *Isis* in 2005, the American historian of science Robert E. Kohler noted that 'fewer articles were being written in a generalist vein'. What the discipline needed, according to Kohler, was 'a general history of science', one to balance the avalanche of 'local microstudies'.[12] Fast forward to 2024, and we're still talking about the same problem. Why might things be different this time?

My observation is as follows: until very recently, historians of science failed to properly engage with the concept of scale. For all the talk of the big picture there was no serious discussion of what 'big' might actually mean. Even concepts such as 'local' and 'global' remained somewhat unclear.[13] For the big picture to succeed, I argue, we need a proper account of the place of scale within the history of science. In order to do this, historians of science will need to draw on scholarship in political geography, the philosophy of history and cultural anthropology, in which scale features much more prominently. At the core of my argument is the notion of the 'politics of scale'.[14] Rather than choosing between big and small, we should instead recognize that different analytical scales produce different politics, and vice versa. Such an approach invites us to get much more creative when it comes to scale, avoiding unhelpful binaries such as local versus global, or micro versus macro.[15] Alongside this, historians of science need to understand scale as both an analytic category and an actor's category. As historians, we make decisions about the appropriate scale of analysis, with various analytical and political consequences. Crucially, our historical actors were also doing the same thing, scaling up and down as demanded. In fact, science and technology have long been one of the principal means through which humans make and contest meaning and value at different scales.

10 Caspar Hakfoort, 'The missing syntheses in the historiography of science', *History of Science* (1991) 29, pp. 207–16, 207.

11 Hakfoort, op. cit. (10), p. 208. The *Cambridge History of Science* series, edited by George Basalla and William Coleman, was a book series distinct from the later *Cambridge History of Science* series of edited volumes published in the 2000s. That said, much the same criticism could be levelled at both.

12 Robert E. Kohler, 'A generalist's vision', *Isis* (2005) 96, pp. 224–9, 224.

13 Peter Galison, 'Ten problems in history and philosophy of science', *Isis* (2008) 99, pp. 111–24, 119–20.

14 Neil Smith, 'Geography, difference and the politics of scale', in Joe Doherty, Elspeth Graham and Mo Malek (eds.), *Postmodernism and the Social Sciences*, London: Palgrave Macmillan UK, 1992, pp. 57–79.

15 Similar arguments have been made in the context of cultural anthropology and sociology. See particularly Marilyn Strathern, *Partial Connections*, Savage, MD: Rowman & Littlefield, 1991; E. Summerson Carr and Michael Lempert, 'Introduction: pragmatics of scale', in Summerson Carr and Lempert (eds.), *Scale: Discourse and Dimensions of Social Life*, Oakland: University of California Press, 2016, pp. 1–24; and K. Knorr-Cetina and A.V. Cicourel (eds.), *Advances in Social Theory and Methodology: Towards an Integration of Micro- and Macro-sociologies*, London: Routledge & Kegan Paul, 1981. See also the classic argument for the 'play of scales' in Jacuqes Revel, *Jeux d'échelles: La micro-analyse à l'expérience*, Paris: Gallimard-Le Seuil, 1996.

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In developing this argument for the importance of scale in the history of science, I build on the recent work of Deborah R. Coen and Nathan F. Sayre. Both Coen and Sayre deploy the concept of the 'politics of scale' to analyse how sciences, such as climatology and ecology, have been used historically to produce different scales for different purposes and with different consequences.[16] In this article, I generalize further and develop a more detailed theoretical account of the place of scale in the history of science. The remainder of the article is organized as follows. I begin with a discussion of scale as it relates to space, drawing primarily on work in political geography. I then move on to a discussion of scale as it relates to time, focusing on work in the philosophy of history. Finally, I conclude with a discussion of scale as an actor's category, borrowing primarily from cultural anthropology. My hope is that by bringing these different understandings of scale together we can make better sense of both the meaning and the politics of the big picture.

Space and scale in the history of science

The 'spatial turn' is now well over a decade old.[17] Historians of science, including myself, routinely use spatial metaphors in our work, in part prompted by James A. Secord's later call to study 'knowledge in transit'.[18] In adopting space as an analytic category, historians of science borrowed primarily from work in historical geography. Indeed, historical geographers themselves, such as David N. Livingstone and Charles W.J. Withers, have contributed significantly to our understanding of the role of space and place in shaping science.[19] However, this overwhelming focus on space has come at the expense of any analytical consideration of scale. As a consequence, certain scales of analysis – the local, the national, the regional and the global – are taken for granted, and structure much of the writing of the history of science. There are signs that this is beginning to change. In a recent edited volume, titled *Geographies of Knowledge: Science, Scale, and Spatiality in the Nineteenth Century* (2020), Robert J. Mayhew and Withers give a serious methodological account of scale in the history of science. Nonetheless, despite claiming to avoid any 'strictly defined and separate hierarchical levels of spatial representation', Mayhew and Withers organize the volume around the familiar division of 'local', 'national' and 'global' studies. The 'politics of scale' is similarly absent in their discussion, notwithstanding a brief mention of Nathan F. Sayre's monograph.[20] With this in mind, I develop a more detailed theoretical account of scale in the history of science, drawing on relatively underutilized work in political geography. By introducing readers to this literature, I hope to give a better sense of the analytical function that scale could play in the history of science, particularly in moving beyond fixed concepts of space and place.

