judicious temperament and less of Huxley's bulldoggish aggressiveness. In that respect, Phillips's life may have some relevance for the sciences in the twenty-first century.

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FALK MÜLLER, **Gasentladungsforschung im 19. Jahrhundert.** Diepholz: GNT-Verlag, 2004. Pp. 300. ISBN 3-928186-76-0. €35.00 (paperback).
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Gasentladungsforschung im 19. Jahrhundert is a careful and detailed analysis of research into gas discharge phenomena in the second half of the nineteenth century. This tightly structured study compares the work of the German physicist Johann Wilhelm Hittdorf and the British natural philosopher William Crookes. The comparison between the two researchers quickly becomes, as Müller comments, 'a comparison between two research programmes which are formed by the abilities, skills and interests of different people, for example mathematical physicists and instrument-makers' (p. 5). Providing in-depth analyses of each scientist in turn, Müller concentrates on reconstructing and interpreting the factors behind their very different approaches to and interpretation of gas discharge phenomena. He investigates their scientific and philosophical assumptions, research programmes, laboratory contexts and experimental practices and skills, as well as their differing interpretations of the significance of the observed phenomena.

This study is situated within research into the material and experimental cultures of science and is theoretically oriented towards the works of Peter Galison and Hans-Jörg Rheinberger. Written as a dissertation at the University of Oldenburg, it integrates knowledge gained through Müller's own experiences replicating Hittdorf's experiments. Müller intends to demonstrate the interaction between the construction of a scientific object, the development of scientific apparatus and the experimental laboratory setting. Instrument-makers and the various instruments involved in the experiments, especially the Hittdorf (Germany) or Crookes (Britain) tube, are given central roles to play.

From the beginning, gas discharge research was confronted with the possibilities and limitations of its materials, and the skill of instrument-makers, who often had both scientific and commercial aspirations, was crucial for the success – or even the development – of a research programme. Müller's story begins in the 1850s, when an instrument-maker (Heinrich Geißler), a physicist (Julius Plücker) and an instrument (an evacuated glass tube with platinum electrodes into which traces of gas had been introduced) combined to produce spectacular, inexplicable and beautifully colourful light effects.

The body of Müller's study is divided into two main sections, on Hittdorf and Crookes respectively. With Hittdorf the experimental space of gas discharge phenomena became part of an experimental system. Müller shows how Hittdorf's research into electro-chemical reactions and electrolysis, and the assumptions that this research was based upon, informed his theoretical and methodological approach. The tube became a 'micro-laboratory' (p. 80), in which the phenomena could be generated under controlled conditions and, in contrast to the largely spectroscopic studies of his predecessors, also quantified. The tube became not only a laboratory within the laboratory, but also offered Hittdorf a window into the world of interactions between electrical currents and matter. Accompanying this research was the continuous attempt to improve the quality of the vacuum within the tube and the struggle with the limitations of the materials. Improvements in vacuum pumps led to the emergence of new phenomena or to new assessments of previously observed phenomena, while the materials of the tube itself, such as the quality and components of the glass, could produce effects that needed to be isolated and differentiated from

other experimental phenomena. The materials from which the instrument was made; the efficiency of the vacuum pump; the skill of the technicians, instrument-makers and experimenters; and the source of electrical power all combined to form a single system in which each component affected the generated phenomena. Integrated into an electrical circuit, the micro-laboratory of the tube became a unique space in which Hittdorf could pursue his main research interest of exploring the relationship between matter and electricity.

Hittdorf's research programme contrasts strongly with that of William Crookes, not least due to differences between the two researchers' personalities. Whereas Hittdorf concentrated on a particular scientific field, Crookes adventurously looked for connections between different fields and for possibilities of extending the scope of scientific research – an ambition that involved him in psychical research and similar scientific borderlands. Crookes's research programme was characterized by his readiness to see new forces or forms of matter in unexpected or unexplained phenomena. The experimental space he created within his tubes thus differed radically from that of Hittdorf. Like Hittdorf, Crookes struggled to create and stabilize his vacuum and, similarly, the vacuum and the effects generated within the tube functioned to define and measure one another. Through research on processes in the evacuated tube, the vacuum itself became an object of investigation. When Crookes returned to the study of matter, it was the invisible-become-visible in the tube that attracted his attention and led him to assume the existence of a new, fundamental, aggregate form of 'radiant matter'.

Müller has written a challenging and fascinating study of the material cultures of science. Through the detailed and meticulous comparison of two research programmes and researchers, he is able to provide penetrating insights into how the culture of the laboratory, skills, instruments and assumptions shape experimental practices and configurations. Although daunting in its wealth of technical detail, the book constitutes – despite its specialist topic – a valuable contribution to the material-cultures approach in the history of science. On the downside, however, it must be noted that the glue-binding of this volume is of poor quality, and that even gentle handling causes pages to loosen.

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David Kaiser (ed.), **Pedagogy and the Practice of Science: Historical and Contemporary Perspectives.** Cambridge, MA and London: MIT Press, 2005. Pp. vi + 426. ISBN 0-262-11288-4. £29.95 (hardback).
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Two figures loom over the pages of *Pedagogy and the Practice of Science*. The first, Thomas Kuhn, is no surprise. His writings on the role that textbooks and training play in the inculcation of paradigms and the practice of normal science did much to open the subject of pedagogy for serious study in the history of science, and though his main ideas on the subject now date back more than forty years, they continue to inform the thinking of contemporary scholars, including many who would scarcely regard themselves as Kuhnians. Several of the contributors to this volume cite Kuhn directly, and David Kaiser and Andrew Warwick conclude it with an insightful essay on 'Kuhn, Foucault, and the power of pedagogy'.

The second figure I would cite, however, is not Michel Foucault but Owen Hannaway, who passed away while I was preparing this review. While not as obvious a presence in these pages as Kuhn, Hannaway is visible nonetheless, and the themes he raised in his slim but weighty volume *The Chemists and the Word: The Didactic Origins of Chemistry* (Baltimore, 1975) prefigured and still resonate with many of those explored in this volume. I well remember Professor Hannaway remarking to me years ago, when I was in graduate school myself, that much of *The Structure of*