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Introduction: Science as public culture

> Appearances in these things are most deceptive: in the theatre experiments are made for illustration, and are generally of a simple kind, and easily comprehended, and the minds of the audience are prepared by the lecturer to follow and understand them. In the laboratory, on the contrary, this aid is wanting when most necessary; and, in consequence, operations . . . of a very accurate kind, and carried on with a perfect design, may appear confused to the uninstructed, or to the uninitiated.
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> John Davy, *Memoires of the Life of Sir Humphry Davy* (1836)[1]

> Certainty, simplicity, vividness originate in popular knowledge. That is where the expert obtains his faith in this triad as the ideal of knowledge. Therein lies the general epistemological significance of popular science.
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> Ludwik Fleck, *Genesis and Development of a Scientific Fact* (1935)[2]

> The career of experimental knowledge is the circulation between private and public spaces.
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> Steven Shapin, "The House of Experiment" (1988)[3]

Science, it has been said, is "public knowledge." The assertion is an appealing one, but it raises a host of problems.[4] When scientists and philosophers say that scientific knowledge is public, they seem to mean that it is accessible to all. Science has its basis in empirical facts, so anyone with normal senses can come to understand it. It is also thought that everyone can contribute to scientific knowledge, at least in principle. All claims are meant to be judged on their coincidence with the agreed-upon facts, without reference to the circumstances of their origin. Claims about the natural world become accepted scientific knowledge in a process that is supposed to be open and egalitarian. The scientific community is sometimes even taken as a model of an ideal open society.

There are, however, many problems with this view. It might be a de-

1 J. Davy (1836), I, pp. 259–260. 2 Fleck (1979), p. 115.
3 Shapin (1988), p. 400. 4 For discussion of these problems, see Ziman (1968).

sirable ideal, but it has evident faults as a model of how science actually works. In particular, it seems not to fit with lay people's experience of the impact of science on their lives. Nonscientists typically do not experience the falsifiability of scientific knowledge or the supposedly democratic character of scientific decision-making. To them, rather, science often appears as a system of authority, the tool of powerful interests in society. Notwithstanding widespread and enthusiastic interest in certain aspects of science, anxiety about unrestrained expertise regularly surfaces in connection with such controversial questions as nuclear power, genetic engineering, and animal experimentation. At such times, the assertion that science is a public activity is called into question.[5]

From the other side of the fence, but frequently in connection with the same controversial issues, scientific bodies have been heard to express concern about the lack of public understanding of science. The gap between expert knowledge and that of the nonexpert population is a matter of anxiety for scientific institutions, perhaps particularly when they feel that their political influence is declining.[6]

The most radical implication of such incidents is that the philosophical image of science that has typically supported assertions of its public character is untenable. Many sociologists and historians of science and some philosophers would now say that a view of science that sees it as entirely open, egalitarian, and consensual is naively unrealistic. A growing body of theoretical and empirical work has considerably modified this image, opening the way to a reexamination of the public nature of scientific activity.[7]

In the first place, this work has shown how the experimental phenomena that lie at the core of science are produced in distinctive local settings. Experimental facts are not simply presented to casual observation like stones picked up on the seashore; they have to be created by active labor with particular kinds of resources. Scientific phenomena are essentially creatures of laboratories, with their particular concentrations of instrumentation and skills. Science, at its point of origin, is not public at all. Nor is this an accidental feature of experimental work; it is arguably quite essential. Sociologists of modern scientific practice have argued that relative privacy is required for successful laboratory work, in order that skills and apparatus can be refined and protected from interference and

5 There have been many studies of controversies of this kind. Among them are some that use a sociological approach to draw out general implications for our understanding of science. These include Wynne (1982), esp. pp. 11–14, 159–176, Collins (1987, 1988), Pinch and Collins (1984).
6 Royal Society (1985).
7 Contributions to this work are surveyed in: Shapin (1982), Whitley (1983), Golinski (1990).

so that confused and chaotic initial perceptions can solidify into clear and distinct facts.[8]

Thus the facts of science emerge initially as a kind of local knowledge, dependent upon the craft skills of the laboratory scientist and his or her specific resources of expertise and equipment. These resources cannot be available to all, so that access to the means by which science is constructed is inevitably restricted. Inequalities of assets between scientists and lay people are not an unfortunate byproduct of current institutional arrangements, but a precondition for the construction of natural knowledge.