Sustained discussion of scale in political geography dates back to the 1980s, and it remained a core feature of the discipline throughout the 1990s and 2000s. The literature is vast, but some of the core contributors include Neil Smith, Erik Swyngedouw, Kevin

16 Deborah R. Coen, 'Big is a thing of the past: climate change and methodology in the history of ideas', *Journal of the History of Ideas* (2016) 77, pp. 305–21; Coen, *Climate in Motion: Science, Empire, and the Problem of Scale*, Chicago: The University of Chicago Press, 2018; Nathan F. Sayre, *The Politics of Scale: A History of Rangeland Science*, Chicago: The University of Chicago Press, 2017.

17 Diarmid A. Finnegan, 'The spatial turn: geographical approaches in the history of science', *Journal of the History of Biology* (2008) 41, pp. 369–88.

18 James A. Secord, 'Knowledge in transit', *Isis* (2004) 95, pp. 654–72.

19 David N. Livingstone and Charles W.J. Withers (eds.), *Geographies of Nineteenth-Century Science*, Chicago: The University of Chicago Press, 2011.

20 Robert J. Mayhew and Charles W.J. Withers, 'Introduction: thinking geographically about science in the nineteenth century', in Robert J. Mayhew and Charles W.J. Withers (eds.), *Geographies of Knowledge: Science, Scale, and Spatiality in the Nineteenth Century*, Baltimore: Johns Hopkins University Press, 2020, pp. 1–28, 13.

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R. Cox, Richard Howitt and Sallie A. Marston.[21] And whilst political geographers disagreed on some of the specifics, there was broad consensus about the core features of scale as an analytic concept.[22] First, most agreed that scale was best understood as a 'social construction'.[23] Rather than taking a particular scale for granted, political geographers insisted that we appreciate how different societies 'produce scale' and how scale itself 'produces social outcomes'.[24] Second, political geographers were very critical of the idea of a 'nested hierarchy' of scales. Traditionally, geographers – like historians – had organized scales in a neat ascending order, from small to big, something like: city, district, province, region, nation, continent, and so on. However, if scale was socially constructed, then this did not make much sense. What's more, political geographers quickly pointed out that 'smaller' scales did not always neatly fit into 'bigger' ones, and that many other kinds of scale could not be ordered in a neat hierarchy.[25] Third, political geographers argued that scale was best understood not simply in terms of 'size' or 'level', but rather in terms of 'relation'. In music theory, a scale is a 'sequence of tones in a specified relationship to each other'.[26] As Howitt notes, the same is true more broadly, in which changes in scale are also changes in relations between elements. Understood in this way, scale is a way 'in which we might emphasize specific elements for analytical attention'.[27] Finally, and most importantly, political geographers argued that scale was fundamentally a matter of politics. The choice to think or act at a particular scale is always also a choice about who or what to include or exclude from analysis. Choices about scale could be oppressive, to render an issue 'local' and so irrelevant to wider concerns. Consequently, moving between scales must be 'conceived as a political strategy', for example when we demonstrate that an apparently 'local' issue is in fact a manifestation of a wider regional or global problem.[28] It is in this sense that we can talk of 'the politics of scale'.[29]

How might this apply to the history of science? To begin with, we need to recognize that the 'local' scale at which we normally operate is neither given nor neutral. This was clear to the early pioneers of the social history of science. The point of studying science at a local scale was precisely to challenge the universality of science. This was achieved by moving to a different scale of analysis than that found in typical histories

21 For a sample of the literature I have found helpful, see Smith, op. cit. (14); Neil Smith, 'Spaces of vulnerability: the space of flows and the politics of scale', *Critique of Anthropology* (1996) 16, pp. 63–77; Erik Swyngedouw, 'Scaled geographies: nature, place, and the politics of scale', in Eric Sheppard and Robert B. McMaster (eds.), *Scale and Geographic Inquiry: Nature, Society, and Method*, Oxford: Blackwell Publishing, 2004; Kevin R. Cox, 'Spaces of dependence, spaces of engagement and the politics of scale, or: looking for local politics', *Political Geography* (1998) 17, pp. 1–23; Richard Howitt, '"A world in a grain of sand": towards a reconceptualisation of geographical scale', *Australian Geographer* (1993) 24, pp. 33–44; Sallie A. Marston, 'The social construction of scale', *Progress in Human Geography* (2000) 24, pp. 219–42.

22 One of the major points of disagreement concerned the ontological status of scale. Sallie A. Marston later moved away from social constructivism, advocating for 'human geography without scale', as part of the ontological turn. See Sallie A. Marston, John Paul Jones III and Keith Woodward, 'Human geography without scale', *Transactions of the Institute of British Geographers* (2005) 30, pp. 416–32; and responses in the same issue. For what it is worth, my view on the ontological turn broadly aligns with David Graeber, 'Radical alterity is just another way of saying "reality": a reply to Eduardo Viveiros de Castro', *HAU: Journal of Ethnographic Theory* (2015) 5, pp. 1–41.

23 Marston, op. cit. (21).

24 Richard Howitt, 'Scale', in John Agnew, Katharyne Mitchell and Gerard Toal (eds.), *A Companion to Political Geography*, London: Wiley, 2003, pp. 138–57, 147.

25 Howitt, op. cit. (21), p. 37; David Delaney and Helga Leitner, 'The political construction of scale', *Political Geography* (1997) 16, pp. 93–7.

