BJHS, 2002, **35**, 97–123

Book reviews

IAN HACKING, **The Social Construction of What?** Cambridge, MA and London: Harvard University Press, 2000. Pp. x + 261. ISBN 0-674-00412-4. £11.50 (paperback).

Ian Hacking does not skimp in answering his title question. He looks at the social construction of women refugees, the psychological subject, quarks, schizophrenia, child abuse, the velocity of light, a limestone-like rock called dolomite and the motives of murderous Hawaiians, among other 'whats'. His aim is less to evaluate than to clarify. He asks about the nature of claims for social construction, and the sources of the 'constructing attitude' (p. 47) now so widespread, not least among historians of science. His book is a tract for our times, full of insights about the recent science wars. But it is also part of a project that, in one way or another, has engaged Hacking for some thirty years. That project is, roughly, to integrate Michel Foucault's insights about knowledge and power into analytic philosophy. There is much of Foucault in Hacking's abiding concern, here as elsewhere, with how the past shapes present possibilities, of thought, language and action.

The first two chapters provide some general orientation. As Hacking shows, people reach for the phrase 'social construction' when they want to deny that an item now taken for granted is an

inevitable product of a universal human condition, or an inevitable discovery about a pre-existing order of nature. He bids us not to exaggerate the novelty of these denials. The constructing attitude of the present day belongs to a tradition of sceptical humanism, inaugurated by Immanuel Kant, and including the logical positivists. There is nothing new in insisting that we humans construct what we claim to discover. What is new is the interest in how we do it, in actual historical process, and especially in how particular social and material arrangements help bring an item into being and then sustain it.

Items in the natural sciences are the 'whats' of the third chapter. Quarks are social constructs, says the sociologist of science. Just look at the history. No, replies the high-energy physicist. Quarks are discovered constituents of nature – real, not constructed. Hacking intends the title of his book in part to promote better intellectual hygiene in encounters like this. He wants us to ask what, precisely, is claimed as constructed, and then to make some distinctions. The key distinction he urges is between ideas – the classification 'quark', say, or the theory of quarks – and objects – quarks as entities in the world. The issue dividing the quark constructionist Andrew Pickering from his critics is not whether the entities, quarks, are real. The issue is whether there might have developed a different but equally successful physics that did not include quark ideas. That odd counterfactual claim needs unpacking, and Hacking delivers, brilliantly. He judges that contingent history shapes scientific knowledge in two ways. First, scientists might have asked different questions. Second, they might have resolved conflicts between theory and world in different ways. According to the questions asked, and the resolutions chosen, a science will develop along one of several different possible pathways.

There is more than a little irreverence in the view that much of what scientists hold for true they might not have, or that the classifications used in the sciences do not match the inherent structure of nature (if there is such a structure), or that scientific knowledge remains stable so far as the surrounding social and material arrangements remain stable. These three related theses – on contingency, nominalism and stability, in Hacking's terms – constitute a metaphysics, with a political edge. 'The science wars, as I see them', he writes, 'combine irreverent metaphysics and the rage against reason, on one side, and scientific metaphysics, and an Enlightenment faith in reason, on the other' (p. 62). The rage against reason is a rage against environmental poisons, weapons of mass destruction and other ruinous products of science. One way to aid those who struggle against ruinous science is to undermine the authority of scientists, and one way to do that is to deny that scientists are lighting up dark corners of a God-given reality. Hacking evokes the rage behind the metaphysics – but also the bewilderment of scientists who value the idea of one truth as a safeguard against totalitarian lies.

Constructionist irreverence carries over from the natural into the human sciences, and intensifies. The label 'quark' names what Hacking calls an 'indifferent kind'. Quarks are indifferent to how we sort them. People are not indifferent. Directly and indirectly, people interact with the kinds we use to sort them. A label can alter a person's self-understanding and behaviour, so much so that the person is no longer of that kind. Hacking looks at these 'interactive kinds' in his fourth chapter, about mental illness, and fifth chapter, about child abuse. It sounds reckless to claim that schizophrenia or child abuse is a social construct, until we ask what, exactly, is claimed as constructed. Child abuse, or the idea of child abuse? Some adults batter children, and that battering is real. But, Hacking shows, the concept of child abuse – what counts as an instance of it, what it means to be of that kind – emerged through the actions of doctors, social workers, journalists, feminists, politicians, support groups, survey-takers and others, starting in the United States around 1960. He makes a number of telling contrasts between the twentieth-century kind, 'child abuse', and the nineteenth-century kind, 'cruelty to children'. Sex between an adult and a child is, we say, an act of child abuse. But that would not have been obvious for the Victorians, who did not classify sexual acts as instances of cruelty. What, then, is constructed? Interactive kinds; but also the matrices within which those kinds come into being, and the people whose lives, inner and

outer, go differently in virtue of a certain pattern of sorting.

The final three chapters, on weapons research, dolomite and the murder of Captain Cook, develop the themes of the earlier chapters, but in a piecemeal way. The chapter on dolomite in particular seems a missed opportunity. Here Hacking describes the history of debates about the formation of dolomite, and then uses the dolomite case to illustrate the insights of old and new philosophical perspectives on science. He alights on inductivism versus deductivism, then interests, networks and such. This is all fine, if unprepossessing. I wish he had turned instead to a contrast introduced in the chapter on the natural sciences, between an old-school, logical doctrine, due to W. V. O. Quine – that observation underdetermines theory – and a new-school, constructionist doctrine, due to Pickering – that the resistance of the world underdetermines scientists' efforts at accommodation. Quine's doctrine directs attention to how scientists modify their theories; Pickering's doctrine to how they also modify their apparatus, their analyses, even the phenomena under study. The dolomite case would have served well to show what these abstractions amount to in practice, and how much the historian who ignored them would be missing.

No matter. The book as a whole is advertisement enough for history of science in a philosophical key, and philosophy of science in a historicist key. Even philosophers who have taken the historical turn have so far been little inclined to think hard about the extent to which the sciences are independent of their histories. I hope Hacking succeeds at putting contingency, nominalism and stability on the philosophical agenda. As for historians of science, the constructing attitude is more or less standard issue among them now. But out of shared metaphysics and shared rage? Often, I suspect, the attitude is little more than a writing strategy, a stance adopted towards the past to ensure that narratives do not come out sounding 'Whiggish'. Hacking invites historians to take themselves seriously, and gives them the philosophical tools with which to do so.

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Peter Machamer, Marcello Pera and Aristides Baltas, **Scientific Controversies: Philosophical and Historical Perspectives**. New York and Oxford: Oxford University Press, 2000. Pp. x + 278. ISBN 0-19-511987-8. £32.50 (hardback).

This book is the long-awaited sequel to Marcello Pera and William Shea (eds.), *Persuading Science: The Art of Scientific Rhetoric* (Canton, MA, 1991). The format is largely the same: take a dozen senior scholars from North America and the European Mediterranean clearly identified with the 'history and philosophy of science' (often the same ones as before), along with a few of their worthier students, and sequester them for a few days in an Italian villa. The results this time are better than before, at least in terms of the range and quality of contributions.

Beyond the usual discussions of the Scientific Revolution, we find here cases drawn from eighteenth- and nineteenth-century chemistry and twentieth-century biology, psychology and anthropology. Another improvement is the editorial insistence that contributors position themselves with respect to each other's conceptions of scientific controversies. Too bad the contributors failed to interpret this charge as an opportunity for disagreement. The reader is thus treated to the spectacle of many apparent differences among these scholars of controversy left unvoiced or air-brushed out of existence. Perhaps the cosiness of the Italian villa was not such a good idea, after all! Or, perhaps, Maurizio Mamiani's chapter on how Robert Hooke and Isaac Newton settled their controversy over the nature of colour explains matters here. I leave it to the reader to decide.

All told, however, a paperback edition of this book would make a rather good textbook on scientific controversies. Peter Machamer's opening chapter is a model of didactic clarity. Since scientific enquiries are supposed to be settled by some definitive piece of evidence or reasoning, the presence of significant controversy proves awkward. The longer controversy persists, the more likely it will take in more issues and threaten the legitimacy of the scientific community. Philosophers have tended to diagnose this situation in terms of some negative cognitive trait, especially stubbornness and ignorance but

sometimes also disingenuousness. An overarching aim of this book, then, is to present scientific controversies in such a way that they appear normal. Of course, this is easier said than done. Perhaps the most successful chapter in this vein is by Pierluigi Barrotta, who dislikes the post-Kuhnian pendulum swing from vilifying to valourizing dogmatic attitudes in science. Barrotta criticizes recent attempts to rehabilitate Joseph Priestley that explain (and excuse) his persistent defences of phlogiston in terms of a strongly held world view. Barrotta argues that this is to get Priestley's ends and means exactly backward. Instead we should see his world view as the motivating force for driving home valid criticisms of what turned out to be the dominant tradition in chemistry. Barrotta is the sort of dialectician Hegel would have loved.

Barrotta's chapter raises an important conceptual difficulty not sufficiently addressed in the book, namely the difference between rhetoric and dialectic. One uses rhetoric to move action, dialectic to move thought. Is the point of a scientific controversy to get people to do something (e.g. to support a research programme) or to believe something (e.g. the truth of a particular theory)? To be sure, all controversies contain both aspects. However, when the controversialists are scientists, the historical narrative tends to focus too much on dialectic, perhaps assuming that winning the rhetorical point is a by-product of winning the dialectical point. Thus the volume's contributors generally lead to us to believe that once closure is reached on a set of previously contested propositions, the research front progresses, funds and kudos flow the right way, and so on. Only Ian Hacking's chapter on the history of multiple personality disorder sees dialectics as clearly subservient to larger rhetorical aims. Thus his narrative focuses on how various psychiatrists regularly adjusted their arguments, and even their terminology, to promote certain professional and political ends. Hacking's story is reminiscent, at least in spirit, of Paul Forman's classic account of the indeterminist interpretation of quantum mechanics in Weimar Germany. What makes both Forman and Hacking intellectually abrasive is the suggestion that the official (dialectical) face of the controversy is relatively epiphenomenal to what is really determining the course of events.

At this point, I wonder whether the difference between dialectic and rhetoric simply reinvents, only at a finer-grained level of textual analysis, the old internal–external history-of-science-distinction. This thought began to cross my mind upon reading Wesley Salmon's intriguing chapter on the lack of controversy over how one explains fluctuations in the apparent brightness of celestial objects. Salmon reports that he actually tried to start a controversy on this point, since the standard explanation contains an assumption that sets astrophysics at odds with laser theory. Yet his informed and detailed critiques were not published in *Science* or *Scientific American*. Moreover, none of his scientist-correspondents wished to contest any of his points; a few even made concessions. Salmon sees a puzzle here. My guess is that the scientists interpreted Salmon less as a swashbuckling dialectician than as an old-fashioned logical positivist querying missing premises in a deductive argument. Is 'dialectics' simply a politically correct internalism?

