Statues of Galileo Galilei and Copernicus on the spire of the Astronomers Monument in front of the Griffith Observatory, Los Angeles

Periodic label

NICHOLAS POPPER

David Wootton
THE INVENTION OF SCIENCE
A new history of the Scientific Revolution
752pp. Allen Lane. £30.
978 1 84614 210 9
US: Harper. $35. 978 0 06 175952 9

The study of early modern science has blossomed in the past three decades. Armies of researchers have directed an unparalleled command of disciplines, linguistic expertise, technical skill and archival acumen to investigating the pursuit of natural knowledge between 1500 and 1750. Their favoured approach has been microhistories and case studies, examinations contextualizing the conditions under which figures such as Copernicus, Galileo, Bacon, Descartes, Boyle and Newton operated.

This scale of magnification marks a dramatic shift. Early twentieth-century historians of science were primarily concerned with charting the emergence of modern science, and they first labelled its formation

in early modern Europe as the "Scientific Revolution". They and their successors saw their role as finding an illustrious past for the resplendent present, and they traced science's progressive realization through the early modern men whose discoveries and ideas stripped nature of its mysteries and produced the peculiar circumstances of modernity.

But beginning with Thomas Kuhn and accelerating after the 1970s, historians of science increasingly recoiled against this Whiggish approach. Kuhn's experience as a physicist had exposed to him a gap between the mythology of science and its practice, and rather than portraying humans as passive mechanisms by which nature was translated into knowledge, he characterized science as an eminently social enterprise. Accordingly, instead of seeking a genealogy for the present, Kuhn and his successors investigated why past scientific knowledge had assumed its distinctive contours.

These scholars turned to anthropological and sociological methods to understand historical subjects within the logics peculiar to their own time. And viewed in local context, many scientific heroes looked very different. Their aims sometimes included both personal and intellectual advancement. Their labour often depended heavily on figures absent from the standard narratives – artisans and craftsmen, wives and sisters, brokers and informants from foreign countries. Sometimes they took credit for work others had done or reserved their findings for private audiences, in contravention of modern science's ideal of transparency and disclosure. Their ideas often emerged from engagement with unexpected studies like philology or law or, more shockingly, seemingly esoteric and credulous pursuits like alchemy and biblical chronology. Ground-breaking discoveries, methods and instruments often appeared the result less of the principled implementation of the scientific method than improvisational problem-solving. And the meaning of their work, far from being self- evident, often turned out to be underdetermined, eliciting elaborate and conflicting interpretation by contemporaries. Gradually, it became clear to many historians of science that such contextual factors were not obstacles, but rather essential features necessary to the production of scientific knowledge.

Proponents of this approach have repeatedly been accused of portraying science as a scam, but in truth, it does not deny the power of science to maintain that the questions scientists ask and their resources for devising solutions are contingent on their environments. And surveying the literature of the past thirty years, it is clear that challengers to the traditional narrative of Scientific Revolution have maintained a coherent constellation of assumptions about early modern Europe – for example, that experience and experiment had more authority than before, as did quantification and collection of evidence on a grand scale, and that the interplay of reason and empiricism by testing theories increasingly took centre stage. But the notion that there was a unified, even straightforward, process, driven by the unleashing of reason by a glorious few, has been permanently shattered. For viewed up close, little of the past seems to fit the tale of a natural, preordained Scientific Revolution cherished by previous historians.

No grand narrative, however, has replaced that older Scientific Revolution. And recent murmurs suggest that something has been lost by ignoring the question of large-scale change over time. True, there have been surveys covering alterations in natural knowledge. But there has been little enthusiasm for

consolidating the case studies of the past generation into a new overarching story. Reviewing Katharine Park and Lorraine Daston's landmark *The Cambridge History of Early Modern Science* (2006) in these pages, Nicholas Jardine offered praise tempered by his observation that its exemplary case studies almost universally avoided mention of the Scientific Revolution, and he fretted that perhaps by jettisoning an outdated framework its authors had blinded themselves to meaningful historical change.