26 Richard Howitt, 'Scale as relation: musical metaphors of geographical scale', *Area* (1998) 30, pp. 49–58, 53.

27 Howitt, op. cit. (26), p. 53.

28 Katherine T. Jones, 'Scale as epistemology', *Political Geography* (1998) 17, pp. 25–8.

29 Smith, op. cit. (14).

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of science written in the middle of the twentieth century.[30] What we need to remember, however, is that this choice was not without its drawbacks, something that would have been clear to political geographers of the same era.[31] In fact, much of the early work on scale in political geography came out of a critique of the growth of 'locality studies' in the 1980s. There was a worry that the turn to the 'local', particularly by those on the political left, had the effect of ceding other important scales of analysis to the political right. 'The right acts globally, why not the left?' complained Smith in 1992.[32]

The history of science, I think it is now clear, fell into this same trap. By focusing overwhelmingly on the local, just at the time when neoliberalism and globalization were on the rise, historians of science managed to disconnect themselves from the political present.[33] This was reflected in the oft-repeated worry that any move beyond the local context risked reinforcing universalism, neoliberalism and globalization.[34] A proper understanding of the politics of scale highlights the fallacy of such an argument. The reason we need histories of science operating at and moving between different scales is precisely to challenge the idea – born of the individualism of neoliberalism – that 'one could *only* act locally'.[35] The reason we need more global histories of science is precisely to critique globalization, not to reproduce it, lest we leave the 'global' as the playground of the intellectual and political right.[36] Gianamar Giovannetti-Singh and Rory Kent make a similar point in their contribution to this volume. A politically engaged history of science, they argue, should pay attention to 'large-scale' crises, such as the wider transcontinental repercussions of the collapse of the Ming Dynasty in seventeenth-century China. In sum, choices about the analytic category of scale are fundamental political choices that historians of science need to take much more seriously.

With this in mind, I want to encourage historians of science to get more creative when it comes to working with scale. The problem isn't simply that too many journal articles operate at a predefined 'local' scale. Rather, when historians of science do work at other scales – the national, the regional, even the global – they tend to treat these as relatively fixed levels within a predefined hierarchy. Edited collections, including a recent volume in the *Cambridge History of Science* series, are still organized according to a rather tired model of scale, divided by nation and region.[37] Similarly, few histories of science attempt

30 Steven Shapin, 'History of science and its sociological reconstructions', *History of Science* (1982) 20, pp. 157–211.

31 Despite being widely associated with the turn towards local case studies, Steven Shapin in fact wrote what I would characterize as 'big-picture' histories of science, at least when it came to monographs. He was certainly more aware of the problem of the 'local' than many. See Shapin, op. cit. (8); and Steven Shapin, 'Here and everywhere: sociology of scientific knowledge', *Annual Review of Sociology* (1995) 21, pp. 289–321.

32 Smith, op. cit. (14), pp. 71–2. See also Howitt, op. cit. (21), pp. 40–1.

33 In other cases, the history and sociology of science actually reflected, and in some cases even supported, the rise of neoliberalism in the 1980s. See Andrew Barry's comments in the concluding round table in this volume on the origins of the Research Assessment Exercise (RAE). Roger Cooter and Claudia Stein, *Writing History in the Age of Biomedicine*, New Haven, CT: Yale University Press, 2013, pp. 1–40, make a similar point in relation to actor-network theory and the social history of medicine.

34 Sarah Hodges, 'The global menace', *Social History of Medicine* (2012) 25, pp. 719–28.

35 Smith, op. cit. (14), p. 70, original emphasis. Neoliberalism presented economies as global at the same time as it confined human action to the individual and the local.

36 For a defence of the global history of science in these terms see James Poskett and Gianamar Giovannetti-Singh, 'Global history of science', in Lukas M. Verburgt (ed.), *Debating Contemporary Approaches to the History of Science*, London: Bloomsbury, 2024, pp. 17–42; James Poskett, 'Race, material culture, and the global history of science', *Global Intellectual History* (2021) 6, pp. 142–57; and Poskett, *Materials of the Mind: Phrenology, Race, and the Global History of Science, 1815–1920*, Chicago: The University of Chicago Press, 2019, pp. 1–18.

37 Hugh Richard Slotten, Ronald L. Numbers and David N. Livingstone (eds.), *The Cambridge History of Science*, vol. 8: *Modern Science in National, Transnational, and Global Context*, Cambridge: Cambridge University Press, 2020.

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to move between scales. In contrast, a number of contributors to this volume do play with scale in creative ways. Michael Bycroft explores the history of science at the scale of different objects of scientific enquiry – a crystal, an ocean, a star – whilst Lisa Ruth Rand pushes beyond the planetary scale and takes the history of science into outer space. Digital humanities might also help identify alternative scales of investigation. Aleksandra Kaye, writing in this volume, deploys social network analysis, and in doing so cuts across traditional spatial scales of nation, region and empire. Getting creative with scale, I argue, is one of the key challenges of the big picture.

Temporality and the 'big picture'

Scale is not just a question of space. It is also a question of time. What are the analytical and political consequences of our choices about timescales?[38] In some ways, this is a more significant question facing the history of science and the big picture. Whilst there has been a move towards more expansive geographies in recent years, the same cannot be said for chronology or periodization. Journal articles rarely cover much more than a decade or two, and even monographs struggle to incorporate a whole century. One of the consequences of the move towards 'local' case studies in the 1980s and 1990s was to narrow not only the spatial dimension, but also the temporal one. By contrast, historians of science writing earlier in the twentieth century had no problem covering not only hundreds of years, but often thousands, if not tens of thousands. This was true across the political spectrum. J.D. Bernal, the Marxist crystallographer, took readers from 'the Old Stone Age' through to the twentieth century, whilst A.C. Crombie, who was definitely not a Marxist, covered over a thousand years 'from Augustine to Galileo'.[39] Such expansive chronologies were not only found in books. Journal articles published in the middle decades of the twentieth century often featured broad time periods. An early issue of the *British Journal for the History of Science*, for example, featured an article on 'Physical optics at the Royal Society 1660–1800', whilst the *Historical Journal* published an article, by Roy Porter no less, entitled 'Gentlemen and geology: the emergence of a scientific career, 1660–1920'.[40]

