

SCIENCE SHAPING MODERNITY — GAUKROGER'S FOUR-VOLUME SERIES COMPLETED

[Essay review of Stephen Gaukroger, *Civilization and the Culture of Science. Science and the Shaping of Modernity, 1795-1935*. Oxford: Oxford University Press, 2020; xiii + 519 p.; ISBN 978.0.19.884907.0]

This book is the final instalment of a coherent effort materializing in four substantial volumes. The question the author has set out to answer is, on the face of it, quite simple: how is it that science, utterly marginal in Europe's medieval culture, has become central to our modern culture? It is this very question that, for many a historian but also philosopher or sociologist of science, has stood at the background or even at the forefront of their very decision to become one. Yet no one so far has had the courage, and the stamina, and the scholarly experience, and the vast erudition, and the organizing power, and the familiarity with a number of indispensable languages that Stephen Gaukroger displays and that are needed to engage the question on anything like the scale it deserves.

To be sure, this fourth volume can also be read as a stand-alone achievement, and in what follows I shall pay ample attention to it in that particular quality. But I want first of all to situate in very broad brush-strokes Gaukroger's four-volume effort in the literature.

Certainly at the scope covered by Gaukroger, there just exists nothing comparable. What, in a way, comes closest is a range of overviews of the history of science written decades, indeed generations ago. The genre has quite rightly been abandoned for offering, as a rule, a poorly organized range of major and more minor scientific discoveries, held together by a positivist or even triumphalist sense of inexorable progress — as if the centrality that science has attained in our modern thinking and way of life has been the self-evident consequence of its unmistakable truth-value. What has replaced the genre is, essentially, a void — a void legitimated in its turn by post-modernist phraseology of the 'end of the grand narrative' kind. Consequently, the history of science as a profession has since the 1980s turned into an archipelago held together by certain professional and, as such, most often quite thoughtful and healthy do's and don'ts, yet no longer by any substantial idea or principle or a pluralist set thereof. In other words, Gaukroger's four-volume series is, as such, without competitor. For anyone concerned with the 'archipelago' state of the profession his series has been welcome from the very start.

Key to Gaukroger's endeavor is his acute awareness that we must distinguish between science as an enterprise directed toward coming to grips with the natural world (and, at later stages, with our social world and with our inner selves as well), and science as an enterprise in need, like any viable enterprise, of consolidation in order to flourish or even to survive. Or, in my own terms, the question of how modern science has *come* into the world is distinct from (yet of course closely related to) the question of how it has managed to *stay* there.¹

Has the void, left so wide open by historians of science ever since the positivism-steered and tacitly assumed *identity* of these two basic questions evaporated, been filled by philosophers? No, it hasn't. Outstanding as many philosophers are in the subtle handling and analysis of concepts, their work tends to lack the facility that historians have with the inevitably somewhat fuzzy way in which conceptual

¹ These being the two questions raised, and answered up to c. 1700, in my *How Modern Science Came Into the World. Four Civilizations, One 17th Century Breakthrough*. Amsterdam UP, 2010 (a much shorter version, directed at a non-specialist audience, is *The Rise of Modern Science Explained. A Comparative History*. Cambridge UP, 2015).

development has taken place over time, and with placing such developments in their larger, social and cultural contexts. So what the vast enterprise undertaken by Gaukroger really requires at its very best is a historian of science equipped with a facility in handling concepts. And it so happens that he himself satisfies that dual requirement – he brings to an essentially history-of-science endeavor a philosophical acumen that raises the outcome to the level that his own enterprise deserves. Historians of science are good at sifting and ascertaining relevant facts and interpreting them, but when feeling in need of some conceptual apparatus there is a curious inclination to import it from elsewhere (most often from philosophy or from sociology). Gaukroger, in contrast, throughout the series develops in the most sovereign manner his own organizing concepts as he goes along. It is this particular feature that enables the outcome of his work to become not just the welcome filling-up of a glaring void at the heart of the discipline of history of science, but an outstanding demonstration of how it can be done.