But let me end on a more upbeat note, specifically Michael Ruse's jaunty account of the controversy surrounding the 'punctuated equilibrium' interpretation of biological evolution, most closely associated with the Harvard palaeontologist Stephen Jay Gould. Gould claimed that each species has its own pattern of development that, except in extreme cases (the 'punctuations'), resists changes in the natural environment. Implied here was a much looser fit between natural selection and organic survival than the 'adaptationist' perspective of the neo-Darwinian orthodoxy. What most struck my interest was Ruse's final explanation for the sustaining intellectual interest in punctuated equilibrium. After noting that Gould's views veer towards the 'form', as opposed to 'function', end of the dialectic that has defined the history of biology, Ruse observes that this is the latest stage of a Harvard (Ruse calls it 'American') tradition traceable to the biochemist Lawrence Henderson, an originator of the modern concept of homeostasis, who also taught the first history of science courses at Harvard.

In the 1930s Henderson also convened the 'Pareto Circle', named for the Italian sociologist who envisioned major social changes as punctuated equilibria. In *Thomas Kuhn: A Philosophical History for Our Times* (Chicago, 2000),

I argued that this is the ultimate source of Kuhn's model of scientific revolutions. Yet no less than Harvard's own senior taxonomist, Ernst Mayr, has been among the many biologists who have dismissed Kuhn's model as an overgeneralization from the history of his own discipline, physics. After reading Ruse's piece, however, I have come to believe that Mayr may have too simple a view about the kinds of interaction that can take place between explanatory accounts of first- and second-order change in a science. In short, how can a controversial version of evolutionary theory turn out to be the template for the most influential metatheory of the history of science? This is certainly a controversy waiting to happen.

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Henry H. Bauer, **Science or Pseudoscience: Magnetic Healing, Psychic Phenomena, and Other Heterodoxies**. Urbana and Chicago: University of Illinois Press, 2001. Pp. xiii + 275. ISBN 0-252-02601-2. $29.95 (cloth). Michael Shermer, **The Borderlands of Science: Where Science Meets Nonsense**. Oxford: Oxford University Press, 2001. Pp. viii + 360. ISBN 0-19-514326-4. £17.95 (hardback).

These two books illustrate current interest in the boundaries between science and the pseudoscientific trash which weakly imitates it. These boundaries move with scientific and cultural change and are sometimes socially important. They are forever being attacked by some and reconstructed in new places by others.

Henry Bauer, for example, has long been an expert in what he calls 'anomalistics' – psychic phenomena, UFOs, Loch Ness Monsters (Nessies) and the like. Bauer dismisses out of hand the rational principles of demarcation of earlier generations of philosophers of science. He declares, however, that his ulterior motive is 'not to disparage science but to suggest that serious anomalistics be allowed a measure of respect, as an honest seeking of knowledge within mysteries even more intractable than those grappled with in the mainstream of natural science' (p. 7). Bauer, then, wants to widen the boundaries of intellectual respectability, rebuilding them to include anomalistics along with present science and social science.

Michael Shermer, in contrast, is a committed debunker of the myths of pseudoscience and of non-science generally. He would like to strengthen the established boundaries of scientific legitimacy against corrosion by popular culture. However, he recognizes that the boundaries around competent science are very fuzzy. There are significant and interesting borderlands lying between good science and nonsense. In particular, smart people sometimes believe weird things. Shermer explores psychological factors which might explain this.

I turn first to Henry H. Bauer's *Science or Pseudoscience*. Bauer, now a professor emeritus of chemistry, came to believe in Nessies in mid-career, which in turn motivated him to become a significant player in the emerging discipline of Science and Technology Studies (STS). Bauer is quite prepared to concede that the fringes of science are full of mistaken, shoddy and fraudulent ideas. He warns the reader, for example, about the commercial huckstering of fringe medicines. But his central message is that we should not be dismissive of the serious efforts of well-informed, well-intentioned people to make sense of anomalous phenomena.

As science changes, anomalous phenomena can suddenly become significant. For example, meteorites changed status at the start of the nineteenth century from being dubious phenomena, perhaps produced by soil being melted where it is struck by lightning, into important solid remnants of heavenly bodies. It is therefore reasonable to study phenomena presently regarded as anomalous because a small proportion of them could turn out to be jackpot-winners – portents of major future forms of understanding.

Bauer briefly characterizes science (both natural and social) in a sophisticated and up-to-date way, and argues that anomalistics is just as well conceived even though it employs riskier strategies. But can a new discipline of anomalistics be set up?

Although single individuals are often interested in a range of anomalous cases, there is very little that holds together the full range of anomalous phenomena which appear in encyclopaedias of the abnormal. Furthermore, the

people involved often divide into fractious factions. They polarize, for example, into believers and debunkers. There is little likelihood, therefore, of all those who investigate anomalies forming a coherent collective discipline. The possibility of a coherent field arises only at a secondary level, that of commenting on rather than engaging in anomalistics, within STS. Bauer's book aspires to be one of the first STS texts on anomalistics.

The first three and the final chapters look at anomalistics in general terms, alluding to a wide range of cases. These cases are not explained, though good references are provided. Chapters 4 to 7 consider case material, in turn inside science, at the borders of science and outside science. Even in this section, the cases introduced – even those on which Bauer has previously published books (Velikovsky and Loch Ness Monsters) – are not looked at in any depth. Bauer himself draws only to a limited extent upon the history of science, but sees historical studies of anomalies as a natural part of anomalistics.

In my judgement, Bauer develops persuasive arguments for anomalistics, including the historical studies. Its various topics attract popular interest and generate important issues for science studies (or STS). It is a useful subject in university courses, as it encourages students to think for themselves rather than following authority. For example, students readily learn to critically engage rather than merely accept the opinions of others when the authorities they are invited to study passionately disagree. However, Bauer's treatment barely begins the project of setting up anomalistics. There is still plenty for other people to do.

A key weakness in Bauer's book is the restricted framework of his analysis. In spite of his STS sophistication, he foregrounds anomalous phenomena almost as if they existed independently of culture, and discusses them by applying his own sophisticated but unreflexive common sense. But surely anomalous phenomena are best understood in terms of their cultural construction? Anomalous phenomena are made, not found. For example, Christianity, but not materialism, leaves room for miracles and for manifestations of the Devil. And statistical investigations sometimes make anomalies invisible, as when a cause of a rare cancer is too rare to show up as a statistical correlation in epidemiological samples of a manageable size. It is interesting to see how people decide between rival explanatory systems, those blind to anything outside their own reductionist limits versus those rich in ways to conceptualize anomalies.

While Bauer's book treats anomalous phenomena as out there in objective reality, Michael Shermer's *The Borderlands of Science* explores similar issues in an open-minded way as boundary problems for science. Many people find it interesting to try to distinguish effective science from the kinds of trash which flourish on American television and the Internet. The two initial chapters of Shermer's book are pitched at readers who regard scientific orthodoxy as the moral and mental high ground, but are not sure how to rationalize their judgements. Like Bauer, Shermer argues that there is no universally accepted rational criterion of demarcation available. So whatever way we set up the problem there will be a range of intermediate cases and practices. These are the 'borderlands of science' of Michael Shermer's title. He sets up a sequence of chapter-long discussions of particular borderlands theories and borderlands people, each discussion building upon some familiar insight that gives comfort to the scientific establishment. The book makes full use of history of science.

The Borderlands of Science is entertainingly written, but anyone with a long attention span should read it chapter by chapter as if each was based on a separate article in a regular magazine column. Otherwise, when they read through the meandering miscellany of fourteen chapter-length topics, they will find themselves wondering at the lack of a unifying structure. The faltering rationale of the 'Contents' listing is not sustained. Not even the book's title holds the chapters together. A substantial chunk of the book is not about the borderlands of science at all. Perhaps the discussion of cloning does indeed illustrate 'moral borderlands' (though I suspect that the notion of a moral issue being a 'borderland' in the sense set up in this book is incoherent, for there are no moral certainties, especially not for materialists). But why is there a chapter here on whether or not Eldredge and Gould's punctuated equilibrium theory constitutes a new paradigm, and another on the gentlemanly nature of the Darwin–Wallace pri-

ority dispute? Both are offered as (arbitrary?) examples of science at its best, a topic worthy of a whole library. At the other extreme, myths are debunked, such as the one about the miracle of Mozart's genius, which have nothing at all to do with science. Of course, every topic has in its favour that it is fascinating to Michael Shermer, from his youthful pursuit of cycling (race myths in sport), to Alfred Russel Wallace (the subject of Shermer's Ph.D.), to the psychology of great men in the history of science (based on Frank Sulloway's studies of the effect of birth order on scientists' openness to unorthodoxy), to Shermer's involvement in the scepticism movement and the debunking of myths (he is editor of *Skeptic* and director of the Skeptics Society). The natural climax of the book, then, is the final section, 'About the author'. Shermer strives to make all his enthusiasms (including himself) fascinating to the reader, without adding novel thinking beyond the occasional apt turn of phrase.

Perhaps there are new generations out there of naive readers with short attention spans whose minds were formed by watching American television, and now also by random exploration of the Internet, for whom Shermer's book, if it is an early part of their reading experience, will be a revelation. Such people will be entertained as they expect to be, for they cannot tolerate boredom, and they will learn that the borderlands of science raise interesting issues. They will not acquire insights new to scholarship concerning the issues introduced but they will be led back to a selection of important twentieth-century foci of discussion in the historical study of science and in the popularization of science.

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Eric Higgs, Andrew Light and David Strong (eds.), **Technology and the Good Life?** Chicago and London: University of Chicago Press, 2000. Pp. xii + 392. ISBN 0-226-33387-6. £16.00, $25.00 (paperback).

Historians of technology do not characteristically turn to the philosophy of technology for analytical frameworks to inform their writing. This is not surprising since they are generally quite adept at developing their own analytical tools, as instanced in Leo Marx and Merritt Roe Smith (eds.) *Does Technology Drive History?* (Cambridge, MA, 1995). But it is surely telling that very few volumes reviewed in the *BJHS* have titles, like these two books, that are framed as open-ended questions. Philosophers often claim that sustained (self-)critical consideration of carefully posed questions is a distinctive feature of their particular form of scholarly life. A sceptic might counter that purportedly philosophical publications on 'truth' and 'realism' are as often marked by attempts to enforce dogmatic closure on troublesome questions as are controversies among historians about social constructivism and industrial declinism. But if we charitably concede the value of philosophical questioning here, we should note another essential philosophical activity in which historians also engage. This is the unearthing of hidden assumptions, especially those of the misleading or ill-grounded variety. Is this not, after all, the very life-blood of historical revisionism?

