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CHAPTER TWENTY-ONE

The Laboratory

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The laboratory is the iconic space of modern science. Such is the power of this status that the historical role of the laboratory in the practice of science and the production of scientific knowledge is easily taken for granted, thereby obscuring the laboratory's changing relationship to our understanding of, and control over, the natural world. The laboratory as we know it today is a product of modernity, and especially of the rise of science as a professional and highly institutionalized activity in the late-nineteenth and early-twentieth centuries. Our view of the laboratory's significance, one might argue, has tracked our historical and philosophical understanding of the very nature of science. With this in mind, this chapter pursues two interconnected goals. First, it presents a short history of the laboratory, beginning with a brief descriptive overview of changes in the laboratory up to about 1800, before focusing on the development of the laboratory during the nineteenth and twentieth centuries. And second, it analyzes how historical approaches to the laboratory have changed over recent decades, showing how these approaches reflect different views concerning the nature of science and varying conceptions of what it means to do science, or to be a scientist.

A Brief History of the Laboratory

It is difficult to be definitive about when something called a laboratory became inevitably and exclusively scientific. According to Steven Shapin (1988, 277) the word laboratory (or *elaboratory*) was not in common English usage before the mid-seventeenth century. The association between the laboratory and science, moreover, remains distinctly Anglophone: in Italy, for example, the word *laboratorio* continues to refer generically to workshops in a wide range of artisanal and artistic as well as scientific settings. Principally associated with the practice of alchemy, early laboratories were places for the preparation of medicines, the production of reagents such as acids, and, above all, the pursuit of the elusive philosopher's stone (the substance believed capable of transmuting base metals into gold and silver). Staffed by apothecaries, alchemists, and a range of laboratory servants responsible for everything from keeping the fires

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burning and doing the washing up to guarding the key to the door, laboratories like this were the private, often secret domain of princes and noblemen, and occasionally their wives. Despite its connection to philosophy and theology—made manifest in books on theosophical alchemy and other manuscripts—the laboratory before about 1650 was a place of essentially practical knowledge based on manual labor. As a result, laboratory work was certainly "not a suitable activity for the independent and leisured free man" and its products, though undeniably useful, did not include certain or scientific knowledge (Smith 2006, 293).

By the end of the seventeenth century some laboratories—mainly connected to academic institutions such as universities, botanic gardens, and academies (Klein 2008, 770)—had become the location of a new kind of experimental science, home to a "new active mode of doing philosophy" (Smith 2006, 305). But not everything done in these laboratories met this definition of science as a philosophical enterprise, nor were all laboratories spaces within which experiments carried out by appropriate persons gave access to legitimate truths about nature: many more were the workplaces of apothecaries, textile dyers, and mining engineers. Laboratories continued to proliferate throughout the eighteenth century in both academic and industrial settings. But, whatever their institutional location, these laboratories had some important common features. They were almost exclusively the site of chemical operations such as distillation, combustion, smelting, dissolution, and precipitation. And they were far more likely to be concerned with commercial production and its regulation than with anything we might characterize as pure scientific research (Klein 2008, 770).

The relationship between the development of the laboratory and the rise of experimental natural philosophy is, therefore, not a simple one. And, although the venue of scientific and particularly experimental activity has long been identified as important in the history of science (Shapin 1988, 373–4), we remain far from having a coherent view—let alone a detailed historical understanding—of how histories of the laboratory and of experiment intersect, where they diverge, and what should be their proper place within broader history of science (Gooday 2008; Klein 2008; Kohler 2008). This short chapter cannot hope to answer questions of such magnitude. But, by drawing attention to them at this stage, I hope to alert the reader to current historical and historiographical concerns that will form the basis of a more detailed discussion of the field of laboratory studies in the second section, leading to some proposals for potentially fruitful future directions of enquiry that are set out in the conclusion.