The question at the heart of Gaukroger's enterprise, then, runs roughly thus: 'in the Middle Ages the center of people's very existence was religious faith; today it is science – how has that vast change come about?' The answer is far from monolithic. As a philosophically deeply informed historian of science Gaukroger is not in for any simplistic treatment of his subject. In the present, fourth volume he deals with a range of issues and debates in the 19th and 20th centuries. Before highlighting some principal features, let me refer the reader to the very informative *Isis* reviews of the three preceding volumes, each full of praise overall. Wolfgang Lefèvre reviewed the first volume, that covers the years 1210 – 1685, in the issue of September 2008 (*Isis* 99: 3, p. 597 – 599).² The second volume, that runs from 1680 to 1760, was reviewed by Peter Harrison in the December issue of 2013 (*Isis* 104: 4, p. 843 – 845).³ And in the March issue of 2017 (*Isis* 108: 1; p. 198 – 199) Catherine Abou-Nemeh reviewed volume 3, which opens in 1739 and closes in 1841.⁴

The opening and closing dates chosen by Gaukroger for each successive volume clearly display some overlap. That overlap is a wholly unproblematic consequence of the thematic approach that he has taken throughout the series. Nor has he felt a need to adhere strictly to those title dates. They rather serve as guidelines that still allow for some occasional flashbacks and flashforwards. In volume 4 the rationale of the 1795 opening date is the first treatise (Condorcet's) in which science, being indissolubly tied up here with the notion of progress, is proclaimed to be the true successor of Christianity as that which gives unity to the very notion of civilization (and also makes it superior). The book ends in the 1930s to include a range of debates about science and civilization now that, with the First World War, the destructive side of science has unmistakably, and deeply problematically, come to the fore. Not only are these dates aptly chosen, they also serve to avoid the entangling with present-day debates that would inevitably follow if the book's subject were taken into the 21st century. It is one of the book's many virtues that the reader begins to see how present-day debates are often not that much more than ill-informed repetitions of fundamentals taken up in those earlier times.

Let us now consider the overall composition and build-up of Gaukroger's argument in this fourth volume.

² <https://www.journals.uchicago.edu/doi/full/10.1086/593223>.

³ <https://www.journals.uchicago.edu/doi/full/10.1086/676361>.

⁴ <https://www.journals.uchicago.edu/doi/full/10.1086/690700>.

Culture and civilization. A book dedicated to the rise of a scientific culture obviously needs treatment of what these two subtly distinct concepts mean, and have meant. Here already Gaukroger displays his sensitivity for both the remarkable similarities and the huge differences between debates about what 'culture' and 'civilization' stand for in Great Britain, Germany, and France – a strength that comes to the fore throughout the book. There is nothing here of the Anglocentrism that, whether intentionally so or not, has marked so much work in the history of science, and often still does.

Unity of science. Almost half of the book is dedicated to debates about the unity of science and some purported hierarchy between them – debates that, during the period, were carried on inside, and about, physics, chemistry, and the life sciences. These chapters are informed throughout by Gaukroger's own stance on the matter – for a significant reason addressed below, he regards such efforts as fundamentally misguided. It is surely unusual for a historian to take sides in long-past events in so outspoken a manner. Yet he manages so artfully to avoid the customary side-effect, partisan treatment, that this particular feature should rather be regarded as just a boon – his own standpoint helps give urgency to the often foundational issues up for discussion.

Expansion of scientific understanding. The choice of subjects under this heading is, once again, a very thoughtful one. Pursuing here a major theme of the previous, third volume, Gaukroger first discusses how the rise of the human sciences widened the spectrum of science, thus enhancing the claims of science to legitimacy and at the same time exploding in effect (although not every scientist picked up the message) any effort at construing the supposed unity of science. From there he moves on to debates about what knowledge domain should be regarded as providing the core of our human understanding of the world – philosophy (whether or not appearing as theology in disguise) or science.

Applied and popular science. In these chapters Gaukroger is quite sensibly concerned to argue that technology and the 'popularizing' of science are not features added to some unaltering hard core named 'science', but that science itself is intertwined from the very ground up with technology and likewise with ways to spread science and in so doing seek to legitimize it.

Science and the civilizing process. In this final chapter before reaching his general conclusion Gaukroger shows, by means of the discourses of some early 'eugenics' proponents, how the newly-gained centrality of the scientific endeavor began to lead to efforts to alter (and, so it was fondly believed, improve) the human species itself.

Of course, each of these themes as such is well-known in the scholarly literature. It is their concatenation in one overarching argument about the consolidation process of science that lends their treatment such compelling force. The subjects that Gaukroger successively brings up are very well chosen, in that they are at the very heart of the key question at issue throughout the series: what it meant for science to become central to modern culture. And indeed, as the reader works his way through the 435 text pages of this volume he needs never be in doubt *what* he is reading or *why* he is reading it. Signposts and half-way summaries have been placed quite judiciously, in neither too small nor too large a number.