BJHS readers interested in recovering the perspectives of technology end-users can probably learn something of value on both counts in the writings assembled here by Higgs, Light and Strong. Unpacking the title of *Technology and the Good Life?* reveals a fundamental question about whether the use of technology has ever or could in future help people attain the 'good life' – good as either 'rewarding' or 'virtuous'. With varying degrees of fidelity the contributors examine both naive and cynical assumptions about the promise of fulfilment that has often premissed the use of technology. They draw variously from the philosophical literature of phenomenology, existentialism and pragmatism, to engage with one central text, Albert Borgmann's *Technology and the Character of Contemporary Life: A Philosophical Enquiry* (Chicago and London, 1984). This book is a classic in the Heideggerian mould of 'situated' phenomenology inflected with existential anxieties about how science and technology limit human freedom, and as such deserves to be better known among the HSTM community. Although important for its historically aware insights on the artefact-obsessed nature of contemporary life, Borgmann's work does unfortunately typify one extreme of the Heideggerian tradition in masking

profound insights in somewhat turgid and convoluted prose. One might thus buy *Technology and the Good Life?* simply to obtain a readable summary of 'Borgmann's philosophy of technology' in the excellent first chapter thus entitled by two of the editors.

Here one finds an accessible account of Borgmann's argument to the effect that technology has by no means brought unambiguously universal human benefits. He contends that a recurrent feature in the history of technology is that cherished patterns of human interaction – 'focal' things or practices – are displaced by technological devices that contribute much less to the quality of the social fabric. The focal practices of, say, maintaining the domestic hearth and of home music-making require qualities of patience, concentration, skill, endurance and social tact that are rewarding to exercise in ways that the deployment of central heating and CD players is not. Hence, alas, the latter inevitably leave us unsatisfied and wanting something more. Drawing on explicitly Kuhnian language, Borgmann gives us such examples to interrogate the modern 'device paradigm': the pattern of expectation that leads people to anticipate that increased use of technological artefacts can bring progress without any concomitant loss or side effects. According to Borgmann this paradigm is highly misleading; devices do not merely disappoint us, but also serve – ironically – to deflect our notions of what are appropriately 'good' ends to pursue. Indeed, we learn eventually to want only whatever our devices can actually offer us. Thus the increasing ubiquity of devices raises important questions about how technological constraints do or should serve to condition social expectations of the life well lived. Borgmann persuasively argues that this phenomenon requires us to (re-)examine the assumptions that we and our predecessors have made about how technologies might make a difference to everyday life.

Having laid out Borgmann's arguments and related them to wider debates in the philosophy of technology, the editors then divide up the chapters of *Technology and the Good Life?* into four sections. In the second section we find critical evaluation of Borgmann's claims, notably in valuable chapters by Larry Hickmann and Carl Mitcham that relate Borgmann's arguments to those of Langdon Winner and John Dewey. In the third we see Borgmann's notion of 'focal practice' applied – with varying degrees of success – to the analysis of film, agriculture, design and eco-restoration. Highlights of the rather eclectic fourth section are Diane Michelfelder's engaging feminist piece on technological ethics, Andrew Feenberg's account of how philosophy of technology has moved away from Heideggerian essentialism about technology to new forms of 'constructivism', and David Strong's contention that philosophy should be put to 'the service of things'. The whole book is rounded off with Borgmann's graceful reply to his critics, the author embracing at least some revisions to his claims and clearly relishing the diversity of views among the philosophers of technology that draw inspiration from his work.

In their introduction the editors declare an ambition to show that the concerns of philosophers of technology should matter to almost every major discipline in the humanities and social sciences – including history of science and technology (p. 7). Readers will need to judge for themselves whether the force of this cross-disciplinary appeal convinces them. And they might then conclude – as this reviewer did – that the exchange should really be more of a two-way process. After all, anyone who acquiesces in the view that 'the cathode ray tube was first developed so that physicists could study the behaviour of electrons under ideal conditions' (pp. 7–8) really does need to learn a little more history of science. If they did so they might find that the cathode ray tube was developed by William Crookes and others several decades before the empirical 'discovery' of the electron to bring an element of the theatrical 'good life' to the study of electricity.

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Andrea Carlino, **Paper Bodies: A Catalogue of Anatomical Fugitive Sheets 1538–1687**. English translation by Noga Arikha. *Medical History*, Supplement 19. London: Wellcome Institute for the History of Medicine, 1999. Pp. xvi + 352. ISBN 0-85484-069-9. $50.00 (hardback).

This handsome volume surveys a peculiar variety of early modern medical prints with flaps that open to reveal clearly defined organs. The very rare engravings were circulated independently as 'fugitive sheets' in the late Renaissance from the middle of the sixteenth century. They are less well known than much anatomical iconography. Building on the work of Ludwig Choulant, LeRoy Crummer and William Ivins, Andrea Carlino argues that they reveal a transformation of engraving from a pedagogic tool to a focus of popular interest. As he situates sixty-two surviving images within cultures of engraving, publishing and graphic design in a substantial introduction, Carlino reveals his fascination with such 'paper bodies'.

The demand for expert engravings of the body grew quickly after the institution of anatomy lessons at major European medical universities. Carlino directs readers both to the status anatomy gained within learned medicine and to the techniques that engravers used to reproduce first-hand knowledge of the body. The heroes of the introduction are two-fold: first, the anatomist Andreas Vesalius, who inaugurated anatomy as a study freed from 'constraint[s] upon the observation of the material, visible, tangible evidence' (p. 7) by using images to transmit medical knowledge; and second, the communities of engravers producing anatomical flysheets from the 1540s to the 1650s, whose work diffused multiple copies of anatomical images to a large audience other than medical physicians, allowing academic learning and interest in dissection to move apart. His argument examines the images as vehicles for popularizing medical knowledge, by emphasizing the visual basis of understanding first-hand observation of the body. In the manner that Vesalius' *Fabrica* marked 'a point of no return in the history of epistemology, education, and anatomical publishing' (p. 32), Carlino argues that a 'visual culture of anatomy' presented authoritative images of the practice of dissection through these fugitive sheets to later generations. The images' relation to Vesalius' work, or to the practice of dissection, is unclear. The author's suggestion that the tradition of anatomical illustration within these woodcuts reveals 'fundamental aspects of Vesalius' achievement [that would otherwise] remain obscure' (p. 5) comes close to posing an argument in reverse.

The thesis, however, organizes the volume. The introduction argues that the increased mimetic content of anatomical images established new links between viewing, pleasure and the transmission of medical knowledge. Before turning to the flysheet as an independent genre, Carlino describes engravings as a new medium that Andreas Vesalius adapted to criticize the tension between text and practice in anatomical instruction. Vesalius designed six images for students to glue together as memory aids in 1538, building on the illustration of the body's parts represented by an early engraving of 1517 that suggests existing interest in plastic techniques to link word and image. Carlino argues that the engraved sheet, however, reached a far larger audience than the academic anatomical treatises that Vesalius and other Italian anatomists wrote during the century. His account isolates these images from changes in medical practice or in new modes of publishing scientific knowledge, since his argument is that the images took on a life of their own as a vector for disseminating anatomical knowledge. By focusing on the printed medium, he suggests that the sheets made medical knowledge available to 'a public that did not belong to any identifiable professional group' (p. 46).

Close attention to the history of engraving and to the circulation of images leads Carlino to argue that the fugitive sheet constituted a means by which anatomical illustration and university learning moved apart from each other. The printing of a large number of such sheets reached both lettered and unlettered with huge success from the 1530s to the 1550s. Carlino turns his attention to the diffusion of anatomical images in Europe following the publication of Vesalius' 1538 *Tabulae* in this section of his essay, which skilfully integrates the careers of engravers and publishers with the publication of the images. His attention to the role of Protestant printers in the dissemination of anatomical treatises is an important reminder of the differences in the status of anatomy in Catholic and Reformation lands; it leads him to suggest the existence of networks of printers among whom engravings were adapted and reused.

The middle of the sixteenth century was a crucial period in the changes in attitudes to anatomical knowledge in the West. Carlino does not examine the relation of other anatomical images of flayed bodies to these 'fugitive sheets', although the resilience of Vesalian imagery provided an important counterpart to these images. Since many of the prints in the catalogue represent substantial periods – over half date from after 1550; a third are seventeenth-century engravings – it remains for readers to relate the genre to contemporary anatomical or medical books for those periods. It is unfortunate that many of the images reproduced in the catalogue were both engraved and sold during a much later period than Carlino addresses, since their development is so interesting. While he does not suggest exactly how many of these images were produced in total, or provide testimony of them, he implies that a large number of similar prints were produced and sold for diverse audiences.

It must be noted that revealing the body's interior is a recurrent image of Renaissance culture. The ways that these images appealed to a large audience, the author realizes, can only be suggested. The question as to how these sheets reflect an independent 'visual culture' deserves attention. The decision to focus on images with paper flaps reflects their peculiar style and iconography, but at times the coherence of these images seems more bibliographic than analytic. The reader must ask what makes them participate in a specifically visual culture: as much as presenting a purely visual argument for dissection, the images stand at the margins of the textual culture of an emerging book trade. While the 'fugitive sheets' are distinct from the well-known plates of Vesalius' *Fabrica*, they do recall images in early medical texts – cat. 54 and 55 (a) and (b) are reprinted from an earlier treatise on bloodletting; others, including the many figures of women at birthing-stools, often shown beside male counterparts who appear pregnant, recall early didactic images from the *Fasciculus medicinae*, an early compilation of Galenic texts from the late fifteenth century. Moreover, several are rich with text, suggesting that they represent a form of medical literacy, rather than a visual form of address, in spite of their iconographic similarities. Their affinities to other media, such as volvelles, suggest their close relations to other early modern publishing strategies. Further attention to the material culture of their publication, including the size of engraving shops and the use of copperplate techniques, would illuminate the cost and the practices of producing such fairly complicated sheets.

Medical historians will, however, be eager to examine these fascinating images. They suggest growing curiosity in the sanctioning of spectacles such as human dissection, and interest in the body as a subject of medical knowledge. Rather than exhibiting a struggle between text and image, these prints provided a typographical solution to a problem of representing the body's layers. The woodcuts seem to legitimize and naturalize the practice of dissection itself among a public fascinated with the practice in a culture where image and text were closely tied. The images that can reveal their interiors openly broached questions of the individuality and the mortality of the self, relationship of the male and female body, and currency of medical knowledge among a wide audience, addressing, in short, a cultural hierarchy of mind and body. The conceit that such engravings formed a trade in 'paper bodies' raises questions as to their ties to actual medical bodies and medical subjects that the author sidesteps. When linking the production and sale of these sheets within a specific visual culture, Carlino often uses the metaphor of mapping, but the link of maps to the images is unclear; if maps provide a new way of understanding the world, what new ways to understand the body are provided by these all too human images, that reveal their interiors? To what extent were these regarded as exemplary images among a broad range of practitioners?

Despite these queries, the volume is a model for presenting a select group of early printed images together with an original, interdisciplinary commentary. By focusing on a unique set of images, it makes a convincing case for situating the circulation of medical knowledge in early modern Europe both among different audiences and in different media.

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STEPHEN GAUKROGER, **Francis Bacon and the Transformation of Early-Modern Philosophy**. Cambridge: Cambridge University Press, 2001. Pp. xii + 249. ISBN 0-521-80536-8. £14.95, $21.95 (paperback).