This desire to recuperate a grand narra- tive underlies David Wootton's ambitious, bracing, relentless, bellicose, maddening, sprawling, sometimes brilliant, and always provocative *The Invention of Science: A new history of the Scientific Revolution*. Wootton presents himself as seeking to integrate the best of both worlds, but his own preferences are clear. His vision descends from the conviction that a majestic Scientific Revolution, spearheaded by a few highly educated European men, yielded a method that mechanistically translated nature into knowledge. In a series of theoretical chapters bracketing the historical body of the book, he repeatedly condemns sociologically informed scholars for eschewing Whiggishness, emphasizing conflict among scientists, and privileging local variation. To him, the real story could not be any more obvious: the Scientific Revolution was a single grand movement, it marks the greatest change in human history since the Neolithic era, and as the force that stimulated subsequent momentous changes like the Industrial Revolution and Enlightenment, it is singularly responsible for the formation of the modern world.

Wootton, to be sure, does not rely on precisely the same tools as earlier generations. He emphasizes less the train of discoveries than the emergence of a language for describing natural inquiry at the core of modern science (indeed, some readers' attention may drift during the many pages devoted to analyses of subtle shifts in vernacular languages). And he is at pains to distance himself from naive scientific realism, insisting that nature does not speak for itself but can be accessed through human investigation and inquiry; as he puts it, his method intends to show how legitimate scientific knowledge is "semi-determined" by nature.

Wootton's climacteric moments include 1572, when Tycho Brahe sighted a "new star" in what prevailing orthodoxy demanded were unchangeable heavens, which provoked the community of astronomers to begin working in ways Wootton deems scientific; 1611, when Galileo spectacularly extended their gains through his use of the telescope; and 1704, when Newton's *Opticks* marked the consolidation of modern science. This vision emerges in a series of roughly chronological chapters tracing the emergence in European vernaculars of terms denoting concepts and categories essential to modern science. Most important for him is the notion of discovery, which entails the belief that knowledge held in the present is always incomplete. This idea, "a crucial precondition for systematic innovation in the knowledge of nature", he depicts as a consequence of Columbus's "discovery" of the New World, which unsettled medieval confidence in the perfection of ancient wisdom. Embracing the possibility of discovery stimulated other core features: the idea of progress emerged as discoveries accumulated, an environment of competition to make discoveries produced the practice of attributing priority to those who achieved them, and a militant commitment to accuracy developed as a way to certify them.

The other essential precondition of the Scientific Revolution was the adaptation of mathematical techniques for observing nature. The power of mathematical analysis had long been recognized in some fields – most notably perspectival painting and double-entry bookkeeping – but its value for astronomy accelerated after Tycho. As astronomers increasingly agreed that it was the key to unlocking the mysteries of the heavens, Galileo demonstrated that terrestrial and celestial bodies operated according to the same rules, demolishing verities upheld by Aristotle and the Church and the long-standing hierarchies of natural disciplines.

The concept of discovery and desire for mathematization propelled a new language, apparatus of concepts, and set of ambitions. This group included the mania for facts; the decisiveness of replicable experiment; the pursuit of laws independent of theoretical explanation; the use of hypotheses and mobilization of observation to test theory; a community of experts sharing standards of judgement and evidence, and more. Wootton shows that this language sometimes first appeared in works outside the usual roster of suspects (though typically in works of major intellectual figures like Montaigne or Hobbes whose contributions are thought to lie elsewhere). He describes scholars operating in ways that had long been possible, yet had never been considered meaningful – Galileo's use of household materials to test Archimedes' principle of flotation and his decision to point a spyglass upward are exemplary. These innovations fuelled each other in an atmosphere oscillating between competition and collaboration. The consequences were astonishing – predictive models of natural activity, machines capable of harnessing unimaginable energy, a world whose perseverance did not require the constant custody of an ever-immanent divinity. "In 1650 nobody quite knew how to study the physical world", Wootton claims, but, he assures us, half a century later, learned Europeans did know. And this placed at their disposal an unprecedented engine for limitless, irreversible and unassailable knowledge of nature.