Likewise very well balanced, and always in proportion, is the relation between the argument of a given chapter, the written illustrations provided to open the reader's mind to its significance, and the empirical material invoked to sustain it. Even when, in the chapter on applied science, Gaukroger is discussing the

case of the airplane in far greater detail than any so specific a topic anywhere else, the reader finds soon enough that he has had every good reason to do so. Furthermore, for each topic under successive discussion all the documentation is being provided that one may wish for, by means of appropriate footnoting and a full bibliography at the end. The possible uses to which the entire series may be put are greatly enhanced by means of a carefully designed, well-detailed General Index that, in covering the entire work, sends you to entries running from 'a priori truths' (26 items in volumes II and IV) to 'Zuñiga, Diego' (2 items in volume I).

The ample and, on occasion, quite spectacular pictorial material provided throughout the book is never in the nature of 'pretty pictures'. Rather, each black-and white or (in a few cases) colored plate helps illustrate some particular point raised in the main text.

Although not brilliant, the prose style is lucid and to the point. Never does Gaukroger give the ongoing accumulation of nuances that his treatment customarily consists of a chance to turn the argument under discussion into a swamp — the argument itself never becomes murky. As compared to earlier volumes and to earlier work of Gaukroger's, I have even encountered here more frequently than before the use of brief, almost aphoristic phrases that help illuminate with a sudden flash some given argument or stance.

As noted at the outset, the book is quite unmistakably, both in its overall argument and in the various subjects selected to make it stick, part of a larger whole. Even so, it can also be read as a study in its own right — the two aspects of the book are both visibly there, yet they never stand in each other's way. It is only in the concluding chapter of this volume, that also concludes the series as such, that the part and the whole come fully together.

They do so in two respects — Gaukroger sums up, in a 12-pages long virtuoso performance, the *method* he has been following right from the start and the principal *results* he has attained along the way.

The first few pages of the conclusion may well be called a declaration of independent method. No one, whether authority or not, has been given a chance to prescribe what method or methods Gaukroger has to follow — 'internalist' here, 'externalist' there; if contextual, then never along any preset lines, be they social, economic, cultural or whatever. Just as he has been both adopting and creating the *concepts* that proved to suit best his basic problem as he set out to investigate it, just so has he been both finding and creating the particular *methodical tools* that appeared to him as the ones most proper to each issue as it came to present itself to him while moving forward.

In the overview of *results attained* that concludes the concluding chapter we may discern three broad stages. The first stage opens with the adoption of Aristotle's natural philosophy in Europe's intellectual world and covers what (so I am pleased to report) Gaukroger is not at all shy to call 'the Scientific Revolution' of the 17th century. At first, from the early 13th century onward, an intellectual climate arises that is fundamentally at variance with any climate in which natural philosophy in any other civilization (notably Greece, China, the Islamic world) has ever found a home for more than quite short-lived periods. And it is not just that, thanks to a theological rift which Aristotelian metaphysics has come to bridge from the early 13th century onward, this European climate begins to turn so different. Indeed, that intellectual climate, so significantly more welcoming to natural philosophy than elsewhere, proves to be not a little flexible when, by 1600, natural philosophy itself undergoes radical change — broadly Galilean, Baconian, and Cartesian change. With natural philosophy now presenting itself in three mostly different main varieties —

mechanical, experimental, and causal-corpuscularian – it gradually turns out to lend itself to being put at the service of natural theology, thus making it sufficiently acceptable to the wider culture after all. We are now in the second stage of consolidation. By mid-18th century, the Christianity / science alliance threatens to come unstuck. The rise of the human sciences, accompanied by the rise and short-lived flourishing of the unifying concept of sensibility, saves the alliance for a while, until by mid-19th century science and Christianity are largely decoupled for good. The quest is opened – and this is where the third stage begins – for a persuasive demonstration that science has a better unified conception of the world on offer than old-time religion has ever had, or even can have. It is in regard of this crucial issue that Gaukroger has morphed himself into a critic. Here is how he sums up his basic view on the matter, revealing in the same breath the basic motive underlying his entire enterprise: “These last developments were premised on the idea that there must be some unified scientific account of the world, and that the understanding it embodies is theoretical (as opposed to practical or instrumental for example) in nature. Challenging this assumption has been one of the main tasks, and one of the *leitmotifs*, of the volumes, coming to a head in this final volume” (p. 432). Yes, so Gaukroger is arguing in these final pages, science has replaced Christianity at the center of our culture, but no, science is not, and never has been, in a position to come up with a fully rounded conception of the world as such – a realistic understanding of what science is about needs to be a more pluralist one.