William Harvey famously told John Aubrey that Bacon wrote philosophy 'like a Lord Chancellor'. Harvey didn't rate Bacon as a great philosopher, so the derisory intent is plain. Yet there are other senses in which, despite his critical aim, Harvey was quite right, and Gaukroger's book is the best attempt so far to detail how accurately Harvey hit his mark.

There were two things that might concern an early Stuart crown servant about natural philosophical learning and, indeed, that led most courtiers to ignore it: its practical irrelevance and its incivility. Philosophers produced nothing of concrete value to the state and their ways of proceeding were models of brawling and argumentative disorder which led to sceptical assessments of philosophers' role in educating princes and future counsellors. Bacon set out to reorient and reshape natural philosophy to cure it of these generic distempers and, in so doing, to make it not just a fit but a central subject for the attention of a sovereign and his officials.

To reform natural philosophy was to reform the individual and collective character of its practitioners. The incivility of existing practitioners was quite literal, flowing from their intellectual and social location outside the *civitas*. Philosophers had to be brought into the civic condition – their manners made suitable for court society, their purposes made subservient to state concerns, their values shifted from *otium* to *negotium*, from the *vita contemplativa* to the *vita activa*. This way of thinking about Bacon and the identity of seventeenth-century English natural philosophers is not now wholly novel, but Gaukroger's undeniable achievement is the thoroughness with which he documents how these aims permeated all aspects of Bacon's project – metaphysical, methodological and political.

Aristotle was a theoretician; Bacon was after knowledge as it contributed to practical ends. That is now a cliché, but its consequences for natural philosophy's objects of enquiry are not. Bacon criticized Aristotle's key distinction between natural and violent motions, not because the distinction was mistaken but because Aristotle made the former central to his philosophy of nature. For Bacon, it was the violent motions that should be of crucial interest to the reformed practitioner: these are, as he tellingly wrote in the *Cogitationes de Natura Rerum*, 'the life and soul of artillery, engines, and the whole enterprise of mechanics'. As Gaukroger says, 'Use, not truth, is what is at issue' and that issue shifts the very object of natural philosophy (p. 137).

Natural philosophy can and must be made sociable as well as useful. Indeed, sociability was a prerequisite for utility. The virtues of reformed natural philosophers were the social virtues. When Bacon wrote in *Novum Organon* that 'truth is rightly called the daughter of time, not the daughter of authority', Gaukroger interprets this to mean that proper philosophical knowledge is built cumulatively and by collective effort. Bacon's account of the Idols shows why this has to be so. These internal impediments to knowledge belong to the same species as the 'passions' and the condition for pursuing reformed natural philosophy is a volitional 'purging of the passions' (p. 121). Our wits are corrupt and, while we may, as Bacon said, 'use a kind of thoughtful prudence against' the Idols, the sovereign remedy is collectively enforced right method: 'we must', Gaukroger summarizes, 'give up any hope of relying on our wits and must accept the rigour of a mechanical rule' (p. 127). Right method, as Bacon repeatedly asserted, achieves the 'levelling' of men's wits. Such a method is 'subversive' of practitioners' individuality, an individuality which is expressed in disputatiousness and which is a cause of practical inconsequentiality. This is why Gaukroger nicely concludes that 'questions which look epistemological turn out to be issues of political organisation' (p. 117).

There were also external impediments to natural philosophical progress. Reformed natural philosophy was, Bacon said, 'a kind of royal work'. It was going to be hugely expensive, and it had to be expensive to acquit its intellectual and practical aims. Bacon clearly envisaged that projects resembling Solomon's House would be underwritten by James I or, after him, by Henry,

Prince of Wales. And, while he expended a certain amount of effort lobbying court officials for support, Bacon was in fact politically clueless. He had no substantial idea how even to begin to make his project a political reality; no one in a position of power seems to have taken his enterprise seriously and, unlike Boyle, he did not think to use his own considerable wealth to get the reformed philosophical show on the road. A programme aimed at practicality was doomed at the outset through a political naivety worthy of academic philosophers and difficult to comprehend in a former court official.

Gaukroger several times quotes Cicero's remark that Cato dedicated himself to philosophy 'not that he might dispute like a philosopher, but that he might live like one' (pp. 1, 114). That is an important sensibility for Gaukroger because he wants to show how Bacon worked to make irrelevant any causal link between philosophical merit and personal virtue. Bacon meant to transform the identity of the early modern philosopher from someone who knew how to live philosophically – that is, morally – into someone whose knowledge allowed him productively to reshape the material world towards civically valued ends. That intention is well documented in Gaukroger's story and, by the twentieth century at least, the intention was substantially realized: the scientist – the best-endowed and most authoritative of the heirs to the subject that used to be called philosophy – was no longer considered to be morally superior to anyone else; indeed, post-Hiroshima scientists laboured hard to show that they were morally no worse than anyone else.

But Baconian rhetoric on this subject did not neatly correspond to seventeenth-, eighteenth- or nineteenth-century realities. Natural philosophers – those who professed Baconian affiliations as well as those who rejected his methodological programme – continued to be celebrated for their personal virtue, and this personal virtue was a cultural resource that vouched for the worth of their knowledge. Gaukroger has made a very great contribution to understanding the intentions driving Bacon's project. Nevertheless, if we want to understand who the seventeenth-century English natural philosopher actually was, we have to leave Gaukroger's preferred world of close textual analysis and enter the world of social and cultural history.

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Francis Bacon, **The *Instauratio Magna*: Last Writings**. Edited with introduction, notes, commentaries, and facing-page translations by Graham Rees. The Oxford Francis Bacon, XIII. Oxford: Clarendon Press, 2000. Pp. xcvi + 363. ISBN 0-19-818470-0. £80.00 (hardback).

When Graham Rees began to publish articles on what he called Francis Bacon's 'semi-Paracelsian' cosmology in the 1970s he presented the world of scholarship with an entirely unexpected and significantly different picture of the great statesman of science. Rees's Bacon was not the familiar one: the one who never made a substantive contribution to the history of science, but who earned his place as a propagandist on behalf of the new science, and the projector and developer of a new inductive logic and a new experimental method which helped to make that new science possible. Rees showed us a Bacon who was committed to a rich and complex theory of matter which, although eclectically inspired by Paracelsus, Bernardino Telesio and others, was very much of Bacon's own making. Furthermore, Rees was able to indicate just how fundamental and pervasive this theory of matter was in all of Bacon's philosophical writings. Written at a time when historians of science were finally separating themselves and their discipline from philosophers and philosophy of science (older readers will remember when the function of history of science was to provide interesting illustrations of the theoretical claims about the nature of science made by philosophers), Rees was able to consider Bacon's idiosyncratic matter theory on its own terms, and to dismiss as irrelevant any intimation that it did not sit square with the Bacon of the philosophers.

Since that time Rees has continued to publish articles on different aspects of Bacon's natural philosophical beliefs, but most of his energies have been directed towards pursuing the Bacon he discovered through a more and more thorough and meticulous reading of his philo-

sophical writings. What we have here, in this latest volume of *The Oxford Francis Bacon*, are more of the considerable fruits of Rees's labours. Forming at present, in the early stages of this projected collected edition of Bacon's works, a companion piece to Volume VI, *Philosophical Studies* c. *1611–1619* (1996), which presented early rehearsals of materials that would later be reworked to make up Bacon's *Great Instauration* (reviewed in *BJHS*, **33**, 2000, pp. 235–7), we now have Bacon's final attempts to contribute to his ambitious scheme for the reform of natural philosophy. Eventually, this volume will be the last of a group (IX–XIII) devoted exclusively to all the works intended for the *Instauratio magna*.

Four of the seven works included here were first published in Isaac Gruter's collection entitled *Scripta in naturali et universali philosophia* (Amsterdam, 1653), and again in William Rawley's edition entitled *Opuscula varia posthuma* … (London, 1658). The remaining three are published here for the first time from manuscripts recently discovered in the Bibliothèque nationale de France. They consist of two versions of *Historia densi et rari*, the *Abecedarium novum naturae*, *Historia et inquisitio de animato et inanimato*, *Inquisitio de magnete*, *Topica inquisitionis de luce et lumine* and *Prodromi sive anticipationes philosophiae secundae*. The first two of these titles are of major importance and make this volume essential reading for those trying to understand Bacon's philosophy. The *Historia densi et rari* is, as Rees notes (p. xxxiv), an indispensable source for information on Bacon's matter theory, and therefore essential for properly understanding his philosophy. The *Abecedarium* is closely related to the *De augmentis scientiarum* (1623), Bacon's Latin expansion of *The Advancement of Learning* (1605), and undeniably one of his most important works.

Rees's introductory matter is excellent, although to avoid repetition he frequently refers the reader to the introductory matter in Volume VI. The translations from the Latin are clear and easy to read without losing accuracy (although it is always possible to quibble: the 'frigid distinction' Bacon refers to on p. 37 is the Aristotelian distinction more clearly, and more usually, said to be between actual and potential, rather than between 'act and power'; and although the translation on p. 129 is correct, did Bacon not mean to say, 'Do an experiment on this. And *on whether* this hardening is made all the greater by frequent solutions and reductions than by fusions and quenchings'?) The commentaries tend to avoid explanation and interpretation, being mostly concerned with indicating probable sources for Bacon's ideas, or other works of Bacon's where the same or similar ideas are repeated. The result is extremely useful (even though no concessions are made to those who do not read Latin), to say nothing of the impressive erudition it displays, but frequently left this reader wanting the benefit of the editor's expertise and familiarity with his subject. It would be nice to know, for example, whether Rees agrees with me in seeing alchemical knowledge behind Bacon's note, at the end of *De animato et inanimato*, that four things are needed for vivifying. What is described could be an imagined reconstruction of biological requirements, but it could equally be an experienced account of what alchemists do when trying to create life. Certainly, there is no shortage of evidence throughout this volume that Bacon performed alchemical experiments, but for the most part Rees confines himself to pointing to alchemical texts, known to be known to Bacon, and which discuss the same issues, with no comment at all about Bacon's own obvious engagement in alchemical experimenting.

In spite of Rees's revelations about the substantive content of Bacon's philosophy, it seems true to say that books on Bacon's philosophy continue to focus on the more programmatic and methodological aspects of his work. Consider, for example, Antonio Perez-Ramos (1988) on the influence of the so-called 'maker's knowledge' tradition, Julian Martin (1992) on the legal and political background to Bacon's thinking, or B. H. G. Wormald's claims (1993) that Bacon's reforms in natural philosophy were meant as a companion enterprise to his wish to reform moral philosophy and civil science. Although Rees's discoveries are acknowledged in these recent works, they have clearly not been considered significant enough to recast the old philosophically orientated historiography. This may just reflect the power of prevailing historiographies, but Rees's work could and

should have initiated a new Bacon historiography. Perhaps, then, we see here depressing confirmation that ideas are not taken seriously until they appear in a book. If anyone can change the face of Bacon scholarship it is surely Graham Rees, but it seems that his articles need to be supplemented by a book-length study. It is certainly ungrateful, however, and probably spiting oneself as well, to wish that such a careful and learned editor should turn back to authorship. There can be little doubt, after all, that Graham Rees's accurate and accessible editions of Bacon's writings will speak volumes to many succeeding generations of historians of early modern science and philosophy, and provide the securest possible foundation for any new historiographies of Bacon.