The uniquely *chemical* associations of the laboratory before 1800 provide a salient reminder of the important distinction between a history of the laboratory and a history of experiment. Many of the classic historical studies of experiment describe events that did not take place in the laboratory at all, but rather in learned societies, salons, private houses, and anatomical theaters[1]—not to mention the wider terrain that is home to what are now called the field sciences (see Chapter 20 and other chapters in Part II). So, while experiment implied a certain control over nature that we have come to associate mainly (though certainly not exclusively) with the laboratory (Latour 1983), the laboratory around 1800 was merely one among many potential locations of scientific activity (Crosland 2005, 233). Nor should we forget that the modern laboratory remains home to much that is not experimental: teaching, testing, assaying, and analysis are all important laboratory activities (Gooday 2008, 784–5). These observations, in turn, raise two important questions. If the laboratory was not primarily a place of

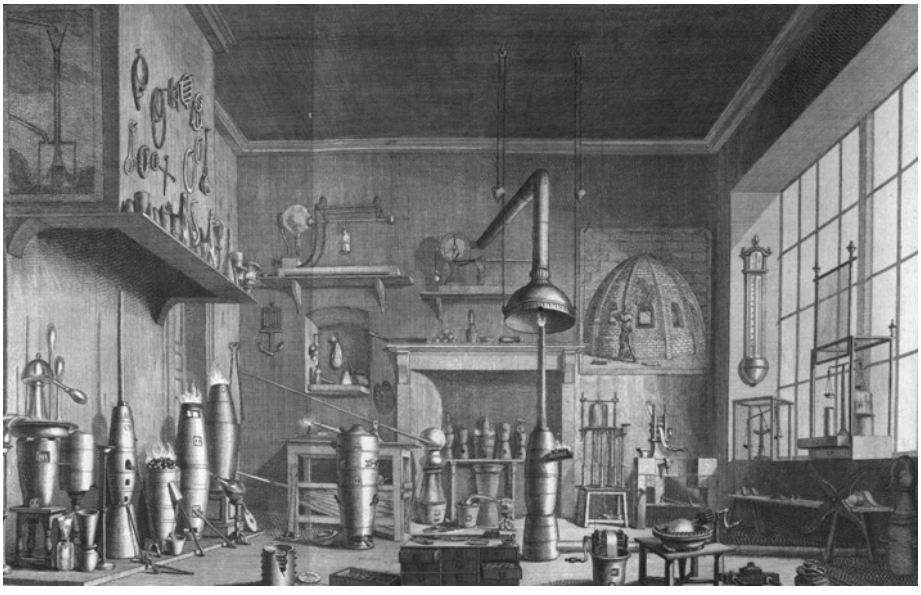

Figure 21.1 Frontispiece from William Lewis (1714–1781). 1763. *Commercium Philosophico-Technicum; or the Philosophical Commerce of Arts: Designed as an attempt to improve arts, trades, and manufactures.* London: Baldwin.

experiment but rather somewhere necessary for doing "chemical work" (Klein 2008, 771), what was it about the practice of chemistry in particular that relied upon the facilities of a laboratory? And what subsequently led practitioners of other sciences to move into the laboratory, ultimately so weakening the association between the laboratory and chemistry that studies of nineteenth and twentieth-century laboratories have, until very recently, tended to focus on physics and the life sciences?[2]

An inspection of the chemical laboratory around 1800 is an instructive place to begin answering these questions. Fortunately, several excellent historical studies provide detailed descriptions—together with numerous potent images—of chemical laboratories of this period and of the work carried out there (Holmes 1989; Beretta 2004; Klein and Lefèvre 2007; Klein and Spary 2010). Fireplaces and furnaces are prominent in all these laboratories, reflecting the dominance in this period of heat and fire as means of effecting chemical change. We should also note some important absences. Eighteenth-century laboratories such as that illustrated in William Lewis's (1763) *Philosophical Commerce of Arts* contained apparatus and instruments for performing a range of manipulations and measurements (Figure 21.1). But they were not equipped with the glass reagent bottles and wide range of glass apparatus that later became central to the material culture of the chemical laboratory (Jackson 2015a; Jackson 2015b). Nor was large-scale pedagogical activity among the major purposes of laboratories like this. Although apprentices certainly trained in the laboratories of apothecaries, perfumers, textile manufacturers, gunsmiths, and assayers, they did so in relatively small numbers. The chemical laboratory around 1800 had long since ceased to be a secret, or even a necessarily private, space (Hannaway 1986, 599) but it had much more in

common with alchemical kitchens than with the institutional laboratories which became essential tools of disciplinary training and research in late nineteenth-century science (Jackson 2011).