In addition to the circumstances of the laboratory, recent studies have also illuminated the ways in which scientific knowledge becomes public, to the extent that it does. The mechanisms by which this occurs have been scrutinized and the resources used, which may be quite different from those employed in the laboratory, have been identified. Science is made public by various kinds of discourse, including conversations and lectures, and the writing of scientific papers, textbooks, and popular works. The results of experiments become defined and gain their significance in the contexts in which they are interpreted. Claims to knowledge become accepted insofar as they are embodied in effective acts of communication. And the persuasiveness of particular claims is not simply a result of what was said, but also of how it was said, where, and by whom. This insight – basically that scientific discourse can be considered as a kind of rhetoric – has led sociologists and literary specialists to examine various genres of scientific writing, with the aim of showing in detail how they are constructed so as to persuade particular audiences.[9]

Rhetoric is one of the requirements for the construction of science in the public domain, but science is not just a product of verbal persuasion. On the contrary, it is intimately involved with manipulation of phenomena and material artifacts. It gains acceptance by mobilizing nature itself, in the form of experimental phenomena that are reproduced by replicating laboratory techniques. Phenomena that have been created by the instruments and skills of the laboratory can be translated to new contexts by extending the practices by which they were originally made. The French philosopher Gaston Bachelard coined the term "phenomeno-technics" to describe the embeddedness of experimental phenomena in bodies of technical practice.[10] Phenomena, the instruments by which they are pro-

8 Works on this theme include: Collins (1985), Fleck (1979), Hacking (1983), Rouse (1987), Latour and Woolgar (1979), Latour (1987), Gooding (1985a).

9 Representative studies include: Law and Williams (1982), Myers (1985), Gilbert (1977), and the papers collected in Shinn and Whitley (1985). See also Bazerman (1988), and Cantor (1989), for broader discussion of the field.

10 Bachelard (1980), p. 61.

duced, and the techniques for using those instruments are translated together in the processes by which science is made into public knowledge.

By considering the working of these processes, we may hope to understand more about how the confidence of lay audiences in scientific knowledge may be established and strengthened or (in certain circumstances) undermined. Rather than assuming the public nature of science, this perspective offers a rationale for empirical studies of the ways in which audiences are constructed and transformed in changing historical contexts.

This kind of approach has already begun to be applied in historical studies. It has become apparent that the question of the public status of science has long been a problematic one. Indeed, it is arguable that controversy over whether scientific practice is or is not sufficiently public derives from deeply entrenched features of its social constitution and supporting ideology in Western culture. When experimental natural philosophy emerged in Europe in the seventeenth century, there were already arguments over the degree to which it was open to public view and the degree to which it should be.

These debates arose, for example, in the Royal Society in London in the 1660s and 1670s. The practice in the Society was for experiments to be made initially in relatively secluded laboratories, and then converted into demonstrations before an audience in socially restricted but ostensibly public meetings. They would also be communicated in written descriptions – in correspondence, or in printed texts that were deliberately crafted to place the reader in the position of "virtual witness" to experimental demonstrations.[11]

One area in which tensions occurred was in dealing with rarities (things that had value because of their scarcity) or with commercially valuable processes kept secret by the practitioners of various arts and trades. Francis Bacon had commended such matters to the attention of natural philosophers, and many of them followed his suggestion. Critics of the Society however, such as Henry Stubbe, voiced the anxieties of artists and tradesmen, whose methods were being enquired into and who feared that valuable information would be revealed in too public a forum. For them, intellectual property was best protected by secrecy, whereas publicity was equivalent to theft. On the other hand, by making occasional concessions to commercial demands for confidentiality, the Society invited the charge that it was betraying the Baconian ideal of free communication, and that its knowledge remained the prerogative of an exclusive sect. The degree to which the Royal Society could or should produce public knowledge was thus a hotly contested issue.[12]

11 Shapin (1984, 1988), Dear (1985).
12 For a discussion of these issues in connection with one particular chemical phenomenon, see Golinski (1989).