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R. R. ANGERSTEIN, **R. R. Angerstein's Illustrated Travel Diary, 1753–1755: Industry in England and Wales from a Swedish Perspective**. Translated by Torsten and Peter Berg. With an introduction by Marilyn Palmer. London: Science Museum, 2001. Pp. xii + 378. ISBN 1-900747-24-3. £34.95 (hardback).

In 1789 a smarmy Danish professor from the College of Commerce in Copenhagen known as Mr Ljungberg was in England, hoping to curry favour with Midlands industrial innovators. Apparently he was a man of some ingenuity, noted for his 'modesty and Gentleman-like behaviour', according to Matthew Boulton, who with perspicacity saw beyond such appearances and, with a prescient SSK-like twist, concluded that he was probably 'employed by the Court of Denmark, to collect such knowledge in this country as might be useful in that'. As the late J. R. Harris, in his *Industrial Espionage and Technology Transfer* (Aldershot, 1998; the above quotation is on p. 484) recently and most impressively demonstrated, Boulton and his friendly rivals (such as Wedgwood, to whom Boulton sent the Dane with a letter of introduction shortly after his character evaluation) had reason to be suspicious of foreign visitors. Throughout the eighteenth century, industrial espionage was a growing problem for manufacturers, and with the publication of Reinhold Rücker Angerstein's travel diary, we now have a detailed account of the activities of yet another Scandinavian spy.

Born in 1718, Angerstein was the son of a successful ironmaster who, following an education at Uppsala, helped run the family ironworks until the age of 31, when the bachelor decided to embark on a 'duty tour' of the Continent and Great Britain, accepting touring 'instructions' from both the Mining and Trade Councils, and financial support from them and Jernkontoret (the Swedish Steel Producers' Association). After visiting Germany, Carinthia, Hungary, Italy, France, Spain, Portugal and Holland, he arrived in England in September 1753 and left in 1755, laden with eight volumes of notes (originally nine hundred pages of text – 150,000 words – and 360 pages of his sketches). Torsten Berg started the massive job of translating this material into English in the 1970s, and thanks to the dedicated work of his son, Peter Berg, this wealth of information is now readily accessible (and, thanks to the Science Museum, affordable). An introduction by Marilyn Palmer, Professor of Industrial Archaeology at Leicester University, and a brief 'background and biography' of the traveller, suggest the contours of Angerstein's achievements, noting that one of the main reasons why Sweden would be interested in supporting such fact-finding tours is because it had the natural resources to expand iron production to meet the increasing demands for bar iron in industrializing countries. Since bar iron exports represented 74% of the value of all goods exported from Sweden in the 1750s – with Britain being a major importer – the Swedish authorities 'were extremely interested in following developments in Britain' which might supplant that level of foreign consumption (p. xv).

But, as Angerstein's diary shows, he was committed to providing information on an exhaustive range of topics relating to the industrial landscape, including workforce numbers and wages, 'sources of livelihood' in different regions, mechanical inventions (copiously illustrated) and manufacturing techniques. It is also a record of all the places he was refused

entry to or thrown out of. What I found particularly interesting is the way he not only spots early examples of de-skilling, but also reflects on national differences, for example how iron from Sweden, Russia, Spain and England is best for different uses or combined for best durability of a particular product (i.e. p. 76), and finally on regional differences (especially in the scale of wages). It seems that in the decades separating Angerstein from Ljunberg, the British government tightened its control over the activities of its visitors. Whereas Ljunberg was arrested and his notes and drawings seized as he attempted to leave England, finally fleeing the country after the Danish Embassy paid £300 bail, Angerstein returned without fuss with plans to reorganize his business interests along the lines of the modern factories he had seen abroad, only to encounter the kind of resistance from suspicious sceptics that people like Boulton or Wedgwood would also face when their own workers staged revolts in the following decades.

Angerstein's Illustrated Travel Diary is packed with useful information – a repository of contemporary facts and figures that provides a detailed portrait of industrializing Britain. The editorial additions of explanatory notes and references, as well as an index, enhance its value.

It is noted that around twenty Swedish spies were sent to Britain in the long eighteenth century. Angerstein's diary is one of five that have been published and is the most thorough. It is hoped that despite the difficulties of the job, more are translated and published. With such sources, we can then hope that more analytical studies, like Svante Lindqvist's *Technology on Trial* (Stockholm, 1984), will be written to further our understanding of the processes of technology transfer, de-skilling and industrial organization from an international perspective.

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W. Clark, J. Golinski and S. Schaffer (eds.), **The Sciences in Enlightened Europe**. Chicago and London: University of Chicago Press, 1999. Pp. xiv + 566. ISBN 0-226-10939-9. £59.50 (hardback).

This is an important, fascinating and thought-provoking book. In her introduction, Outram draws out the theme that runs through the text and is explored in diverse ways: the tension between the particular and the general, unity and diversity, as found both in Enlightenment thought and in how historians approach the period. In this context, the extent to which these papers are indebted to Foucault and Habermas is unsurprising.

The text is divided into five sections, their general introductions providing good overviews, with a tantalizing glimpse of the contents in the introduction to the first main section, entitled 'Bodies and technology', indicating a tour ranging from monsters and museology to philosophical theatres and automata.

This section takes up many of Foucault's arguments in exploring, first, 'political arithmetic'. In Andrea Rusnock's essay the interest in measuring population change is linked to broad explanatory categories including geographical, climatological and pathological factors. Another area of statistical examination is also included – the idea of measuring sex ratios and linking this to a Christian defence of monogamy. Rusnock suggests that this shows how older traditions of theology and natural theology are drawn into the use of the new techniques.

Jan Golinski examines barometers as 'machines of enlightenment', with the emergence of the barometer as a consumer object used to relate the interleaved story of material, intellectual and popular culture. Commercial instrument-makers, virtuosi and the public are seen to circulate around the barometer with their own agendas concerning science, profit and status.

Ken Alder examines the relationship between ideas of meritocracy, social class and the state through an investigation of French military engineers and their responses to changing patterns of warfare, from static to more mobile. This is allied to the shift in mathematical techniques used, from geometrical to more analytical 'mixed mathematics' (p. 112), mirroring the change from sieges to more fluid battlefields.

Simon Schaffer looks eruditely at the phenomenon of automata in the Enlightenment. He examines the relationships between machines

and the social order and the value of the metaphors associated with automata and machines for philosophes trying to reduce their society to order. While this value was apparent for some, others remained unconvinced in the face of the threat automata and their associated materialism posed.

Part 3, 'Humans and natures', sees the theme of boundaries explored in some detail. Michael Hagner notes how other lines were drawn across the social map of the Enlightenment through thinking about monsters. These anomalous creatures, which were problematic for ordering and classifying, were used to explore problems in generation theory and human nature. The boundary between different literary genres is investigated by Marina Frasca-Spada, who sees science and novels examining human nature and sharing narrative structures that do not allow their easy separation. The different positions of men and women in science and the rationality ascribed to them is the theme of Mary Terrall's examination of the 'Gendering of science'. Emma Spary's chapter on 'The nature of enlightenment' takes up a theme that several writers suggest, that the most fruitful resources for understanding the development of science are those found in the study of polite conversation and the commercialization of leisure. It also offers to rescue the category of natural history from earlier, less sensitive examinations which tended to emphasize modern discipline boundaries and expunge links between natural history, 'connoisseurship', 'utility' and 'sensibility' (p. 299).

Part 4, 'Provinces and peripheries', opens with Paula Findlen's rather descriptive chapter on the female Newtonian Cristina Roccati. Towards the end of the chapter this unusual Newtonian is linked to issues such as popular lecturing, suggesting that she could not fully participate due to lack of resources at her peripheral location, and one means of overcoming this – the extensive use of diagrams and illustrations.

Lissa Roberts writes on science in the Dutch Enlightenment, suggesting a unifying theme here is utility and seeking it out well through an examination of anatomy and physics theatres, popular science lectures and Dutch scientific societies.

A look at science around the Baltic follows, with Lisbet Koerner showing how the Enlightenment was adapted to the cultural and geographical landscapes by highlighting reforms affecting the peasants and serfs. The sense of place and their being at the periphery of Europe is evoked well also, with a strong interest in ethnography growing from, for example, their having to justify remaining on the edges of other enlightened lands.

This section draws to a close with William Clark's look at Prussia, where the growth of cultural and anthropological disciplines are dominant after Kant's analysis, where the philosopher suggested a reductive approach to metaphysics, morals and religion.

Section Five contains two reflections that return to big theoretical issues. The 'Afterword' reflects the tensions between the particular and the general. Lorraine Daston suggests the question is 'not what is enlightenment?' but 'who are the enlightened and how did they get that way?' (p. 495).

Nicholas Jardine examines Foucault and Koselleck's views on enlightenment and their ideas on the growth of unified approaches to history and knowledge of the natural world. He returns to the big issue: the tension between the fragmentation of knowledge into discipline areas apparent towards the end of the eighteenth century and the continuing interest, exemplified in *Naturphilosophie*, in broad unifying systems of thought. He illustrates this tension in approach in an examination of texts comparing and contrasting two histories (of botany by Michel Adanson and natural history by James Smith) with Johann Spix's history of zoology. Adanson, he suggests, writes about progress in the science saying it is due to observation and methodological correctness. Smith is a little more subtle, he argues, indicating how patronage and commerce affect the growth of the disciplines. Spix, though, ties zoology at particular times and places to the culture in which it developed. Here questions of styles of history to answer broad questions about the development of areas of human thought are raised.

Jardine would not be surprised that these examples recall the issue of internalist versus

contextual approaches in the history of science at present. To paraphrase him, we are now aware that the history of enlightened sciences is 'shot through and through with novelty, contingency and locality' (p. 493). How, as historians, we can cope with the tension between wanting grand narrative and understanding the particular manifestations of scientific understanding is a challenge that this book takes up expertly.

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David N. Livingstone, D. G. Hart and Mark A. Noll (eds.), **Evangelicals and Science in Historical Perspective**. Religion in America. Oxford and New York: Oxford University Press, 1999. Pp. vi+351. ISBN 0-19-511557-0. £39.99 (hardback).

Evangelicals and Science in Historical Perspective has much to say to historians of science, despite being published in Oxford University Press's 'Religion in America' series. The contributors are a mixture of historians of religion and historians of science, and their essays cover the seventeenth to the twentieth centuries, with limited coverage of Britain as well as America. The introduction and John Brooke's overview together provide a succinct introduction to the conjunction set up by the title 'evangelicals and science', outlining many issues that are also problematic in 'science and religion' studies more broadly.