This problem, however, cannot be solved simply by adopting a 'big-history' approach, in which the chronology is expanded exponentially until we reach the beginning of the universe over 13 billion years ago.[41] Rather, the problem once again stems from a failure to consider the analytical and political significance of scale in the history of science. Time, like space, is too often conceptualized along a fixed scale, neatly organized from smaller to bigger: day, week, month, year, decade, century, and so on. Instead, historians of science need to think of timescales in much more creative and flexible ways. We need to theorize temporal scale with the same analytic depth as spatial scale. In making this argument, I draw on scholarship in the philosophy of history, particularly the work of Fernand Braudel and Reinhart Koselleck.

Although much more structuralist than later thinkers, Braudel nonetheless provides a useful starting point for thinking analytically about time in history. Today, he is primarily

38 For a helpful discussion of temporal scales in history, see Sebastian Conrad, *What Is Global History?*, Princeton, NJ: Princeton University Press, 2016, pp. 141–60. See also Patrick Manning, *Navigating World History*, New York: Palgrave Macmillan, 2003, pp. 265–73.

39 J.D. Bernal, *Science in History*, London: Watts and Co., 1954; and A.C. Crombie, *Augustine to Galileo: The History of Science, A.D. 400–1650*, Cambridge, MA: Harvard University Press, 1953.

40 A.W. Badcock, 'Physical optics at the Royal Society 1660–1800', *BJHS* (1962) 1, pp. 99–116; and Roy Porter, 'Gentlemen and geology: the emergence of a scientific career, 1660–1920', *Historical Journal* (1978) 21, pp. 809–36.

41 For the classic statement on 'big history' see David Christian, 'The case for "big history"', *Journal of World History* (1991) 2, pp. 223–38. For a perceptive critique and historicization of 'big history' from the perspective of the history of science see Ian Hesketh, 'The story of big history', *History of the Present* (2014) 4, pp. 171–202.

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associated with the phrase 'the *longue durée*', but Braudel's approach was in fact much more subtle than a blanket call to incorporate longer chronologies. Braudel argued that historians needed 'an awareness of the plurality of temporalities'.[42] Yes, the *longue durée*, but also what he called the 'event' as well as the 'cyclical phase'.[43] For Braudel, the point was to examine 'the dialectic of temporalities', the way in which different timescales proceeded and interacted.[44] Taking this argument seriously, I think, is a good place for historians of science to start. Rather than picking a fixed timescale – a year, a decade, a century – we should instead try to move across multiple temporalities, situating a particular event within broader cycles and long-term changes, and examining how these interact.

From here, we can start to move beyond Braudel's structuralism, with its threefold division between event, cycle and *longue durée*. Following Koselleck, I argue that historians of science should see 'historical time' in more general terms as 'the relation of a given past to a given future'.[45] Understood in this way, we can productively expand our conception of time, addressing 'several layers of time of differing duration and differentiable origin'.[46] The challenge for the historian is to 'analytically separate different temporal levels upon which people move and events unfold'.[47] This effectively takes Braudel's core idea – that there are multiple interacting temporalities in history – but offers more flexibility. We are no longer restricted by a threefold structural division of time, nor a simple 'dialectic' relationship between timescales. Writing in this volume, Gianamar Giovannetti-Singh and Rory Kent provide an excellent example of such an approach in action. Rather than adopting a fixed timescale, Giovannetti-Singh and Kent explore what the history of science looks like when examined along a range of interacting temporalities, from immediate moments of racialized violence to long-term shifts in geopolitical relations. Similarly, James A. Secord, in his contribution to this volume, makes the case that historians of science need to radically rethink both chronology and periodization, especially the divide between the so-called 'premodern' and 'early modern'. Sarah Qidwai's contribution also invites us to think more critically about periodization, especially in the context of histories of science and religion. What, for example, have been the intellectual and political consequences of writing histories of Islamic science at the scale of the so-called 'Golden Age'? And how might our understanding of science and religion be transformed by adopting different temporal scales?[48] In sum, analytical attention to the concept of time must be a core feature of the history of science and the big picture.

Time, however, is not just an analytical problem for the history of science. It is also a political one. Throughout the 1990s and 2000s, plenty of books were published with long chronologies written for public audiences. Many of these directly addressed the history of science and technology. Jared Diamond put technology at the centre of world history in *Guns, Germs and Steel* (1997), whilst Niall Ferguson identified science as one of the 'killer

42 Note Braudel's use of 'the history of the sciences' as an example of the *longue durée*. Fernand Braudel, 'History and the social sciences: the *longue durée*' (tr. Immanuel Wallerstein), *Review* (2009) 32, pp. 171–203, 173, 180.

43 Braudel, op. cit. (42), pp. 174–6.

44 Braudel, op. cit. (42), p. 187.

45 Reinhart Koselleck, *Futures Past: On the Semantics of Historical Time*, New York: Columbia University Press, 2004, pp. 1–3. My reading of Koselleck follows that of Helge Jordheim, 'Against periodization: Koselleck's theory of multiple temporalities', *History and Theory* (2012) 51, pp. 151–71.

46 Reinhart Koselleck, *Zeitschichten: Studien zur Historik*, Frankfurt am Main: Suhrkamp, 2000, p. 9, quoted in and translated by Jordheim, op. cit. (45), p. 157.