Historians' understanding of the significance of these arguments, at this critical juncture for the origins of modern experimental science, has been greatly advanced by Steven Shapin and Simon Schaffer's book, *Leviathan and the Air-Pump* (1985).[13] These authors have shown how the formation of the experimental way of life in the early Royal Society involved the constitution of a relatively private space for experimentation and a series of declaredly public settings for communicating its findings. These included the Society's meetings, its publications (especially its journal, the *Philosophical Transactions*), and the extensive correspondence of the Secretary, Henry Oldenburg. In each setting, material, social, and rhetorical techniques were mobilized in order to put the desired message across. Robert Boyle in particular showed how experiments should be displayed and written reports framed in order to convey a persuasive effect. Shapin and Schaffer brilliantly expose the contingent nature of these practices by discussing the alternative views of a perceptive and resolute critic of the Society, Thomas Hobbes. From Hobbes's vantage point, we can see how problematic were the means for making public knowledge bequeathed to modern science by Boyle and his allies.

As methods for converting private opinions into public facts, the Royal Society's procedures involved a reordering of the social setting in which knowledge was pursued. On Shapin and Schaffer's account, the public form taken by the new science was a microcosm of the general pattern of consolidation of the social order after the upheavals of the mid-seventeenth century civil wars. For this reason, controversial issues of metaphysics or religious doctrine were excluded, and a gentlemanly consensus was formed around matters of fact. In addition, as Bruno Latour has pointed out, their study also suggests how experimental natural philosophy contributed to a remodeling of public life as a whole, from the seventeenth century on. Making facts through agreement among the witnesses to an experiment, and then extending them by replicating the experiments in other locations, Boyle showed how social relations should be reorganized by science. The circulation of instruments and the reproduction of knowledge-producing practices were thereafter to become prevalent features of the social landscape. As Latour puts it, "Since Boyle's time, . . . we live in societies built on laboratory-made objects; ideas have been replaced by skills; apodictic reasoning by managed doxa; universal assent by old-boy networks of professional colleagues."[14]

Of course, this situation did not come about overnight. The study that follows focuses on a rather later period in a lengthy and convoluted historical process – that of the extension of the practices of experimental science through society. I shift attention to the period of the eighteenth-

13 Shapin and Schaffer (1985).
14 Latour (1990), esp. pp. 148–155 (quotation on p. 152).

century Enlightenment and its immediate aftermath. By using the term "Enlightenment" I am committing myself to an analysis on a larger scale than a single personality, locality, or institution. Many valuable local studies have appeared in recent years, and my work is heavily indebted to a number of them. But my aim is to illuminate developments in scientific practice and their transmission through society – processes that cannot be described purely at the local level. We need to raise our eyes to a wider horizon in order to grasp how discursive and technical practices may be translated from one local context to others – from the chemist's laboratory, for example, to the bleach fields or the pharmacist's shop. In this connection, Enlightenment seems an appropriate term, provided it is understood as a concrete historical process and not as the diffusion of disembodied ideas. I suggest that the experience of enlightenment, involving certain patterns of communication and social interaction – a certain way of life in the public realm – is of key importance in the extension of scientific knowledge through society at large.[15]

A number of historians have led the way in exploring relations between natural philosophy and Enlightenment public life. The role of public discourse and experimentation in the culture of eighteenth-century Britain has been opened to investigation. Echoing interpretations of science in Enlightenment Scotland, Roy Porter has argued that its manifestations in the English provinces should be viewed as a form of cultural expression by an affluent middle-class elite. Science, like music, literature, or fashion is a cultural form, to be understood historically in relation to social forces such as emulation and consumerism.[16] From a rather different perspective, Schaffer has proposed that public experimental display was integral to the project of natural philosophy at this time. Demonstration of the powers of nature was intimately connected with metaphysical, aesthetic, and ethical principles; but it also gave rise to moral and political dangers that threatened the enterprise of enlightenment itself.[17]

In a substantial new study, Larry Stewart has shown how public suspicion of the experimental philosophy of the early Royal Society was gradually overcome as the settings in which it was practised were multiplied in the early decades of the eighteenth century. Such entrepreneurs as Jean Theophilus Desaguliers and Francis Hauksbee pioneered the presentation of lectures and experimental displays in London coffee houses and inns. Their successors, like Benjamin Martin and John Ferguson, took to the road to tour the burgeoning provincial towns. By attracting

15 My conception of the Enlightenment as a way of life in the public realm is informed by two seminal works in social theory: Sennett (1977) and Habermas (1989).
16 Porter (1980, 1981). 17 Schaffer (1980, 1983).