This pluralist note goes further than this particular and very welcome conclusion alone. As I trust I have made amply clear, there are many reasons for profoundly admiring Gaukroger’s achievement. An additional reason is that he neither claims nor even implies that the ‘how did science get consolidated’ narrative he has been telling in his own way and by means of his own chosen methods would be the only possible way to tell it. Let me end this essay review by listing, however briefly, some major aspects of his argument that fail to persuade me or that I find missing altogether. These are: the nature of Europe’s exceptional development in regard of natural philosophy and science ; a profound, mid-17th century crisis of legitimacy, and certain elements left out of the consolidation dynamics as Gaukroger conceives it.⁵

Gaukroger quite rightly adopts a major observation made by Joseph Ben-David in 1971,⁶ that flourishing phases of natural philosophy in China, in Greece, and in the Islamic world were halting at best and short-lived in any case, with modern science as it arose in Europe representing the sole exception to that rule – an exception which, therefore, cries out for explanation. Actually, for Gaukroger as also for myself this acute observation of a customary ‘boom/bust’ pattern, with Europe in due time coming to form the exception to the rule, has served as the very starting point for our to some extent parallel quests. Given the vastness of his own enterprise Gaukroger can easily be forgiven for not taking in addition the seductively beckoning, cross-culturally comparative route that full elaboration of Ben-David’s insight requires. Even so, his regretful decision not to take that route has had some unfortunate consequences for his own enterprise.

In regard of those other civilizations from which, in respect of science, Europe has come to deviate so widely and so deeply, it is just not good enough to attribute that ‘boom/bust pattern’ to the one mechanism

⁵ In what follows I either sum up or elaborate on certain elements in a sustained comparison between the books mentioned in note 1 and Gaukroger’s first volume that I made in ‘Two New Conceptions of the Scientific Revolution Compared’ in the journal *Historically Speaking*: 14, 2, April 2013 (<https://doi.org/10.1353/hsp.2013.0010>).

⁶ I summed up Ben-David’s pertinent views in my *The Scientific Revolution. A Historiographical Inquiry*. University of Chicago Press, 1994; pages 254-256 and 367-377.

Gaukroger has in store for it: "...the solution of a defined range of specific problems was the rule, and success in this enterprise usually brought an end to significant attention to theoretical scientific problems" (p. 424). After all, such problems always came in tandem with the pursuit of medicine and with widely-spread, philosophy-laden moral teaching (in Greece and in China as well as in the Islamic world), thus allowing consolidation over significant periods. What was at risk of losing momentum was not so much continued pursuit *as such*, as rather the ongoing, relatively oversight-free, forward-looking exploration of novel territory.

In that somewhat narrower regard Europe did not really begin to deviate until the 1660s. The pattern of creative exploration in the Buridan-to-Oresme period is just as boom/bust as it has been elsewhere. And the still more radical, renewed exploration phase that starts in Europe with the fall of Byzantium and culminates in the three largely separate, revolutionary transformations brought about by Galileo and Kepler, by Beeckman and Descartes, and by Bacon, Gilbert, Harvey, and van Helmont puts the fate of exploratory science actually at even greater risk of losing indispensable momentum than earlier or elsewhere. Both Galileo's and van Helmont's findings, as well as Descartes' cosmology or Gassendi's atomism carried with them the dual threat of strangeness and sacrilege. It is not for nothing that the decade and a half between the first phase of the Scientific Revolution (c. 1600 – ca. 1645) and the very much different second phase (c. 1660 – c. 1685) constitutes the Revolution's lowest point, thus indicating that momentum was already slipping away in the broad manner this happened in the earlier cases of, notably, mathematical science and natural philosophy in the Islamic world and in pre-Renaissance Europe.

As to the issue of sacrilege, Gaukroger's effort to distinguish between a Christian theology of two kinds, with Aristotelianism serving as the metaphysical bridge between them, looks almost irrelevant in the face of that looming crisis. Very considerable friction with quite basic, thus far undisputed Christian verities could not be avoided even in the best of cases. What exacerbated the problem of well-perceived sacrilege was the strangeness, that is, the profoundly counterintuitive nature of many of those novel discoveries, not only those that pointed at the Earth as a planet but, by their very nature, many hundreds more. What, up against these two big risks of intrinsic strangeness and apparent sacrilege, saved the exploratory pursuit of revolutionary science (both mathematical and experimental), and of revolutionary natural philosophy as well from losing momentum for good was the creation, in the nick of time and against the background of vast changes in the European power structure at the time, of two major legitimating ideologies. In the Catholic realm a very special Jesuit mishmash fulfilled that role to some extent, whereas Protestant Europe (and England in particular) witnessed the rise of a 'Baconian Ideology', where strategically operating apologists like Thomas Sprat and John Glanville managed to couple Baconian belief in progress through the rise of a science-based technology onto a broadly Christian message.