Despite its gradual crystallization, Wootton claims this outcome was long inevitable (and not just because, he assures us, good knowledge always drives out bad, though there are no clear guidelines on how long we have to wait). He describes the logic of his history as "path-dependent"; once certain pieces of evidence had been encountered, questions asked, and verities destabilized, specific outcomes were inescapable. Once the spyglass existed, that is, Ptolemaic astronomy was doomed. Wootton applies this logic to historical change as well as to knowledge of nature. For example, he credits the modern notion of facts to the invention of the printing press, a technology which allowed a qualitative change in the circulation and volume of information available to scholars. As he explains, "once the printing press had been invented, the concept of the fact . . . became inevitable, just as it was inevitable that the telescope would eventually be used to discover the phases of Venus . . . . The question was not whether, but when, where, and by whom". These specifics, however, are mere accidents of history; individuals manifest rather than cause change, caught as they are amid the play of surging, retrospectively obvious forces. By this logic, the Scientific Revolution was a foregone conclusion as soon as Columbus decided to sail westward.

There is much that is bold and insightful, including highly original investigations on the invention of the steam engine and the emergence of a "terraqueous" conception of the earth, probing philological

explorations across myriad languages, truly learned expositions of discoveries and events, and more. But given his express ambitions, the question is whether Wootton's account effectively absorbs and transcends the past generation of scholarship.

Unfortunately, it is hard to say that Wootton has achieved his aim. When engaging it, his combativeness often leads him to recruit straw men against whom to argue, to dismiss persuasive research on dubious grounds, and to rush past analytical knots. Some of his punches do connect; for example, his theoretical claim that historians cannot help but engage in a certain degree of Whiggishness is indisputably correct (this does not mean they should not seek to restrain it), as is his argument that the transformation of early modern science was neither sudden nor violent. But central arguments often seem stale or dated. The many approaches that he lumps under the single rubric of relativism do not uniformly contend that "all perspectives are equally valid". The relativism of most historians of science is not a form of denialism, but an analytic device of healthy scepticism that guards against judging the knowledge of any one moment by an absolute, universal standard (typically that of the present). It is pernicious to conflate this responsible historicism with flat-earth theory. Similarly, he laments how scholars since Kuhn have depicted science as constantly riven by debate when many powerful changes take place by universal, tacit assent. This view sits uneasily with his own claim that competition is one of modern science's fundamental features. It also makes it impossible to see why historians of science gravitate towards agonistic episodes, which is because their tensions expose assumptions that otherwise remain embedded in the practice of consensual science.

The determinism of Wootton's vision requires the elision of a great deal of historical complexity. Consider his point that the printing press inevitably birthed the modern fact. Gutenberg devised the press in roughly 1440; Wootton claims that Italian natural philosophers first used the term for "fact" in its modern meaning in the 1570s (an early date relative to other scholars), and that the category only gained widespread intellectual currency in French and English after 1660. The publishing industry and market experienced repeated transformations during this long gestation; it seems unconvincing to depict these as historical wheel-spinning. There are many comparable occasions where readers are asked to ignore long periods of uncertainty, and it is unsatisfying to suggest that these closed solely because of the long-dormant consequences of preexisting factors without any influence from immediate contextual factors. This effectively concedes defeat on the questions of why and how structural forces effect significant change at specific moments – one of the strengths of microhistories.