aristocratic patronage and middle-class subscriptions for their performances and publications, and by linking natural philosophy with a range of technological activities from navigation to engineering projects, these men won science its place in British society. They formed an essential link, though one largely overlooked by traditional historiography, between the mechanical philosophy of Boyle and Newton and the technical innovations of the Industrial Revolution.[18]

These studies, and others cited in this book, justify my concentration on the Enlightenment in Britain. To restrict our attention to a single nation is not to narrow the focus, but on the contrary to broaden our coverage of the context in which public science was pursued. Because distinctive national experiences of Enlightenment have been identified in England and Scotland, research on science in this milieu seems particularly necessary.[19]

Our focus upon chemistry allows us to probe more deeply into the connections between the practice of a particular science and the circumstances of Enlightenment public life. Neither the continuous identity of the discipline nor the fixity of its boundaries need be assumed. As we shall see, the identity of chemistry was frequently redefined in lectures and textbooks; its disciplinary continuity was sustained through repeated statements of what the subject was about. Its boundaries were neither fixed nor impermeable: Chemists profitably recruited phenomeno-technics from many other sciences, including those of heat, pneumatics, and electricity, to advance their own.

Chemistry began to be constituted in the public realm in Britain toward the middle of the eighteenth century. In Scotland in particular, efforts were made to communicate chemistry in the circumstances of Enlightenment public life. The initial focus of this study is on the work of William Cullen and Joseph Black, who argued for the importance of chemistry in social circumstances that were themselves the subject of self-conscious intellectual deliberation. Scottish thinkers felt that the novel experience of interaction in the civic realm raised deep moral problems for society and polity. Behavior in the public spaces of the eighteenth-century city was discussed in relation to its implications for individual identity, moral responsibility, and social progress.

This debate yielded rhetorical resources for the public presentation of experimental science, but it also generated possible obstacles to realizing the ambitions of scientists. On the one hand, chemistry could be shown as a means of cultural and material improvement, capable of mobilizing the energies of gentlemen and aristocrats in the pursuit of national prog-

18 Stewart (forthcoming). I should like to thank Dr Stewart for allowing me to read the manuscript of this book prior to publication.
19 Porter (1980, 1981); Wilson (1983); Pocock (1980); Gascoigne (1989), esp. pp. 1–3.

ress. This made it appear as a public asset. On the other hand, proposals for technological innovations raised the specter of conflict between private and public good, and the development of specialist skills seemed to threaten ideals of gentility and politeness. Continuing debates about the public status of science were thus an important part of the Scottish experience of enlightenment, and a significant influence on the form that chemical practice took in that context.

In the English provinces in the 1770s and 1780s, Joseph Priestley and his allies set about launching chemistry onto the public stage in a quite different way. Priestley described his discoveries of new "airs" in carefully crafted written narratives, and encouraged lecturers to demonstrate them to public audiences. The rhetoric of both demonstrations and texts was aimed at diffusing factual knowledge among as wide an audience as possible by allowing them to witness, or if possible to replicate, experimental findings. For Priestley, the purpose of this was to provide the population with direct experience of the providential powers of nature in order to liberate them from the ignorance on which corrupt authority was founded. His methods of making his experimental work public were thus subordinated to an overarching moral and political vision of the role of knowledge in spreading enlightenment. The field of pneumatic medicine, with its therapeutic techniques and associated methods of analysis of atmospheric air, was born out of Priestley's experiments and developed by his colleagues and friends in English enlightened circles.

Because of the close relationship between scientific practice and the forms of public life, the development of chemistry was shaped by dramatic changes in the constitution of civic culture at the end of the eighteenth century. This was a crucial element in the radical transformation of the discipline initiated in France by Antoine Laurent Lavoisier which became known as the "Chemical Revolution." We shall see how acceptance or rejection of Lavoisier's new theories was linked with different views as to how scientific knowledge should be established publicly. Arguments about methods of reasoning, about the use of certain instruments, and about the situation of audiences in relation to experiments were all interconnected. In the controversy surrounding the Chemical Revolution, visions of how the chemical community should be structured were at stake just as much as the results of particular experiments.