47 Reinhart Koselleck, *Sediments of Time: On Possible Histories*, Stanford, CA: Stanford University Press, 2018, p. 3.

48 See Shahzad Bashir, 'On Islamic time: rethinking chronology in the historiography of Muslim societies', *History and Theory* (2014) 53, pp. 519–44.

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apps' which allegedly distinguished the 'West and the Rest' in *Civilization* (2011).[49] Neoliberalism went in for 'big history' and long chronologies, just as professional historians of science retreated to their local studies. It is only during the last few years that the intellectual and political left has started to respond, as exemplified by the work of David Graeber and David Wengrow, a point reinforced by John Tresch in his contribution to this volume.[50]

There is ultimately a 'politics of chronology' just as much as there is a politics of space.[51] Contemporary political debates demand that historians of science operate on radically different temporal scales. This is especially the case when it comes to the current climate crisis. As Dipesh Chakrabarty argues, 'the Anthropocene requires us to think on the two vastly different scales of time that Earth history and world history respectively involve'.[52] Different timescales, then, come with vastly different conceptions of the political itself. 'What does it mean to dwell, to be political, to pursue justice when we live out the everyday with the awareness that what seems "slow" in human and world-historical terms may indeed be "instantaneous" on the scale of Earth history'? asks Chakrabarty.[53] Thomas Simpson, writing in this volume, provides a historical answer to this question. By charting the different ways in which temporal scales have been invoked politically in the past, we can get a better sense of how temporality in the present might enable or restrict our collective response to climate change.

Debate over the concept of the Anthropocene also highlights two different aspects of temporal scale which are related but nonetheless distinct. On the one hand, the Anthropocene is a debate about 'duration'. It is a question of how far back to go in order to identify the origins of climate change. Do we go back fifty years, to the mid-twentieth century? Or 250 years to the beginning of the Industrial Revolution? Or perhaps even further, over 12,000 years, to the Agricultural Revolution? Clearly different answers to that question imply radically different political conclusions, particularly when it comes to both response and responsibility. However, the Anthropocene is also a debate about 'speed'. It is about the pace of environmental change in the past, present and future. Is climate change something that happens very slowly? Or can it happen relatively quickly? And crucially, how do processes operating at different speeds interact, such as the burning of fossil fuels and the warming of the planet? Again, the different answers to these questions imply different politics. Historians of science should therefore consider both 'duration' and 'speed' when thinking about the temporal scale of study.[54] Indeed, this is exactly what Nathan Sayre does in his history of rangeland science, in which he identifies 'faster and slower processes – both social and biophysical', sometimes converging, but often diverging.[55] Similarly, Rob Nixon deploys the concept of 'slow violence' to highlight aspects of the history of environmentalism which are otherwise hidden when moving at

49 Jared Diamond, *Guns, Germs and Steel: The Fates of Human Societies*, New York: W.W. Norton, 1997; and Niall Ferguson, *Civilization: The West and the Rest*, London: Penguin, 2011.

50 David Graeber, *Debt: The First 5000 Years*, New York: Melville House, 2011; and David Graeber and David Wengrow, *The Dawn of Everything: A New History of Humanity*, London: Allen Lane, 2021.

51 Sebouh David Aslanian, Joyce E. Chaplin, Ann McGrath and Kristin Mann, 'AHR conversation. How size matters: the question of scale in history', *American Historical Review* (2013) 118, pp. 1431–72, 1451.

52 Dipesh Chakrabarty, 'Anthropocene time', *History and Theory* (2018) 57, pp. 5–32, 6.

53 Chakrabarty, op. cit. (52), p. 30.

54 On 'duration' see Immanuel Wallerstein, 'Time and duration: the unexcluded middle', *Thesis Eleven* (1998) 54, pp. 79–87; and Lucian Hölscher, 'Time gardens: historical concepts in modern historiography', *History and Theory* (2014) 53, pp. 577–91. On 'speed' see Paul Virilio, *Speed and Politics* (tr. Sylvère Lotringer), Los Angeles: Semiotexte, 2006.

55 Nathan F. Sayre, 'Scale and polities', in Tom Perreault, Gavin Bridge and James McCarthy (eds.), *The Routledge Handbook of Political Ecology*, London: Routledge, 2015, pp. 504–15, 504.

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high speeds.[56] Writing in this volume, Duygu Yıldırım also takes a critical approach to speed, introducing what she calls 'a belated history'. As Yıldırım argues, the concept of 'new' – so central to the history of science – was not always synonymous with 'progress'. In the Ottoman Empire, for example, the pace of change could be slow or otherwise tentative, even at the same time as knowledge was increasingly identified as 'new'. The big picture, therefore, might be an invitation to slow down as much as it is to speed up.

All of this ultimately points to the fundamental relationship between temporal scale and our understanding of human agency.[57] This, I argue, is what the politics of temporality boils down to. A concept like the Anthropocene has the potential to identify collective responsibility and therefore galvanize collective action. But, as Christophe Bonneuil and Jean-Baptiste Fressoz note, the Anthropocene, with 'its grandiose time frame', also has the potential to inhibit a sense of individual human agency and thereby 'anaesthetize politics'.[58] Similarly, Simpson, writing in this volume, analyses the relationship between temporality and different understandings of agency, including 'environmental agency'. Recognizing how different temporal scales shape our sense of individual and collective agency, whether human or non-human, is another key challenge for writing the history of science and the big picture.