Doing chemistry—especially doing chemical experiments—was a smelly, dangerous business, best kept below stairs, well away from polite society. Here is a plausible explanation for why eighteenth-century chemists—whether they were doing experiments or producing commercial products—worked in laboratories, while most natural philosophers did not (Klein 2008). In the famous Society of Arcueil, for example, the great Berthollet performed chemical experiments in a laboratory located at the bottom of the garden and not in the drawing room, library, or even the kitchen of his palatial country house.[3] The laboratory was not, in the first instance, a place of experiment. It was the particular space in which the technical hazards of chemical practice, whatever its purpose and setting, could be made to conform to social norms.

The combined demands of chemical practice and pedagogy acquired a new urgency during the first half of the nineteenth century. First, changes in chemistry's disciplinary status and its move from the medical to the philosophical faculty of the reformed German research university necessarily brought chemistry within the polite, scholarly realm (Meinel 1983; Meinel 1988; Meinel 2000). And second, developments in chemists' investigative approach to organic nature—beginning, famously, with Justus Liebig's introduction of large-scale laboratory training in Giessen (Morrell 1972)—exposed a rapidly increasing number of students to the potentially incendiary combination of naked flame and organic substance. In exactly the period when new theories of chemical composition and constitution were providing ever-increasing legitimacy to chemistry as a philosophical endeavor, the practice of chemistry had never been more dangerous (Jackson 2011, 56–7).

Several studies have demonstrated the role of industrialization and competition in driving the nineteenth-century construction of institutional chemical laboratories in various German states (Borscheid 1976; Tuchman 1993). During the middle decades of the century it became increasingly common for academic chemical laboratories to be housed within grand, purpose-built institutes. But, as I have argued elsewhere, the interior design and fittings of these laboratories also changed rapidly in this period in response to the introduction of new investigative methods and novel glass apparatus, as well as further developments in chemical pedagogy (Jackson 2011). Training in Liebig's famous Giessen laboratory focused almost exclusively on the technique of combustion analysis and the interpretation of the results this produced in terms of the composition of organic substances. Towards the end of the century, by contrast, student chemists learnt a wide range of techniques, including how to perform the dozens of reactions and manipulations upon which the practice of organic synthesis relied. And while many aspects of the Giessen laboratory—for example, its central tables, coke-fired furnaces, and limited ventilation—resembled earlier laboratories, late nineteenth-century chemical laboratories increasingly incorporated what remain ubiquitous modern features.

Some of these related to the storage and use of new laboratory apparatus, especially chemical glassware components that, when skillfully combined, allowed chemists to control the reaction, purification, and characterization of organic substances (Jackson 2015a; Jackson 2015b). But many others were concerned with maintaining a safe working environment, particularly for inexperienced chemists in training.

Ventilation was a major concern, leading to the introduction of effective fume hoods in August Hofmann's Berlin laboratory in the 1860s (Jackson 2011, 58). So, too, were fire and explosion. The directors of late nineteenth-century institutional chemical institutes adopted a range of strategies in managing these day-to-day hazards of practical organic chemistry. They certainly encouraged safe practices through teaching and the hierarchy of the laboratory as a social institution (Meinel 2000, 298–9). But they also addressed this central problem in material ways, at every level from the provision of individual items of apparatus through to the design, construction, and fitting of the laboratory building itself, as well as its location and garden setting (Jackson 2011, 57–8). In the institute built around 1900 for Emil Fischer, Hofmann's successor as professor of chemistry at the University of Berlin, for example, fire extinguishers were available at the door of each laboratory. The institute building, meanwhile, incorporated special rooms with reinforced walls containing protective steel enclosures called ballistic cabinets: dangerous procedures in which flammable substances were subjected to extremes of temperature and pressure inside glass apparatus were controlled by specific physical—and not merely social—means (Jackson 2011, 59–60).