In Britain, the debate over the new chemistry was heightened by a growing domestic dispute concerning the proper social and political functions of public science. In the 1790s, a period marked by a strongly conservative reaction to the French Revolution, the Enlightenment values that had sustained the public culture of science in Britain were called into question. Political radicals such as Priestley and Thomas Beddoes reasserted the importance of chemistry within a program of social and intel-

lectual progress. Conservatives such as Edmund Burke and John Robison identified such a chemistry as symptomatic of the subversive and pernicious aims of the Enlightenment. The polarized political climate of the end of the Enlightenment shaped reactions to the discovery, by Beddoes and Humphry Davy, of the intoxicating effects of nitrous oxide. The experiments on this "laughing gas" were widely ridiculed as symptomatic of the anarchy and delusion unleashed by supporters of the Revolution. The Priestleian program of pneumatic chemistry in the service of social and moral progress was judged to have degenerated into a fiasco.

This incident had a critical significance in Davy's career, and arguably also in that of chemistry itself as a public science. Davy left Beddoes's employment in Bristol, turning his back on the provincial enlightened milieu in which pneumatic medicine had flourished; he moved to the Royal Institution (RI) in London, where he rapidly gained an outstanding reputation as a lecturer to audiences drawn from the metropolitan social elite. In this setting he articulated a conservative version of the Enlightenment aspirations for chemistry, stressing how its applications could benefit humanity in a stable and stratified society. The personality he projected through his lectures provided an image of a scientific genius that had great popular appeal.

To these audiences, and also to more select specialist groups assembled at the Royal Society and in the RI laboratory, Davy demonstrated the spectacular potency of the voltaic pile, an instrument that conferred unprecedented powers of chemical analysis. He publicly established the efficacy of the pile as an engine of discovery, and on this basis was able to secure acceptance for his isolation of the elements sodium and potassium. Davy showed how command of a public audience enabled experiments to be mobilized with unprecedentedly persuasive effect, as he continued to defeat those who challenged his assertions. Although he had less immediate success in persuading chemists that he was right about the elementary nature of chlorine, his public audience was a considerable asset to him in pressing this claim also.

The form of public science that Davy constructed was in marked contrast to that favored by Priestley. Far from being invited to share in the production of scientific knowledge by replicating experiments, Davy's public audience was expected to remain entirely passive, awed by the power of the philosopher and his instruments, and accepting his interpretation of phenomena. This transformation in the role of the public audience for chemistry was closely connected with the emergence of new instrumentation and a more consolidated social structure for the specialist community. Although he set himself against some of Lavoisier's new doctrines, Davy adopted many of the rhetorical and technical practices that characterized the reformed discipline. He showed how the use of more

concentrated instrumental resources and more refined practices of experimentation required a greater measure of social discipline within the community of chemists and less direct involvement by a lay public.

To some extent, Davy provided a model for other specialist chemists in the first two decades of the nineteenth century. His discoveries were widely hailed and his broadly conservative utilitarian rhetoric was reproduced by other lecturers and writers. Chemists used a variety of new technical tools to carve out careers for themselves in applied chemistry and education. But the chemical community achieved only a limited degree of autonomy from the demands of a public audience during this period. Many chemists continued to practice their science in ways that acknowledged a duty to make its doctrines accessible and its techniques widely reproducible. The legacy of Enlightenment public science was a lasting one, notwithstanding the radical transformation the subject had undergone.

Looking at early nineteenth-century chemistry in terms of its Enlightenment past, we can get a new outlook on the degree to which radical change had occurred. I aim to avoid the risk of teleology that lurks in the use of notions like "specialization" or "professionalization" to characterize developments in this period. Rather than trying to subsume historical change under some supposedly universal process, I shall concentrate on placing scientific practice in its setting – in the structure of the community of practitioners and their activities in the public sphere. I shall show how certain techniques, instruments, and modes of discourse continued to be used by the chemical community in its enduring relationship with a public audience. Davy's efforts to provide the chemist with powerful instrumentation and a pacified audience were respected, but not universally followed. Most chemists used analytical techniques that were more accessible (though no less effective) than the voltaic pile, and preserved a more democratic relationship with their public. This dimension of continuity with eighteenth-century practice was an important aspect of the changing discipline of chemistry.

By addressing questions of discipline-formation in this slightly oblique way, I hope to show how a sociologically informed scrutiny of scientific practice may address issues more traditionally associated with the social history of science. A focus on techniques, instruments, and discourse, and their functions in the community of practitioners, can fruitfully complement study of institutions, popularization, and other external aspects of science. Such a broad-based approach will be necessary if we are to understand in detail how science is constructed as "public knowledge."