The reputation of twentieth-century American evangelicals, with their Flood geology and Creation science, has made it easy to dismiss evangelicals as opposed to science due to their utter commitment to the word of the Bible. And, until recently, historians of nineteenth-century science have provided another reason for ignoring evangelicals, due to the enormous influence attributed to natural theology in the pre-Darwinian world. Evangelicals did not accept that God's existence and attributes could be proven from the evidences of nature. Thus, the argument goes, if natural theology was so central to the sciences, evangelicals cannot have been involved with the sciences. *Evangelicals and Science* goes beyond those two misconceptions about evangelicals and the sciences in seeking a more positive way of evaluating the interaction and demonstrating clearly that it was not a simplistic oppositional relationship.

The two strongest sections of the volume address these two areas of concern. That on 'Theological engagements' focuses on the late eighteenth and early nineteenth centuries. Mark Noll contributes an essay on the American situation and David Bebbington provides a complementary one for Britain. Noll makes much of the distinction between features that are 'intrinsic' and 'extrinsic' to the sciences, and argues that American evangelicals were much more concerned with extrinsic features – for instance, with the ethical and moral implications of the sciences, rather than with their content. On Bebbington's account, this is in contrast with British evangelicals who were far more aware of the methodology of science, which they regarded as being empirical and fact-based in the same way as their religion. I suspect that this apparent national difference is an artefact of the present state of research, but it would have been interesting to see it explicitly discussed. One also has to wonder whether Noll and Bebbington had read the essay by Jon Topham which completes this section and takes a far more robust approach to evangelical attitudes to natural theology.

The other strong section is that called 'Specific encounters', which is a series of relatively short essays on late nineteenth- and early twentieth-century American evangelicals. Although Jim Moore is the only one who makes this the point of his essay, all the contributors seem to be asking 'how did it happen that evangelicals could believe this?', where 'this' is variously scriptural geology, the story of Darwin's deathbed conversion, Creation science and the survival of the Ark on Mount Ararat. (The fifth essay in this section is David Livingstone's on the reception of Darwinism in Edinburgh, Princeton and Belfast, which is a valuable piece, although very similar to another essay of his which appeared in another 1999 volume. Ron Numbers's essay on Creation science is taken from his 1998 book.) These essays are all fascinating, but

could have benefited from a deeper analysis of their implications for the relationship between evangelicals and science, such as Moore provides.

There are two more sections in the book, one of which contains a pair of essays on seventeenth-century Puritans, one reassessing the Merton thesis, the other reassessing the Foster thesis. Both are full of sound stuff, but both are theoretical and hard going. The final section is called 'Wider domains' and contains three essays on sciences other than the natural sciences (i.e. social science, moral philosophy and biblical scholarship). These are not uninteresting, but the nature of their relationship with the rest of the volume is not addressed.

When I first encountered this volume, I read just the essays of particular interest to me, and came away believing it to be a historiographically significant volume, deserving strong commendation. I have now read it from cover to cover, and I find I have many questions left unanswered. All of these essays claim to be about 'science' and about 'evangelicals'. Yet, just as 'science' changed over time, so did 'evangelicals'. Just as geographical differences would have merited explicit discussion, so would chronological ones, especially in a volume which starts with the Puritans and ends with Flood geology. Another problem lies in combining essays from historians of science with those of historians of religion (and without a list of contributors for identification purposes). I could criticise some of the authors for being naive about the history of science – yet I have to wonder if other reviewers would be criticizing other authors for their history of religion.

If you treat edited volumes as a source of useful and interesting essays, then this volume will be a valuable resource. It will only be those few committed scholars of evangelicals and the sciences who bemoan the absence of larger conclusions drawn from the material here presented. The introduction is too short, and I fear that this reader, who did indeed 'persevere to the end', did not regard the afterword as 'a reward' (p. 10). Still, as the editors admit, this is a beginning rather than an ending, and for making that start, it is to be commended.

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Myles W. Jackson, **Spectrum of Belief: Joseph von Fraunhofer and the Craft of Precision Optics**. Transformations: Studies in the History of Science and Technology. Cambridge, MA and London: MIT Press, 2000. Pp. x + 284. ISBN 0-262-10084-3. £23.95 (cloth).

Glass is a much underrated and little understood resource for historians of science. Air-pumps, electrical machines, microscopes, prisms, spectroscopes, telescopes – the list could continue – all depend for their proper functioning on the material properties and qualities of the glass from which they are made. Unlike all but a few historians of science, natural philosophers and scientists have been well aware of glass's importance to their practices. For them, glass has been a highly valued and often hard-fought-for commodity, regarded as crucial to making their experiments work. Access to the right kind of glassware, as Myles Jackson emphasizes in this brilliant book, was at the core of successful optical experimentation. Getting the recipe for glass right was a difficult and secretive business requiring skill and circumspection. Those who had the knack for glassmaking were valuable commodities in themselves, well worth cultivating and protecting. Jackson looks at the career of one of these indispensable glassmakers, the Bavarian optician Joseph von Fraunhofer, celebrated for his discovery of the 'Fraunhofer lines' – the dark lines in the solar spectrum which were to become the key to nineteenth-century spectroscopy. In the process he produces an exemplary account of the material and political cultures of nineteenth-century science.

Fraunhofer's career, as Jackson points out, makes for a classic 'rags-to-riches' story. Born of a long line of artisanal glassmakers, orphaned at an early age and rescued from another family tragedy by the convenient intervention of the Bavarian Elector, Fraunhofer was transformed by a combination of princely favour and vigorous self-help into the 'father of German optics'. Jackson carefully dissects this traditional story, using it to cast new light on the fraught relationships between artisans and philosophers, industry and science, manual labour and intellectual *savoir faire*. The Fraunhofer that emerges from this narrative is the product of careful fashioning, not only his own as he tried

to carve out a cultural place for himself in the early nineteenth-century German lands, but that of his biographers and hagiographers, anxious to appropriate Fraunhofer's career to the service of German science and the state. His life story served as an example of their well-deserved superiority in science and industry. Jackson is good at showing just how conscious Fraunhofer himself was of the need for careful self-presentation. He wanted to make a name for himself as a *Naturforscher* – a natural philosopher – as well as a superlatively gifted and productive artisan glassmaker. Succeeding as he did in joining the ranks of the Munich Royal Academy of Sciences meant finding a way of reformulating the distinctions between craft skill and scientific knowledge.

The tensions between skill and science form one of the key themes of Jackson's book. On the one hand he argues clearly just how important the craft skills of glassmaking were not only to Fraunhofer's own career but to the whole edifice of German optics. On the other hand he demonstrates as well just how difficult it was for contemporary natural philosophers to accept Fraunhofer's work as really philosophical. Contemporary natural philosophers celebrated science as transparent knowledge. Artisans, however, were routinely castigated for the secretiveness of their guilds and practices. The chapters in which Jackson charts the doomed efforts of British natural philosophers to replicate Fraunhofer's glassmaking activities make for hilarious reading in this respect. Wedded as they were to an ideology of philosophical transparency, along with their conviction that what artisans really needed was a good dose of gentlemanly discipline and careful management, they could never understand that the missing ingredient in their recipes was Fraunhofer himself – or at least someone like him. The resources poured into this effort by the English Royal Society and the Board of Longitude demonstrate clearly just what was at stake here, moreover. Fraunhofer's glass was destroying the once-dominant English optical industry. Newton's successors were faced with the prospect of having to buy their telescope lenses from abroad.

As Jackson emphasizes again, this serves to show us that German pride in Fraunhofer as a national icon of scientific superiority was far more than mere window-dressing. There were significant economic and political concerns. His person encapsulated a large part of the Bavarian state's efforts to transform itself into a significant European economic power. Jackson even points to the decline of the German optical industry that followed Fraunhofer's death. Not even his apprentices and colleagues had been fully successful in absorbing the tacit craft knowledge that he embodied. Jackson implies (at least) that part of the secret of Fraunhofer's success (and that of the German optical industry) was his recognition (*contra* the British) that the kinds of tacit craft skills that he and other artisans possessed really did make a difference. Fraunhofer's key role after death was, however, as a scientific icon. He stood for the successes and the possibilities of German scientific precision industry. He embodied the way in which contemporary German technological prowess remained embedded in the humble traditional craft knowledge of the German working man. As such he was the ideal candidate for philosophical beatification by those such as Hermann von Helmholtz anxious to forge a secure place for science and technology in the policies of the late nineteenth-century German Reich.

Jackson's account of Fraunhofer's career and its cultural ramifications is careful and nuanced. His story is diligently researched and lucidly argued throughout. What he shows is that received distinctions between science and industry, knowledge and craft, philosophy and economics, cut no ice in dealing with the complex history of the sciences' material and political cultures. On the contrary, he shows that what is required is just what is provided here – an account that shows that distinctions like those are typically the outcomes of ongoing debate and negotiation. Historians of science have recently started paying a great deal more attention to the material cultures of science and Jackson's work is a welcome example of this. He shows just how important a material resource like glass – its control, management, manipulation and production – was to the production of an intellectual practice like the theory of optics. It is also an example of a history of science that recognizes that knowledge and skill have political histories too. As such, as Jackson himself concludes, it is a story that has an important

moral for the current practice and politics of science as well as for its history.

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Xiang Chen, **Instrumental Traditions and Theories of Light: The Uses of Instruments in the Optical Revolution**. Science and Philosophy, 9. Dordrecht, Boston and London: Kluwer Academic Publishers, 2000. Pp. xxiii + 211. ISBN 0-7923-6349-3. £60.00, $99.00 (hardback).

The relationship between scientific instruments, communities of practitioners and the trajectory of science has been studied increasingly by historians of science over the past decade. This book, part of a series entitled 'Science and Philosophy', is a contribution to the rapidly developing field. The 'optical revolution' (an uncommon and contentious label) refers to the theoretical rejection of the particle theory of light in favour of the wave theory during the nineteenth century. Xiang Chen argues that optical instruments were important tools in this overthrow of one intellectual framework by the other.

Central to the book is the author's notion of an 'instrumental tradition'. He bases this on operational, rather than technical, aspects – on the 'procedures adopted by a community concerning the proper uses of instruments' (p. xvi). Two distinct traditions are identified: a 'visual tradition', based on 'faith in the eye', and a 'geometrical tradition', 'rooted in doubts about the reliability of the eye' (pp. 122 and xvii). These traditions are not as clear-cut as they first appear. Chen identifies practitioners in the visual tradition who are careful to adopt procedures to ensure that observation is made under optimal conditions; geometrical practitioners, similarly, regard the eye as an imperfect optical element, but seek to minimize its role or to replace it entirely. Thus Chen places the seemingly different extinction photometer and shadow photometer – the one founded on detection of a threshold brightness, the other on the matching of the contrasts of shadows – in the same category (visual) by claiming a similarity of procedural aspects. Nor are the traditions readily distinguishable in a sociological sense: 'not everyone in the community always acts according to the better exemplars set up by the tradition' and 'we should not be surprised to find someone who adopts procedures endorsed by one tradition in some cases, but switches to a different set of procedures belonging to another tradition under different circumstances' (p. xviii). Thus the traditions are rather more permeable or fluid than the major model that the author cites, Peter Galison's *Image and Logic* (Chicago, 1997). But, unlike microphysics, we find in Chen's cases no 'pidgins' or 'creoles' devised to foster crude communication between separate communities, nor 'trading zones' to share information and theory obtained from segregated technical cultures. Instead, Chen argues that optical instruments during the early nineteenth century were employed to stabilize support for both the particle and wave theories.