Scalar sciences

Up to this point, I have discussed scale as an analytic category, in both its spatial and its temporal dimensions. However, following work in cultural anthropology, historians of science should also understand scale as an actor's category.[59] Indeed, this is the direction taken by much of the best recent work in the field. Deborah Coen in particular has called for 'a history of scaling', studying how late nineteenth-century climatologists constructed and moved between different environmental scales.[60] Similarly, Nathan Sayre has charted the development of different ecological scales in twentieth-century rangeland science.[61] Finally, Nicholas B. King has demonstrated how twentieth-century epidemiologists conceived of disease at different scales, with various political consequences for intervention and planning.[62] As these examples suggest, much of the existing work on scale in the history of science is focused on the modern environmental and medical sciences. In this section, I want to generalize further and develop a more detailed theory of scale as an actor's category. My overall claim is that the sciences have long been one of the principal ways through which humans make scale. Historians of science therefore have a key role to play in charting the social construction of scale more generally.

In making this argument, I draw on work in cultural anthropology, particularly the writing of Anna Lowenhaupt Tsing. In both *Friction* (2005) and *The Mushroom at the End of the World* (2015) Tsing deploys the concept of scale to make sense of how her

56 Rob Nixon, *Slow Violence and the Environmentalism of the Poor*, Cambridge, MA: Harvard University Press, 2011.

57 Conrad, op. cit. (38), p. 156; and Tyson Retz, *Progress and the Scale of History*, Cambridge: Cambridge University Press, 2022, p. 5.

58 Christophe Bonneuil and Jean-Baptiste Fressoz, *The Shock of the Anthropocene: The Earth, History and Us* (tr. David Fernbach), London: Verso, 2016, p. 80, quoted in Chakrabarty, op. cit. (52), p. 28.

59 'Scale is what actors achieve by *scaling* ... it's not the analyst's job to impose an absolute one.' Bruno Latour, *Reassembling the Social: An Introduction to Actor-Network-Theory*, Oxford: Oxford University Press, 2005, pp. 183–4, original emphasis. See also Judith T. Irvine, 'Going upscale: scales and scale-climbing as ideological projects', in Summerson Carr and Lempert, *Scale*, op. cit. (15), pp. 213–32.

60 Coen, op. cit. (16), p. 312.

61 Sayre, op. cit. (16).

62 Nicholas B. King, 'The scale politics of emerging diseases', *Osiris* (2004) 19, pp. 62–76.

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ethnographic subjects understand the world. As Tsing argues, 'scales are claimed and contested in cultural and political projects'.[63] Tsing even discusses how contemporary environmental scientists construct scale. One of the key characteristics of modern environmental science, argues Tsing, is a desire for 'scalability', which she defines as 'the ability of a project to change scales smoothly'.[64] The problem, Tsing notes, is that the world is not so simple. Not all aspects of nature are as 'scalable' as scientists would like.[65] Following Tsing's work, E. Summerson Carr and Michael Lempert have also contributed to theorizing scale from an ethnographic perspective, publishing an edited volume titled *Scale: Discourse and Dimensions of Social Life* (2016). In introducing the volume, Carr and Lempert ask 'how, why, and to what ends people and institutions scale their worlds'.[66] Most importantly, Carr and Lempert argue for the 'inherently perspectival nature of scale, asking of our material "whose scale is it …?"'[67] John Tresch, writing in this volume, adopts a similar approach. Through a history of 'cosmograms' – material representations of the world – Tresch uncovers how and why a variety of sciences, from astronomy and geography to psychology and mathematics, have been used to construct the biggest scale of all – that of the cosmos. For Tresch, this is not just a big-picture history of science, but also a history of 'big pictures'.

I want to suggest, following Tresch, that this is a more general phenomenon in the history of science. The sciences have been one of the principal means through which scale is imagined and enacted. A brief historical survey reveals that the use of 'scale' in the modern sense – as a 'series of gradations' – in fact emerged in the context of early modern science.[68] The older Latin sense of the term, *scala*, meaning simply 'ladder', came to take on a broader philosophical and conceptual meaning. The English natural philosopher Francis Bacon rather characteristically combined both the ancient and modern forms, invoking the metaphor of the 'scale or ladder' to explain the relationship between experiment and knowledge. In *The Advancement of Learning* (1605), Bacon suggested that 'all true and fruitful natural philosophy hath a double scale or ladder; ascending from experiments to the invention of causes, and descending from causes to the invention of new experiments'.[69]

Around the same time, 'scale' started to crop up as a concept in mathematics, metrology and mapping. Prior to the sixteenth century, European maps did not feature a 'scale' as we would understand it today. It was only with the colonization of the Americas, and the subsequent development of new mapping techniques, that a 'scale' started to be added to maps. Tellingly, this was initially by direct analogy with navigational instruments, in which fine gradations of 'scale' were also increasingly important. Maps produced at the House of Trade in Seville during the early sixteenth century, for example, started to feature a diagram of both a mariner's astrolabe and a mariner's quadrant, and they did so

63 Anna Lowenhaupt Tsing, *Friction: An Ethnography of Global Connection*, Princeton, NJ: Princeton University Press, 2005, p. 58.

64 Anna Lowenhaupt Tsing, *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins*, Princeton, NJ: Princeton University Press, 2015, p. 38.

65 Tsing, op. cit. (64), p. 38.

66 Summerson Carr and Lempert, 'Introduction', op. cit. (15), p. 4.

67 Summerson Carr and Lempert, 'Introduction', op. cit. (15), p. 15.

68 'scale, n.^{3}'. Oxford English Dictionary, Oxford University Press, September 2023, at https://doi.org/10.1093/OED/8334910014, accessed 30 November 2023.

