COMPANION TO THE HISTORY OF MODERN SCIENCE

EDITED BY
R. C. OLBY, G. N. CANTOR,
J. R. R. CHRISTIE and M. J. S. HODGE

ROUTLEDGE
LONDON AND NEW YORK

First published in 1990
by Routledge
11 New Fetter Lane, London EC4P 4EE
29 West 35th Street, New York, NY 10001

Set in 10/12pt Ehrhardt, Linotron 202, by Promenade Graphics, Cheltenham
Printed in Great Britain
by Richard Clay Ltd, Bungay

British Library Cataloguing in Publication Data
Companion to the history of modern science.
1. Science, history
I. Olby, Robert, *1933–*
509

ISBN 0–415–01988–5

Library of Congress Cataloging-in-Publication Data
Companion to the history of modern science/edited by R. C. Olby
. . . [et al.].
0 p. 00 cm.
Bibliography: p.
Includes index.
ISBN 0–415–01988–5
1. Science—History. I. Olby, Robert C. (Robert Cecil)
Q125.C565 1989 89–10483
509—dc20 CIP

CONTENTS

65

SCIENCE AND THE PUBLIC

STEVEN SHAPIN

1. INTRODUCTION AND SURVEY

A remarkable feature of present-day science is that we know, or think we know, with self-evident certainty who is a scientist and who is a layperson, where science ends and where other forms of culture begin. And it is no less remarkable that the judgements of scientists and the laity on these matters display such a measure of agreement. In few instances are we even aware of engaging in decision. It is as if the notions of 'science' and 'the public' could simply be read from their exemplars by inspection. Even historians and sociologists of science, on the occasions when they do consider the categories of science and the public, tend to focus upon the relations between two known entities, rather than analysing how the entities are themselves constituted.

The task here is to describe and explain aspects of the historical construction of these categories. On what bases, and for what purposes, have boundaries been drawn between scientific and other forms of culture, between the social role of the practitioner of natural knowledge and other social roles? In the course of addressing these questions we will move from the self-evident to the problematic. At the end of the exercise we will, in a sense, know less about the entities 'science' and 'the public' than we did at the outset. But we also know that much of what we previously took to be self-evident knowledge was inadequately founded. Our recompense for knowing less will be a potential programme for empirical and theoretical research.

We start by describing the elements of 'the canonical account' – our contemporary common wisdom about the historical relations between science and the public. We then consider certain dimensions along which practitioners of science and other forms of culture have historically been discriminated, paying particular attention to the social and cultural correlates of the notion of intellectual 'competence'. Certain forms of scientific practice involved the acquisition

and deployment of intellectual skills which were not prevalent in lay culture or in the culture of the generally literate. Such a cultural gulf was not, however, a 'natural' or inevitable feature of the place of science in the overall map of culture. We describe several systematic attacks upon the propriety and legitimacy of a scientific culture thus divorced from the common-sense and ordinary competences of the wider public. And we examine the significance of mid- to late-nineteenth-century Scientific Naturalism as a vehicle for establishing and validating important modern social and cultural boundaries between science and the public. The production and justification of specific items of scientific knowledge is often dependent upon decisions about who is a competent practitioner and who is a member of the laity. Episodes are described in which public testimony about natural phenomena was evaluated according to its social source, and we point to the endemic roles of trust and authority in scientific communication. Some aspects of communication between members of the scientific community and the public are examined, in terms of what practitioners want from the public and how, in specific circumstances, it was judged proper and politic to secure those desiderata. Special attention is paid to the function of 'natural theology' as a bridge between scientific and lay culture, and to the vehicles by which scientific knowledge was channelled to the public. Finally, we discuss what the public and the state have wanted from men of science. The roles of patronage and of utilitarian concerns are assessed, and the social and cultural consequences of professionalisation for relations between science and the public are examined.

2. THE CANONICAL ACCOUNT OF HISTORICAL RELATIONS BETWEEN SCIENCE AND THE PUBLIC

The self-evidence of our knowledge of the categories of 'science' and 'the public' is supported by a canonical account of their historical relations. In the past the relations between science and the public were intimate, pervasive and consequential. What belonged to science was poorly demarcated from what did not, just as the role of the man of science was scarcely discriminated from other social roles. The public and other social and cultural structures were powerful compared with science. Public concerns could influence not only the direction of scientific work but also, at times, the content of scientific knowledge. As we come closer to present times, those relations have radically changed. Indeed, it might be said (in the canonical version) that science has progressively shed its public and circumscribed the role of the public, as well as that of non-scientific intellectuals, in scientific affairs. This shedding and disciplining of the public have been the conditions for the production of properly scientific knowledge, for wherever science has been substantively influenced by public concerns, there reliable and objective knowledge has been compromised. As the categories