Interestingly, instruments of the mid- to late nineteenth century get little discussion. This is a pity, as interferometers displayed new phenomena of considerable importance in buttressing the wave theory of light, and crystallized their own distinct grouping of practitioners. Such groups, which by the 1860s included nascent spectroscopists and disparate specialists of photometry, are never revealed in the book. Indeed, the historical context of the cases is not always well described, nor are the cases that are discussed clearly motivated. A chapter on photometry, for example, relies almost exclusively on the publications of Richard Potter, Professor of Natural Philosophy and Astronomy at University College, London during the 1830s and 1840s. Good line drawings illustrate the principles of the instruments clearly (on the other hand, a minor criticism is the more than usual number of typographical errors and, in my copy at least, several pages with blurred printing). Experimental practice is not clearly described. Tables commonly list measurements to tenths or even thousandths of a percentage while, as Chen himself notes, contemporary practitioners found precision better than one or two percent impossible to achieve. Other chapters devoted to optical dispersion and polarization are similar in sketching simple technical details to focus on the theoretical tests provided by the instruments.

The penultimate chapter more interestingly discusses optical toys such as stereoscopes, stroboscopes and kaleidoscopes for studying the nature of visual perception and so strengthening the visual tradition.

While the subtitle, *The Uses of Instruments in the Optical Revolution*, highlights the book's theme of competition between the particle and wave theories of light, the author admits that the contention quietly defused by the end of the century: 'both sides in the debate became apathetic about the question of the nature of light ... [The] closure of the "optical revolution" took the form of proliferation of disciplines, rather than a replacement of a theory by another' (p. xxiii). Thus the social differentiation mediated by instruments appears to have been at least as important as their role in supporting theory.

Categorization, a central theme of this book, is also a problem in describing its approach. As already mentioned, it does not focus on either historical or sociological analysis. Analogies with Galison's studies of instruments are not explored to advantage. Nor is other recent work elicited for support, such as Terry Shinn's elaboration of 'research-technologies' as specialisms frequently centred on practitioners developing instruments. The philosophical basis of the book, while drawing connections most clearly with the work of Thomas Kuhn, is not linked to more current ideas, such as Davis Baird's work in the philosophy of instruments or to other strands in the philosophy of technology. By contrast, the notion of a visual tradition in instrumentation is one that promises to be an active research area for the foreseeable future.

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Daniel Gasman, **Haeckel's Monism and the Birth of Fascist Ideology**. Studies in Modern European History, 33. New York: Peter Lang, 1998. Pp. vii + 482. ISBN 0-8204-4108-2. $69.95 (hardback).

The social implications of Haeckel's Darwinian monism have long been controversial. On the one hand his naturalistic ethics have been seen as initiating Nazi euthanasia and genocide. On the other, Haeckel's anticlerical monism and his emancipatory and naturalistic social thought have provided inspiration for a radical counter-culture, which was often espoused by feminists and socialists. Daniel Gasman's study on monism and the birth of fascist ideology is wide-ranging and erudite, and a really exciting foray into the relations between science and politics. He traces Haeckel's immense influence in science, culture and politics. Interestingly, given the subject matter, he has far more to say about France and Italy than about Germany.

The book tackles Haeckel's wider impact rather than analysing what exactly Haeckel did scientifically, the social implications his research has and how closely the Monist League was tied to Haeckel's agendas. Gasman took a pioneering role in raising some of these issues, but his earlier book of 1971 did not convincingly resolve them in sufficient historical depth. After all, if one examines two of Haeckel's closest associates, the cell biologists Richard and Oscar Hertwig, they moved in contrasting political directions, and Oscar Hertwig broke with Haeckel by writing a pioneering critique of social Darwinism and eugenics. Nick Hopwood has analysed how the embryologist Julius Schaxel developed the monistic legacy in a Marxist framework. Not only was Haeckel's own position on basic issues like mechanism and recapitulation subject to some modification, but there was a plurality of science-based philosophies in Imperial Germany. One has to disentangle the influence of Wilhelm Ostwald's energetics from that of Haeckel in the Monist League.

Yet once the inherent social-scientific components of monism are put to one side, it is greatly to Gasman's credit that he has written an erudite, challenging and highly informative book. He convincingly establishes that Haeckel's cultural influence was pervasive. This is a study which has much to say about Gauguin and Dada (although not on left-wing artists like Grosz). We are treated to a broad cultural spectrum – as Haeckel's influence on Zola was acknowledged to have been substantial, and interestingly a link is made to Kafka as writing 'in the Haeckelian Monist transformationist tradition' (p. 75). Gasman claims that Haeckel diverted Italian

Marxism to fascism. Enrico Ferri and Arturo Labriola provide the central proof that fascism followed from 'Haeckelianism', but many Marxist readers of Haeckel did not rally to fascism although Gasman regards this as a logical development. Similarly, in France, use of descriptors as 'pre-Nazi' for Vacher de Lapouge does not sort out the complex politics of Lapouge's position.

A problem is that seeing monism as a system of natural laws and recapitulation means that Haeckel's contribution is pitched by Gasman at a very generalized level. What is characterized as 'Haeckelian' was arguably complex and variegated, and it is not altogether satisfactory to see Monism as 'parallelling' other ideas. There are rich and discursive footnotes, for example on the vexed issue of fascism and anti-Semitism, and on Haeckel and the ideology of progress. The botanical influence of von Wiesner on Houston Stewart Chamberlain is worth considering, and recent work on Oswald Mosley suggests the formative impact of aviation technology rather than biology. One difficulty is that Haeckel's thought was itself evolving, and must be related to different phases of Imperial German politics. Another problematic element concerns the origins of structures and imagery of fascist ideology. Gasman consigns Roger Griffin's analysis of fascism as a palingenetic ideology of rebirth to a footnote, observing that its developmental implications are insufficiently analysed. But Gasman fails to carry out this crucial task of investigating the links between Haeckel's theory of palingenesis and fascist theory. Somehow the index and pagination of the book are at times out of step, and editorial interventions have caused confusion, as between Charles and Richard Webster. Yet, overall, this is a thoughtful and stimulating work, and a tour de force in the exposition of a major biological input to devastatingly explosive ideas.

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Jeremy J. Gray, **The Hilbert Challenge**. Oxford: Oxford University Press, 2000. Pp. xii + 315. ISBN 0-19-850651-1. £20.00 (hardback).

A few books have recently appeared which try to give a sense of the complex developments of mathematics during the twentieth century. Jeremy Gray's is one of the most original attempts of this kind. Instead of listing results and themes in an encyclopaedic fashion, Gray touches on the most important issues of a century of mathematics by reconstructing the origin and fortune of the so-called 'Hilbert's problems'. These twenty-three problems were put forward by the German mathematician David Hilbert at the International Congress of Mathematics in 1900. They ranged from foundational issues, to number theory, the axiomatization of physics and other branches. In his lecture, integrally reproduced at the end of the book, Hilbert presented this list of problems as an attempt to 'lift the veil behind which the future lies hidden' (p. 240), and to imagine which issues would be the most attractive to future generations of mathematicians. In fact, what Hilbert said in that historical session shaped the very future of modern mathematics. Already an authoritative figure in the international panorama, Hilbert managed to attract the attention of the mathematical community towards several research topics in which he had been more or less directly involved. For a mathematician to contribute to the solution of any of these problems has invariably been to make her or his reputation.

In the first half of the book, Gray sketches Hilbert's studies and early research, showing in a clear and concise manner why Hilbert chose these twenty-three problems, how they related to previous research traditions and how different scientific communities reacted to his 'challenge'. This leitmotiv offers Gray the opportunity to touch on a series of crucial historical issues, such as the relations between the different branches of mathematics around 1900, the relevance of the work of Henri Poincaré and Leopold Kronecker, the different priorities in the French and German mathematical traditions, the competition between the schools of Berlin and Göttingen, and the long-lasting controversy between Hilbert and Luitzen Brouwer on the very nature of mathematical reasoning. In a central chapter, Gray describes Hilbert's turn to foundational issues in

the 1920s, and outlines the features of the logical tradition that stemmed out of his research programme. In this way reference is made to the achievements of major figures of twentieth-century mathematical logic like Gödel, Church, Turing and Cohen. The remaining part of the book clarifies the relevance of Hilbert's work for the developments of mathematics during the Cold War years. By discussing the efforts made to solve or reframe some of the problems, Gray skillfully introduces the main issues at stake in the West and in the Soviet Union. He shows how Hilbert's work and ideals informed much of twentieth-century mathematics, both at the technical and at the philosophical level. They were seminal to the redefinition of the boundary between pure and applied mathematics, to the trend towards an increasing abstraction of mathematical reasoning and to the success of the 'structural' image of mathematics. Interestingly, the epistemological and moral dimensions of Hilbert's programme seem to be crucial to understanding its dramatic impact upon early twentieth-century culture. In presenting his problems, Hilbert was openly challenging the growing cultural pessimism of the turn of the century. 'In mathematics there are no *ignorabimus*' is one of his most famous statements. Hilbert's stand for the values of universal reason and intellectual rigour became even more remarkable during the Weimar period. The reader might therefore want to know more about the way in which the Enlightenment values defended by Hilbert shaped the technical aspects of his work, and how much of the passionate support and staunch opposition met by his scientific programme depended on its moral and philosophical dimensions. In this perspective, a broader philosophical framing of the mathematical controversies between Hilbert and his opponents might be useful, expanding on Gray's references to key figures like the mathematician turned philosopher Edmund Husserl (p. 103) and to the 'wholly destructive impact of the Nazis on mathematics in Germany' (p. 186).

The book stands out in the panorama of the historiography of mathematics as an example of how problems and themes in modern mathematics can be presented rigorously, and yet in a fashion that makes them accessible to the wider audience of the historians of science.

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Susanne Zimmermann, **Die Medizinische Fakultät der Universität Jena während der Zeit des Nationalsozialismus**. Ernst-Haeckel-Haus-Studien: Monographien zur Geschichte der Biowissenschaften und Medizin, Band 2. Berlin: VWB, 2000. Pp. 223. ISBN 3-86135-481-0. DM 48.00 (paperback).

Haeckel's long-term association with the University of Jena was but one episode in the University's strong tradition in biology and medicine. Although Georg Uschmann provided an excellent history of biology at Jena, his understandable reluctance to confront the issue of the nazification of the University means that this is a period requiring reinvestigation. Susanne Zimmermann provides a thorough study of the medical faculty under National Socialism, and it is a welcome addition to the genre of studies of German medical faculties in that period. Her agenda includes the acceptance of Nazism by medical teachers and students, the *Gleichschaltung* of the medical faculty, the dismissal of Jewish teachers, assistants and students, medical education and medical provision, racial hygiene and resistance. It was in 1930 that the popularizer of Germanic racial ideas, Hans F. K. Günther, attained a chair with the election of the Nazis to Thuringia.