By about 1870 chemical laboratories were an important feature of many German universities. Second only in cost to anatomical institutes, the institutional chemical laboratory was an essential tool of professional chemical training and cutting-edge research, mainly in the field of organic chemistry (Jackson 2011, 60–2). The early decades of the nineteenth century had seen a spectacular expansion in popular interest in chemistry, encouraged by the publication of manuals and treatises and the availability of "portable laboratories" including adequate apparatus for basic practical inorganic chemistry (Gee 1989). But the basics of practical organic chemistry could not safely be learnt at home, an important factor driving the institutionalization of chemistry during the second half of the nineteenth century.

These changes also provided the model for subsequent and much more widely studied aspects of laboratory history. David Cahan's work on the "institutional revolution" of the 1870s described the rapid institutionalization of physics, and especially the physics of precision measurement, in a newly unified Germany (Cahan 1985; 1989). In architectural terms, the physikalisch-technische Reichsanstalt (PTR) resembled existing institutional chemical laboratories. But, like many other state-funded laboratories across Europe from the late nineteenth century onwards, the PTR's main purpose was to create, maintain, and distribute the standards of measurement upon which late nineteenth-century science and technology relied (Schaffer 1992). One important consequence of this focus on metrology—first noted in Graeme Gooday's study of the "laboratory revolution" in British physics—was that, while training was a central function of institutional physics laboratories of the 1870s and 1880s, these laboratories were not, in fact, primarily places of experimental research (Gooday 1990).

Studies of the institutionalization of medicine and the life sciences, especially physiology, have revealed a pattern of late nineteenth-century laboratory building in academic settings broadly similar to that described here for physics (Cunningham and Williams 1992, and especially Lenoir 1992 in that volume). By the end of the century institutional laboratories had become defining features of all the major scientific disciplines. The institutional laboratory around 1900 owed its origins to the particular difficulties associated with practical chemistry, and it had been developed into an essential tool of training and research. It also played an equally important role in

establishing the legitimacy, reliability, and productivity of practical science in all its forms, functioning as an essential badge of intellectual—and especially academic—credibility (Jackson 2011, 61–2).

The role and status of laboratories in the life and human sciences is complicated by their dependence on living subjects—both plant and animal—and, especially in the case of humans, by the requirement for the subjects' participation, whether willing or coerced (Kirk 2010; Lundgren 2013, and see also Chapter 9 of this volume). Robert Kohler (2002) has shown that biological sciences push at the boundary between field and laboratory. Human sciences similarly connect clinic and laboratory, thereby bringing laboratory science into contact with broader society in ways that highlight its moral and ethical dimensions.

This chapter has deliberately privileged the development of academic laboratories in the period after 1800. As a result, it has paid more attention to modern laboratories as sites of training and research than to their equally important but much less well-understood functions as places where industrial processes and military technologies were developed, product quality tested, forensic investigations pursued, and government policy and legislation supported and enforced. This decision does not reflect any lack of commitment to the importance of industrial and government laboratories, whether engaged in activities of primarily social, political, economic, or military significance. Rather, it is driven by a much lesser degree of clarity concerning the grand narrative of these developments. Despite a rapidly growing literature dealing with late nineteenth- and twentieth-century laboratories within or funded by industry, the military, and government (e.g., Meinel 2000; Reinhardt and Travis 2000; Burney 2002; Rooij 2011; Slayton 2012), there remains no clear framework for those developments—an important future direction we shall revisit in the next section.

Up to this point, this chapter has focused on laboratories located in Western Europe and North America. That geographical focus is, to a considerable extent, a consequence of the topic and it is certainly reflected in the existing secondary literature. It has been a major argument of this chapter that, while the early laboratory was a chemical workplace, the modern laboratory is a product of the professionalization and institutionalization of science in nineteenth-century Europe. Germany took a clear lead in these changes, followed first by other European countries and later by the United States. There are numerous excellent studies of the translation of laboratory training on the German model to Britain, France, and the United States (Rezneck 1970; Rossiter 1975; Rocke 2003) including a few that have focused on women's access to laboratory training and work (e.g., Richmond 1997; Micault 2013).