The above does not in any way weaken my full agreement with Gaukroger that the consolidation dynamics he has examined over his four volumes was not a foreordained but rather an in large part contingent affair, going through unforeseeable ups and downs of many varieties. Where we differ, is in noticing the steepest and riskiest 'down' of them all, the 'strangeness and sacrilege' legitimization crisis of the 1650s. We differ also to some extent over how legitimacy was re-established (at least for the time being). This concerns the realm of the arts and crafts and the gradual, centuries-spanning transformation of many of

them into science-based technology. By ignoring this domain until, in vol. 4, he arrives at mid-19th century efforts in the latter direction, Gaukroger misses the very powerful consolidation dynamics that already far earlier rested in the arts and crafts. This dynamic consisted, in the 17th century, of the confident *promise* of a scientifically reinforced technology and, over the 18th, of the slowly expanding *reality* thereof in the domains of, notably, British mining and navigation.⁷ Clearly other consolidation dynamics were at play as well, and we are in great debt to Gaukroger for identifying several of them for the first time. But his is not the whole story. I even wish to identify two further, likewise powerful motors furthering ongoing consolidation.⁸

One is the dynamic intrinsic to both revolutionary-mathematical and revolutionary-experimental science. Such inherently endless ‘problem → solutions → new problems → new solutions’ sequences as characterize our present-day science to so large an extent, already carried Galileo’s and Kepler’s discoveries to Newton’s synthesis thereof in less than half a century. Similarly so with Bacon’s aural experiments, within half a century leading to substantial discoveries in musical acoustics. Even such 17th century examples alone can be multiplied almost at will. Sequences like this signify a powerful dynamic in its own right. But that is still not all there is to it. The same dynamic was also, and fairly quickly so, found to run in large measure on procedures of *feedback control* as the broad pathway proper to modern science. Starting with Galileo in particular, numerous protagonists like Hooke or Huygens went to great lengths to establish the best procedural ways available to eliminate bias to the largest extent humanly attainable, and thus to sift, with some luck and for the time being, between what is most probably largely correct and what is most probably untenable or at least not yet up for empirically controlled research – an effort that has likewise gone on to the present day.

This oh so typical procedural habit does not only possess considerable consolidating power. It began at once to appeal to people with a particular bent of mind, early on summed up by Pascal in a striking two-liner: “We have an incapacity for proof which no amount of dogmatism can overcome. We have an idea of truth which no amount of scepticism can overcome”.⁹ I am writing these sentences by mid-April 2020, in the midst of the Covid-19 crisis. I am deeply impressed by the apparently large number of people capable of facing with a degree of acceptance or even some equanimity a situation where the origin of the crisis, and humanity’s way out of it, are neither just anybody’s guess nor a matter of unshakeable *a priori* certainty, but something intangible in between. More than that, immensely powerful people very loudly *not* of that part-sceptical part-confirmatory bent, like the current presidents of Brazil or of the United States, find themselves obliged, far too late and haltingly at best yet *not* never, to lend their ear to people who professionally share that particular outlook, to wit, to scientists specialized in the now acutely pertinent disciplines of virology and epidemiology. In that sense, too, we see before our eyes *that*, but also to some extent *how*, science has, indeed, become central to our culture.

⁷ Outstanding, too much neglected work in this regard has been done by Donald L.S. Cardwell, notably in his *Turning Points in Western Technology*. New York: Neale Watson, 1972.

⁸ For full treatment (in the book mentioned in footnote 1) of these two dynamical elements I refer to ch. 17, sections ‘17th-century props’ and ‘Advances on many fronts: the big picture’, and to the many passages these two sections go back to.

⁹ “Nous avons une impuissance de prouver, invincible à tout le dogmatisme. Nous avons une idée de la vérité, invincible à tout le pyrrhonisme.” (I am following, with one small exception, the translation by A.J. Krailsheimer in the 1966 ‘Penguin Classics’ edition of the *Pensées* (no. 406 in Lafuma’s arrangement)).