There is a considerable amount of prosopographical material on the nazification of the medical faculty, and documentation of a range of atrocities. The study examines links between the medical faculty and the nearby concentration camp of Buchenwald. The racial hygienist Karl Astel and colleagues' lectures were dismissed as propaganda by a large group of Norwegian student hostages. What might also have been examined is the Allied policies to the University in terms of its Nazi past. The Anglo-American CIOS organization reported on the medical faculty of the University. Who did the Americans bring out to the West when they withdrew, and how did they treat the Nazi legacy of the University? A comparison of US and Soviet

policies towards the University's Nazi past would be of great interest.

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Vaclav Smil, **Enriching the Earth: Fritz Haber, Carl Bosch, and the Transformation of World Food Production**. Cambridge, MA and London: MIT Press, 2001. Pp. xvii + 338. ISBN 0-262-19449-X. £23.95 (hardback).

In 1840 the German chemist Justus Liebig declared that agriculture's principal objective was the reliable production of digestible nitrogen. After millennia of humankind's struggle with the nitrogen problem, that objective had been achieved by the First World War. Between 1909 and 1914 Fritz Haber and Carl Bosch of the Badische Anilin- & Soda Fabrik (BASF) developed the process that permitted the industrial synthesis of ammonia, a process that is still the basis of the world's nitrogenous fertilizer industry. In *Enriching the Earth*, Vaclav Smil, Distinguished Professor of Geography at the University of Manitoba, presents a comprehensive and multidisciplinary survey of the nature and the history of this important and overlooked problem.

The book's central task is to account for the global dependence on the Haber–Bosch process. Smil argues plausibly that the industrial synthesis of ammonia may be the most important technical achievement of the twentieth century. Thanks largely to the Haber–Bosch process, the earth's population has increased from 1.6 billion in 1900 to over 6 billion today. Dependence upon ammonia fertilizers continues to increase, especially in the developing world. By 2050, Smil predicts, nutrients derived from the Haber–Bosch process will be 'indispensable for ensuring the basic nutrition for some 60% of the world's people' (p. 175).

In an unconventional introductory comment, Smil admits that some readers will not be interested in every chapter. Several chapters focus on agronomic issues, others on ecological concerns and still others on the emerging food and nutritional policy issues that are affecting and will affect the developing world. Smil displays a remarkable command of the literature and the future prospects of each of these subjects. Most impressively, he continually explains the interconnectedness of nitrogen fertilizer issues: how carnivorous diets utilize proteins more efficiently than vegetarian ones, how specialized Chinese agroecosystems can efficiently manage nitrogen inputs, how the physical structure of certain clays affects fertilizer efficacy, how soil erosion and global warming will increase demand for nitrogenous fertilizers in the future, how nitrogenous fertilizer wastes can damage coral populations and water supply and how the increasing obesity of the world's population may affect world food demand.

For the historian of science, four chapters are of special interest. The author begins with a survey of plant nutrition issues that were at the core of nineteenth-century agricultural science. The second chapter addresses the increasing interest in the 'nitrogen problem' in the late nineteenth century as natural sources of nitrogen, like guano, became more scarce. Smil then turns to detailed narratives on Haber's research on the basic problem of nitrogen synthesis and Bosch's commercialization of the process for industrial-scale production. He offers thorough and well-illustrated explanations of the technical and scientific hurdles that Haber and then Bosch overcame in order to create a working process. These sections are based on a modest degree of archival research and present effective summaries of these important issues. Especially valuable is Smil's use of two recently published and massive German-language biographies of Haber to provide English readers with a summary of the chemist's interest in the nitrogen problem. Smil also provides a history of the overlooked evolution of the ammonia production process in the twentieth century. Ever more efficient production methods have emerged, notably, through the interrelationship between the fertilizer and petroleum industries. At present, methane is the primary source for hydrogen in ammonia production.

Despite its large amount of valuable and interesting material, the book will never be a bestseller. The more technical chapters employ a challenging vocabulary and are overstocked with

statistics, graphs and chemical formulae that might have been placed among the appendices or among the footnotes. The historical chapters have a Whiggish tone in their saga of discovery, innovation and progress, which some may find disconcerting. Moreover, the book does not address a host of recent trends in the history of science scholarship, including the part nitrogen synthesis has played in the emerging academic–industrial nexus, the role of the state in promoting big science and agribusiness through nitrogen fertilizers and the social and cultural contexts in which farmers choose to employ these fertilizers, to name but a few.

These concerns notwithstanding, historians of science, technology, agriculture and the environment, as well as agronomists, ecologists, nutritionists and food policy planners, will find useful information and a passionate tale in *Enriching the Earth*. Above all, Smil succeeds in achieving what he set out to accomplish; it is impossible to come away from the book without a greater appreciation for the importance of the Haber–Bosch process of nitrogen fixation.

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Simon A. Cole, **Suspect Identities: A History of Fingerprinting and Criminal Identification**. Cambridge, MA and London: Harvard University Press, 2001. Pp. 369. ISBN 0-674-00455-8. £23.95 (hardback).

The idea that the ridge patterns on our fingertips are permanent and unique to each individual revolutionized modern life and law. Yet there have been relatively few historical studies of this transformation. Simon Cole, a specialist in science and technology studies, has now provided us with what will, for many years, remain the single most comprehensive and illuminating work on the subject.

That finger marks were somehow distinctive to individuals has been known since antiquity. What was first achieved in the nineteenth century, however, was the elaboration of this venerable concept into a fully fledged system of identification centred in massive archives of fingerprint records. A fingerprint pattern, it came to be accepted, could never lie; identical ridge patterns could belong only to one particular individual. Conversely, two individuals – even identical twins – could never possess identical fingerprints. Understandably, the procedure had its biggest impact on the detection of crime, especially on the detection of those dreaded figures: the habitual criminals, repeat offenders who came to be regarded almost as a class of professionals in crime. If all criminals could be fingerprinted then recidivists could be identified easily by comparing their fingerprints with the records. The value of fingerprinting in crime detection, then, depended upon and was directly proportional to the extent of the archive of specimens and the ease with which that archive could be searched.

Although systematic fingerprinting has rarely been used outside police work in the West, its origins were neither purely Western nor purely forensic. Within the English-speaking world (and in extensive areas outside it), the system that prevailed evolved not in America or Britain but in colonial India. The other sophisticated scheme was developed in Argentina. Cole argues persuasively that the question of identification was most pressing in regions characterized by mobile, multiracial populations that were supposedly disorderly, dishonest or turbulent. Within Europe itself, concerns with the identification of habitual criminals were responsible for the import of fingerprinting at the end of the nineteenth century and the displacement of the complex anthropometric system of identification developed by the French police official Alphonse Bertillon, which itself had replaced unsystematic and unwieldy registers of photographs and identification marks only relatively recently. Fingerprinting succeeded in establishing itself as irrefutable in the courtroom and its subsequent career up to the end of the twentieth century was one of world-wide faith, steady progress in technique and incessant accumulation of specimens. Only over the last few years have fingerprint-matching procedures come in for serious criticism as fundamentally unscientific, with experts beginning to predict that DNA typing will eventually take its place in detective work and in the popular imagination.

Central to Cole's study is the transformation

of identity from being based on personal recognition by members of one's community to 'a paper record held by the state … that everyone believed in: judges, bureaucrats, scientists and the general public alike' (p. 4). The identification of criminals and impostors had, in the early nineteenth century, relied upon recognition by others; the protracted trial of the Tichborne claimant in England was only an extreme instance of what was the norm. Growing anxieties over habitual criminals sharpened interest in a foolproof system of identification. Initially, photographs seemed to be the answer but not for long. Apart from the quickly discovered fact that photographs could and did lie, a large register of photographs or one of identifying marks was not the easiest database to search to identify a suspect. Ease of retrieval was crucial and none of the existing systems could be searched quickly or easily. Even at the end of the nineteenth century, therefore, police officers in London remained steadfast in their faith in identification by personal recognition – every week, Metropolitan Police officers would inspect remand prisoners at Holloway prison in the hope of identifying offenders they had encountered earlier.

The first easily searchable database of criminal records was evolved by Alphonse Bertillon, who argued that the measurements of eleven fixed dimensions of the human body, together with a rigidly specified list of identifying marks and a standardized full-face and profile mug-shot, amounted to a unique portrait of an individual. These data were classified on an index card file ordered according to the measurements. When one had a suspect, one measured him – the system was never confidently applied to women – and then one looked for an identical record in the cabinet. Retrieval was easy in Bertillon's scheme but reliance on precise measurements meant that the system was only as good as the operators who took the measurements. Any sloppiness there would lead to misclassification and, eventually, might prevent the successful identification of a recidivist. So, although the scientific reputation of anthropometry was high, it became obsolescent once fingerprinting – a cheap and easily learnt technique – came along and a way had been found to classify the innumerable ridge patterns into a database that could be searched quickly and reliably. Many scientific figures – most notably Francis Galton – dreamt of using fingerprint data to unlock the secrets of heredity and even, perhaps, the biology of the criminal but none of those dreams were ever realized. Fingerprinting remained a tool to identify criminals – even civil uses of the technique, so common in the British Raj and even in today's India, never made much headway in the West.

Cole's sweeping study takes us from the colonial origin of fingerprinting to its twenty-first-century uncertainties. The discussion of the early, imperial history of fingerprinting is admittedly brief and, by concentrating on British racial distrust of Indians, overlooks how the introduction of fingerprinting in India by Sir William James Herschel was actually triggered not simply by racial suspicions but also by the purely bureaucratic challenge of establishing a modern bookkeeping state in the heart of a very different polity and tradition. Cole's grasp of the British story, too, can sometimes be rather slack; the conviction of Harry Jackson for burglary in 1902 was not the second (p. 172), but the very first conviction by a British jury on fingerprint evidence.

These, however, are quibbles. The book improves in leaps and bounds as it comes to focus on twentieth-century America. The final, meticulously detailed chapters analysing recent debates over the scientific basis of fingerprinting and the emergence of DNA typing are alone worth the price. The fundamental point of contention today, Cole shows, is whether the traditional way of matching fingerprints by counting points of similarity can claim to be scientifically irrefutable. When the print being matched is an incomplete smudge found at a crime scene, then the question is no longer academic; a person's liberty – and in large parts of the United States, life – may depend on it. Small wonder, then, that many defence attorneys and fingerprint experts – people whose livelihood depends on the reliability of point-counting – are at odds on this issue. Whatever one's position on the question itself, Cole's judicious and objective analyses of the issues and their contexts should be required reading for all

fingerprint examiners, attorneys and judges. *Suspect Identities* is not only an outstanding contribution to the vast scholarly literature on the history of biological concepts of human identity. Identification experts and lawyers with little interest in abstract issues would find in this book a balanced and informative guide through practical perplexities that have recently befogged their lives. This, in short, is the kind of book so many historians of science dream of writing – a major work of scholarship that is also of immediate relevance to practitioners.

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