69 Francis Bacon, *The Two Bookes of Sir Francis Bacon of the Proficience and Advancement of Learning, Divine and Humane*, Oxford: Thomas Huggins, 1633 (first published 1605), p. 138. Bacon returned to this metaphor in *Novum Organum* (1620), describing 'the ascending and descending scale of axioms'. Francis Bacon, *Novum Organum*, London: William Pickering, 1844 (first published 1620), p. 179.

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explicitly to indicate 'scale'.[70] This was part of a wider trend, whereby divisions on measuring instruments came to be conceptualized in more abstract terms as a 'mathematical scale', as with John Napier's logarithms and related discussions of 'geometrical scale'.[71] Most significantly, it was during the sixteenth and seventeenth centuries that the term 'scale' first came to be used in the modern sense within music theory. The German theologian Johannes Lippius, writing in his *Synopsis of New Music* (1612), defined a 'musical scale' as 'the order of ascent from low to high, or of descent from high to low'.[72] As indicated by the title of Lippius's book, this was part of a broader reassessment of ancient knowledge in which older ideas about music might be revitalized through new approaches. As all this suggests, we should therefore think of 'scale' as a concept that defined – and was defined by – the 'new science' of the sixteenth and seventeenth centuries.[73]

Scale continued to structure much of science throughout the eighteenth, nineteenth and twentieth centuries. As Coen points out, the long nineteenth century was an age in which the sciences transformed – and were transformed by – new understandings of scale. This was the age of 'deep time', in which the temporal scale of both human and geological history expanded massively. This was the age of the 'subatomic', in which the discovery of the electron in 1897 redefined the scale of matter. And this was the age of the 'electromagnetic', in which the speed of light transformed understandings of both spatial and temporal scales of interaction. All of this was paralleled in the political sphere, in which the emergence of new social categories – nation, population, class and capital – similarly reflected changing understandings of scale.[74]

From the early twentieth century right up to the present, scale remained a central component of scientific thinking. As Coen and Sayre have demonstrated, this was especially the case in the environmental sciences. It was also true of the new biological sciences of the twentieth century. Most of the major debates in twentieth-century evolutionary biology were in fact debates about scale. When Richard Dawkins published *The Selfish Gene* (1976), he was reviving a long-running debate over the 'levels of selection'. Was the fundamental unit of natural selection the gene, the individual, the group or something else? According to Dawkins, 'The largest practical unit of natural selection – the gene – will usually be found to lie somewhere on the scale between cistron and chromosome'.[75] This debate went alongside the study of the effect of scale on

70 Matthew Edney, *Cartography: The Ideal and Its History*, Chicago: The University of Chicago Press, 2019, pp. 166–216; and María Portuondo, 'Cosmography at the *casa*, *consejo*, and *corte* during the Century of Discovery', in Daniela Bleichmar, Paula De Vos, Kristin Huffine and Kevin Sheehan (eds.), *Science in the Spanish and Portuguese Empires, 1500–1800*, Stanford, CA: Stanford University Press, 2009; Alison Sandman, 'Spanish nautical cartography in the Renaissance', in David Woodward (ed.), *The History of Cartography*, 6 vols., Chicago: The University of Chicago Press, 2007, vol. 1, part 1, pp. 1095–142.

71 Jim Bennett, 'Early modern mathematical instruments', *Isis* (2011) 102, pp. 697–705. See also James Hodgson, *A System of Mathematics*, 2 vols., London: T. Page, W. & F. Mount, 1723, vol. 1, which begins with practical instruments, and moves on to navigation and cartography, before concluding with a more abstract discussion of 'scale' defined as a 'series of proportionals' on p. 667.

72 Quoted in and translated by Daniel Lawrence Taddie, 'Scale: an historical study of musical terminology and concepts', PhD dissertation, the University of Iowa, 1984, p. 162.

73 A similar claim could be made about the emergence of modern political philosophy in the sixteenth and seventeenth centuries. Thomas Hobbes's argument in *Leviathan* (1651), and the emergence of modern political philosophy in general, relied on 'formulating clearly … for the first time the relationship between micro-actors and macro-actors'; that is, a relationship of scale. See Michel Callon and Bruno Latour, 'Unscrewing the Big Leviathan: how actors macro-structure reality and how sociologists help them to do so', in Knorr-Cetina and Cicourel, op. cit. (15), pp. 277–303, 278–81.

74 Coen, op. cit. (16), pp. 314–15.

75 Richard Dawkins, *The Selfish Gene*, Oxford: Oxford University Press, 1976, p. 36.

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development, what came to be known as 'allometry'. Beginning with D'Arcy Wentworth Thompson's *On Growth and Form* (1917) and moving through to Knut Schmidt-Nielsen's *Scaling: Why Is Animal Size So Important?* (1984), biologists identified relative size as a key factor in both embryological and, later, evolutionary development.[76] Once again, scale emerged as a central concept in modern science. And once again, as Dawkins's book made clear, there was a politics to scale.[77] Whether or not size constrained, and whether or not selection operated at the level of the gene or the group, had profound political implications concerning the control or otherwise of biological futures.