Indeed, the reader is pressed to ignore much detail, often on shaky grounds. Newton's belief that the ancients understood gravity was "a private eccentricity, a useful defence (we may suspect) against the pride that might be engendered by the realization that he was the greatest scientist of all time; only one or two of his closest friends were prepared to take it seriously". Concerning Galileo's surprising polemic against the value of parallactic measurements, Wootton assures us that "contemporaries were right to ignore him, and we should, too". The past generation of scholars have laboured to show how such seemingly aberrant evidence profoundly illuminates both social and epistemological dimensions of the history of science; Wootton's dismissals exclude evidence that does not fit his own a priori notion of

science. There is a similar arrogance in the way that he casually describes his subjects as "wrong" about how knowledge is gained or quibbles with them (for example: "Hooke's imagery is misleading – and he was misled by it").

Contemporary scholars come in for similar battering. In recent years, historians of science have increasingly focused on the practice of science rather than its rhetoric or ideas. Scholars like Lawrence Principe and William Newman, armed with impeccable training in chemistry – and similar scepticism to sociology – have struggled to decode the mysteries of medieval and early modern alchemists. They have, instead, revealed many alchemists as sophisticated experimentalists with prescient views on matter theory, pragmatic knowledge and more, and in this way have synthesized the trajectory of alchemy into a new chronology of the Scientific Revolution. Wootton dismisses their arguments on the sole grounds that alchemists did not have ideals of transparency appropriate to a modern science. In the same vein, scholarship influenced by book history has demonstrated that early modern scientists habitually circulated their findings through closed manuscript networks rather than through print publication. Even when it was published, they have further revealed, material mediated by the press was often altered in the course of production, and readers at the end of this chain frequently interpreted their sources in unexpected ways. Wootton's brusque dismissals of such findings are insufficiently justified.

Ignoring the messy practice of science for its final polished products has real consequences. For one, presenting science as a mechanical exercise diminishes the inventiveness, creativity and collaborative energy required for new ideas (and that will surely be needed to unravel current mysteries like quantum entanglement, whose solutions may make current orthodoxy appear an unfortunate detour). In the case of early modern science, it particularly obscures the vast array of craftsmen, artisans, apothecaries, wives, daughters, sisters, servants and other "invisible technicians", as well as Ottoman, Arabic, Jewish, Indian and African informants, practitioners and sources, whose labour and expertise were essential to early modern science, but who were rarely if ever credited in print or by subsequent historians. One of the field's most exciting new terrains is an expanding literature that excavates these relationships on a global scale, establishing connections between colonial physicians and enslaved African healers, Spanish illustrators and Amerindian guides, rural French laundresses and bureaucratic engineers, Arabic mystics and European stargazers. It makes no appearance here; nor does the similarly growing body of work that reveals through imaginative and precise work that Europe's imperial science and technology often did not perform their functions as well as the local versions they replaced. Science cannot be reduced to its printed manifestations.

Wootton's claim to integrate the social and the natural in his account yields a very old-fashioned result, for what he seems to mean by this is that a small group of early modern European men fashioned a tool of inquiry that let nature speak. Rather than the story of multiple modernities that global science is revealing, he wishes to re-institute a view of a single modernity fashioned by the predictable canon of Bacon, Descartes, Newton, etc. Wootton's perspective emerges most powerfully when he claims that the driving force behind the relativism he loathes is multiculturalism (which he superciliously pronounces "honourable in intention though profoundly problematic in practice"). This is only the shrillest of

occasions in which the diversity of the early modern world is studiously ignored. Though he ridicules the idea that all knowledge is “ethnic or partisan”, Wootton’s self-described objective historical process in fact articulates a very specific point of view.

Despite his admirable desire to construct a new history of the Scientific Revolution, Wootton falls back on comfortable old verities. There is a politics to his choices, one that compounds a denigration of forms of research that he does not practise. Increasing the magnification on figures in the past, struggling to reconcile the microscopic and the macroscopic, seeking to embrace a more encompassing understanding of humanity’s knowledge of nature and its relationship to other types of knowledge – the new grand narrative David Wootton seeks will be a tapestry woven together by these threads, along with the many shreds salvageable from the older story. That is what advancement in the history of science will look like. For it, too, still moves.