In recent years, valuable attention has been devoted to the spread of institutional laboratories beyond the West. In addition to studies focused mainly on the development of laboratory science in imperial settings in the nineteenth and twentieth centuries (Gooday and Low 1998; Arnold 2000, esp. chapter 5; Günergun 2009; Chakrabarti 2012; Clarke 2013; Günergun and Etker 2013), there is also a growing body of work dealing with postcolonial laboratories (e.g., Baytop 1997; Kikuchi 2013; Phalkey 2013). These histories increasingly give due credit to non-Western figures as active participants in the creation of their own future and they show that the laboratory became an established feature of science outside the West by the late nineteenth

century. There is clearly much important work to be done in this area but non-Western laboratories are now firmly on the historical agenda.

This account of the origins of the modern laboratory has pointed to the historical contingency of what now appear to be inevitable connections between the laboratory and major areas of scientific activity. As a result, it has drawn attention to some important opportunities presented by the existing literature. By outlining how the chemical laboratory was transformed during the nineteenth century from a place of specifically chemical labor into a site of academic training and experimental research, and how other scientific disciplines adopted laboratories like this by the end of the century, for example, it indicates that—even in the most-studied case of academic laboratories—our understanding of the processes by which modern science became a laboratory activity remains imperfect. And it has delineated some important areas—most notably concerning non-Western laboratories, non-academic laboratories and twentieth- and twenty-first-century laboratories—where, despite many outstanding recent studies, we simply do not know enough to be able to construct a coherent macro-level account. Future work in all these areas will make an important contribution to our understanding of the nature of the modern scientific enterprise. Such work, moreover, will be greatly facilitated by knowing something of the origins of the field of lab studies and the range of approaches scholars have used to investigate the laboratory as a social, historical, scientific, and cultural entity.

Lab Studies as a Field: Past, Present, and Future

The previous section noted in passing some of the historiographical problems inherent in a methodological focus on the laboratory as a location of scientific, and especially experimental, activity. By choosing the laboratory (or any other site of science) as an analytical category, the historian exercises a series of commitments concerning the nature of science, its proper venues and practitioners, its performance and product. But because these commitments are frequently implicit there is a tendency for them to remain invisible. Articulating and understanding the consequences of such commitments is important if we are to realize the possibilities offered by lab studies and how these might best contribute to the history of science as a whole. The goal of this section is to sketch the driving forces behind the original field of lab studies and its more recent offshoot, the trend towards writing histories of science through its many and various locations.[4]

Unlike the laboratory, it is easy to say when the field of lab studies was born. Offspring of the late 1970s turn to practice, during which historical and philosophical enquiry were supplemented by methods drawn from anthropology and sociology, lab studies reached a first maturity in the 1990s. Drawing upon the work of Ludwig Fleck and Thomas Kuhn, and gaining momentum from the new sociology of scientific knowledge at the heart of the Edinburgh Strong Programme, some of the first lab studies involved a newly empirical, ethnographic approach to science and scientists.[5] Dissatisfied with existing macro-social studies of science, Bruno Latour and Steve Woolgar (1979, 15) famously sought "to provide a reflexive understanding of the detailed activities of working scientists" through an account "based on the experiences of close daily contact with laboratory scientists over a two year period."

Latour and Woolgar's *Laboratory Life* has since become a classic in the field. But, because it argued that what we call scientific facts are the negotiated outcome of interactions between scientists, it was construed by some—distressingly wrongly, according to Latour (1999)—as an attack on science. This perception was reinforced by later sociological studies of present-day laboratory practice—notably Harry Collins' (1985) *Changing Order*, which exposed the difficulty of relying on experimental replication as a method of establishing new facts. The field of lab studies, as it emerged around 1980, was primarily sociological and philosophical rather than historical. Its methods were empirical and its goals were significantly epistemological, and it was by no means hostile to science and scientists. What is it that scientists know? How is it that they know those things? Why is scientific knowledge stable enough to be useful yet capable of change? Questions like these motivated studies of present-day laboratories in the 1980s and early 1990s.