To return to my core argument: scale is as much an actor's category as it is an analytic one. Attention to the history of scale provides a productive way to write both big-picture histories of science and histories of big pictures – or what we might call 'scalar histories' of 'scalar sciences'. The history of racial science is another good example in this respect. Elise Burton and Sayori Ghoshal, writing in this volume, demonstrate the way in which 'race' functions as both an analytic and an actor's category in the history of science. On the one hand, race should be understood as a fundamental analytical concept by historians of science, and not just those interested in the history of racial science. On the other hand, race is clearly an actor's category, a concept through which scientists translated between the scale of the individual and the group, often with profoundly damaging consequences. Howard Chiang, in his contribution to this volume, makes a related point when it comes to gender. On the one hand, gender – like race – should be treated as a core analytic category for historians of science. On the other hand, gender itself was a key concept for many of our historical actors. The very meaning of the term 'gender', as we understand it today, emerged in the context of twentieth-century sexual science. And related concepts, such as 'transvestism', were similarly produced through specific kinds of scalar thinking, especially, as Chiang demonstrates, through cross-cultural comparisons across European and East Asian societies. The history of science and the big picture might therefore be thought of as a history of what Tsing calls 'a world of multiple, divergent claims about scales'.[78]

Conclusion

The history of science and the 'big picture' presents both a theoretical and a methodological challenge. In this article, I have set out what I see as the core conceptual tool needed to meet that challenge: the concept of *scale*. The big picture cannot simply be an attempt to endlessly expand the scope of historical study, whether chronologically or spatially. Rather, the big picture should be seen as part of a broader theoretical and methodological critique of what it means to situate science in a 'local context'. This, I argued, can best be achieved by applying the concept of the 'politics of scale'. Building on the work of Deborah Coen and Nathan Sayre, I developed a more general theoretical account of scale in the history of science. Drawing on work in political geography, I argued that scale is best understood in terms not only of 'size' and 'level', but crucially of 'relation'. Drawing on work in the philosophy of history, I argued that the concept of scale can

76 D'Arcy Wentworth Thompson, *On Growth and* Form, Cambridge: Cambridge University Press, 1917; Pere Alberch, Stephen Jay Gould, George F. Oster and David B. Wake, 'Size and shape in ontogeny and phylogeny', *Paleobiology* (1979) 5, pp. 296–317; Knut Schmidt-Nielsen, *Scaling: Why Is Animal Size So Important?*, Cambridge: Cambridge University Press, 1984; John Tyler Bonner, *Why Size Matters: From Bacteria to Blue Whales*, Princeton, NJ: Princeton University Press, 2006.

77 'I am not advocating a morality based on evolution', wrote Richard Dawkins, shortly after having told his reader that 'this gene selfishness will usually give rise to selfishness in individual behaviour'. Dawkins, op. cit. (75), p. 1.

78 Tsing, op. cit. (63), p. 58.

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help us critically rethink the role of time – as duration, as speed, as chronology and as periodization. And drawing on work in cultural anthropology, I argued that historians of science need to understand scale as an actor's category just as much as an analytic category. Ultimately, my hope is that the concept of scale can help us move beyond 'the micro–macro standoff'.[79]

All that said, the challenge of the big picture is not simply an intellectual one. It also speaks to broader structural issues in teaching and training. It speaks to what we value as professional historians of science. The success of the big picture therefore depends not simply on the skilful use of theory, but also on how we shape the institutions that structure our profession. This point was made forcibly by David Kaiser nearly twenty years ago. The expansion of the history of science as a professional academic discipline in the twentieth century ultimately led to a narrowing of 'the range of "appropriate" or "acceptable" topics'.[80] It also produced a tendency towards what Kaiser calls 'archival positivism', whereby unpublished manuscript material came to be seen as the only meaningful way to develop new historical analyses.[81] This had the effect of devaluing broader theoretical claims or syntheses based on published material, especially in the North American context in which 'tenure' is paramount. The result was, as Kaiser put it, that 'each practitioner knows more and more about less and less'. The history of science then came to lack 'epistemic bite'.[82]

Alongside this formal structural problem of postgraduate training, there is also a more informal problem of attitude. Even some of those who ostensibly promote the big picture have a tendency to fall back into the protective blanket of hyperprofessionalism. In the same article in which Robert E. Kohler calls for 'a general history of science', he also provides a long list of reasons why anyone wanting to pursue a successful academic career should probably steer well clear of the big picture. 'They are just too hard to do well,' complains Kohler. Most of us apparently 'lack experience or some requisite skill'. And anyway, a general history of science is ultimately 'the sort of writing that most of us attempt (if at all) as mature scholars'.[83] This attitude is precisely part of the problem. It betrays a failure to understand the analytical and political significance of scale in the history of science. The 'local' should not be thought of as some kind of default scale of analysis, a safe training ground from which you then build up a neat stack of case studies, until, finally, you attain the mastery required to write a general history of science. 'Large-scale' narratives should not be the exclusive preserve of 'mature scholars', hence the deliberate choice to feature those at a range of career stages in this volume. Instead, we all need to learn to think much more creatively about scale, to recognize that the difference between 'breadth' and 'depth' is a matter of perspective, and ultimately to engage in what the anthropologist Marilyn Strathern calls 'scale switching'.[84]

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79 Summerson Carr and Lempert, 'Introduction', op. cit. (15), p. 8.

80 David Kaiser, 'Training and the generalist's vision in the history of science', *Isis* (2005) 96, pp. 244–51, 245.

81 Kaiser, op. cit. (80), p. 246.

82 Kaiser, op. cit. (80), pp. 248–50.

83 Kohler reserves his greatest ire (in a footnote) for global histories of science: 'The call for global history could backfire if by setting the bar of achievement so high it simply discourages more conscientious scholars and tempts the less scrupulous to facile recycling'. Kohler, op. cit. (12), pp. 225, 299.

84 Strathern, op. cit. (15), p. xvi.

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