The same questions, moreover, could be translated from the present into the past—a move that opened the way for studies of historical laboratories including, to give an early example of outstanding importance, Owen Hannaway's (1986) comparison of Andreas Libavius' Chemical House with Tycho Brahe's Uraniborg laboratory. But, as Steven Shapin (1988, 276–8) soon pointed out, historical studies of laboratories and other sites of experimentation involved considerable sensitivity to language and custom as well as to social structure and scientific practice. Shapin's much-cited essay "The House of Experiment in seventeenth-century England" referred to a large variety of locations, almost none of which were called laboratories.

Numerous scholars from differing disciplines participated in the development during the late 1980s and early 1990s of what Kohler (2008, 762 and n. 3) has called "diversely fruitful theoretical frameworks for understanding laboratories." Many of these frameworks took due account of the historical complexity of the laboratory, and they included those studies of the laboratory as primary site of the institutionalization of various scientific disciplines in a range of national settings discussed in the previous section. When Karin Knorr Cetina identified "laboratory studies" with "the cultural approach to the study of science" in 1995, she envisaged a broad and productive future for the new field as a component of both history of science and the new discipline of science studies. Robert Kohler—himself a noted historian of the laboratory—has since regretted lab studies' failure to fulfill this early promise, using his 2008 review essay to urge for re-invigoration of the field (762). I agree with Kohler about both the present state of the field and the desirability of change. My analysis of how we have come to this point is somewhat different, however, and this leads me in the final section to make some alternative proposals for future lab studies.

The Laboratory at the Intersection: Practice, Pedagogy, and Material Culture

In 2008, Robert Kohler (763–4) suggested two possible reasons for what he saw as the decline in lab studies since the mid-1990s. The first was that scholars could see nothing further of theoretical interest to be derived from such studies. The second related the decline in lab studies to the general unpopularity of institutional history. What we lack, Kohler claimed, are studies of the systematic integration of the

laboratory with its wider social setting. As a result, Kohler (2008, 761) argued that future lab studies should produce a "systematic, macrosocial history of the lab." There is certainly valuable work to be done in this direction. But I propose some additional, complementary possibilities for future lab studies, built on a rather different conception of the laboratory.

For Kohler, laboratories are primarily "cultural spaces" whose "conventions … embody those of other important social institutions" and he is certainly right that it is insufficient to focus solely on "the science done in labs" (2008, 763–4). But, as I have shown elsewhere, laboratories are also essential material and pedagogical resources in the practice of modern science, irreducible to mere locations or venues of scientific activity (Jackson 2011). Studies of the laboratory therefore offer the possibility for a different kind of integration from that proposed by Kohler, for micro-histories that consider the totality of the laboratory, integrating their institutional essence with what goes on within their walls. Setting out the bones of this approach and indicating how it can be used to produce consciously historically, fully situated accounts of the production of scientific knowledge is the goal of this final section.

This focus on the production of scientific knowledge is deliberate and it runs counter to the reasons offered by Kohler for the decline of lab studies as a field. If we focus our attention for a moment on the questions at the heart of early lab studies (listed above), there seems to me to be plenty of interest, both theoretical and historical, to pursue. And if laboratory history as institutional history has ceased to attract practitioners this is perhaps because, somewhere in the transition from studies driven by primarily epistemological concerns to those conceptualized within cultural or social history, scholars have lost sight of the essential, and essentially historical, connection between the practice of science and its venue. Current studies address one or the other but they almost never integrate the two.[6] Indeed, only in this integrated form might this field properly be called lab studies.

An example from the history of chemistry will help me to explain why the approach I am proposing here is far from being a return to mere institutional history or narrow technical internalism, why the connection between practice and place matters, and what we might hope to learn from studies that achieve this integration. We have been repeatedly led to believe that the structural theory of organic molecules was both essential and sufficient in enabling the synthesis of organic compounds from the mid-nineteenth century onwards—this ability providing the foundation for the rise of vast chemical industries devoted to the production of chemical dyes, pharmaceuticals, agrochemicals, and a range of new synthetic materials. My recent studies of chemical practice in the laboratories of chemists, including August Hofmann, have shown otherwise, revealing the limitations of such theoretical knowledge and the absolute dependence of synthetic capability on practical expertise that was developed, learnt, taught, and deployed in a very particular place: the institutional chemical laboratory (Jackson 2014a; Jackson 2014b).

The laboratory as practical, material, and pedagogical resource, as well as social space, is the central core of my historical account of what Hofmann knew, how he knew it, and how this knowledge could provide the basis of a science that was stable enough to be useful in industrial settings and yet capable of rapid further development. This approach foregrounds in historical context exactly the questions driving early lab studies and it certainly depends on suitably adapted forms of the methods developed by

early scholars in the field. But it also draws upon more recent approaches originating in studies of scientific pedagogy (Warwick 2003; Kaiser 2005; Warwick and Kaiser 2005) and the materiality of scientific—and especially chemical—practice (Klein and Lefèvre 2007; Klein and Spary 2010), including a focus on instrumentation (Holmes and Levere 2000; Morris 2002).

Marrying tools for investigating the laboratory with the insights provided by the ongoing study of science as practice produces important historical results. Some of these relate to important questions about the nature of scientific knowledge and, specifically, the relationship between practice and theory—as reflected in a new understanding of the role of practical knowledge of organic synthesis in generating and securing developing structural theory (Jackson 2014a; Jackson 2014b). But they also reveal fresh perspectives on the acquisition and dissemination of scientific knowledge and research expertise, as well as the undeniably collective nature of much scientific research in the modern period. Many excellent studies of scientific practice have been produced by the study of individual lab notebooks (Holmes, Renn, and Rheinberger 2003). Such notebooks, where they survive, are certainly important sources for the lab historian. In an age where historians are increasingly pressed to show the relevance of their work to current concerns, including the best means of fostering creativity and encouraging innovation, however, there is surely much to recommend an approach that makes it possible to incorporate both individual and collective contributions to the development and prosecution of science as a social, material, and technical activity.

Its focus on science may cause this approach to appear incompatible with—perhaps even hostile to—Kohler's broader social concerns. It is not. On the contrary, it is only by including the kind of approach I have described here alongside other, more purely social historical approaches that we shall come to understand the laboratory's changing position in the world—producing exactly that "systematic, macrosocial history of the lab" Kohler urged a new generation of historians to pursue. The laboratory—whether for teaching, testing, or research—is the material nexus of scientific practice, a manifestation of all that makes science something to be trusted and suspected, looked up to and laughed at. In seeking to understand the place of science in society, we could do a lot worse than begin by understanding science in its own social space.

Endnotes

1 Gooding 1985; Shapin and Schaffer 1985; Schaffer 1998; and see also Cunningham 2010 on anatomy as an experimental discipline.

2 James (1989) is exemplary of the relative neglect of chemical laboratories. This collection of 13 essays about the development of laboratory science in the nineteenth century contains only three essays about chemical laboratories, of which only two are concerned with the laboratory as a physical space.

3 Crosland (1967, 283) refers to Berthollet's laboratory but gives no indication that at least some of Berthollet's experiments were performed far away from the main house.

4 See, for example, the recent project "Sites of Chemistry" sponsored by the Society for the History of Alchemy and Chemistry.

5 Kuhn's (1977) *Essential Tension* is perhaps more significant than his famous (1996[1962]) *Structure of Scientific Revolutions* in this context. These developments were also fueled by the publication in 1979 of a new English edition of Ludwik Fleck's

(1935) *Genesis and Development of a Scientific Fact*. Golinski (2005[1998]) provides an excellent introduction to constructivism and the Edinburgh Strong Programme.

6 Compare, for example, Rooij's (2011) proposed laboratory taxonomy with the studies of practice presented in Holmes, Renn, and Rheinberger 2003. This separation reflects the failure of more recent scholarship to realize the possibilities Knorr Cetina (1992, 115) believed laboratory studies offered for considering "experimental activity within the wider context of equipment and symbolic practices." It also leaves the path open for a new integration of histories of scientific practice within lab studies.

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