of the public and of science have become disentangled, so the roles of each have been codified. The public's role now consists solely in acceding to scientific judgements and in rendering support for activities that scientists have deemed desirable or essential. If the public takes a more active role, it runs the risk of eroding the scientific character of the knowledge in question. It could be said that the past three centuries have witnessed an inversion of the power relations between science and the public. Where science – to the extent that it can be recognised as a discrete activity – was once influenced or interfered with by the public and other institutions, the scientific community now controls its own proceedings, stipulates the nature of proper relations between itself and the public, and even extends its influence importantly into the arena of public affairs.

There is much to recommend the canonical account. The relations between science and the wider public *have* altered dramatically since the seventeenth century. These changes *have* involved the winning by the scientific community of far greater autonomy in ordering its own affairs; they *have* involved a substantial shift in political power to scientific practitioners and away from interested non-practitioners and public institutions. The canonical account presents us with matters which need careful description and explanation. The weakness of that account is the attendant, and largely unacknowledged, tendency to equate description with explanation, and to make out of a series of historical events a process which is its own explanation. That tendency, commonly manifested in studies of scientific 'professionalisation', locates in the historical process an immanent force by which the modern relations of science and public have been progressively unveiled.[1]

Modern historical practice, like modern science, tends to suspect the legitimacy of teleological explanations. In this area, the most effective antidote to teleological temptations is the display of the enormous labour expended by individuals in the past in constructing the very categories of 'science' and 'the public' and in stipulating the proper nature of transactions between them. There was nothing 'natural', 'inevitable' or 'immanent' in these developments; they were massive historical achievements. The work that allows us to apportion items to 'science' and to 'the public' was done in specific historical settings, for specific purposes. Moreover, these classifications were widely contested. Different groups of interested persons upheld divergent views of what science was or ought to be and how the boundaries between it, other forms of knowledge and public concerns should be drawn. We start, therefore, with a sketch of how the categories of science and the public have been defined, defended and, on occasion, subverted. Following that, the discussion can shift to the relations that have subsisted between these categories: the concerns of the scientific community *vis-à-vis* the public; the concerns of the public and public institutions *vis-à-vis* scientific culture and the scientific community and the consequences that have flowed from these engagements.

How, then, have the entities 'science' and 'the public' been delineated in history? In what do these categories consist, and on what grounds are they set in opposition? We can analyse the social and cultural dimensions along which 'science' and the 'public' have historically been arrayed, and we can examine a number of revealing historical moments at which the boundary between the two categories has been constructed and subverted, drawn, redrawn and defended.

3. CULTURAL COMPETENCE AND THE GULF BETWEEN SCIENCE AND THE PUBLIC

One of the most obvious means by which we, and people in the past, discriminate between 'science' and 'the public' involves the notion of cultural competence. Accredited members of the scientific community are those deemed to have acquired relevant cognitive and manipulative skills that members of the public do not possess. As a result of this differential acquisition of skills, there is a discrepancy between what the public know how to do, or what they understand, compared to what qualified scientific practitioners can do or what they know. This discontinuity of competences is, of course, a historical phenomenon: it is something that has developed over time to its present situation. However, it did not proceed at the same rate in all sciences, nor has it been linear or uncontested in its development. As Thomas Kuhn has shown, the first scientific area to develop a gap of comprehensibility between its qualified practitioners and the generally-educated public was that of the mathematical sciences, including astronomy, optics and statics, as well as mathematics proper.[2] Even in antiquity, practitioners of these sciences did not expect that members of the generally-educated public would read their productions, or, if they did read them, would understand them. In the sixteenth century, Copernicus said that he wrote for other mathematicians and not for the literate public in general. The mathematical physics of the seventeenth-century Scientific Revolution, similarly, was not comprehensible as such by non-mathematically-qualified intellectuals, nor did those who produced it think that it ought to be. To evaluate Newton's mathematical works one had to be a mathematician; it is traditionally doubted whether more than a handful of contemporaries did in fact read and understand *The Mathematical Principles of Natural Philosophy*. If indeed, as Galileo and others said, the Book of Nature was written in the language of mathematics, then scientific texts ought to reflect that reality. Ability to speak and to read esoteric mathematical and technical, rather than everyday, languages was therefore an effective discriminator of who could be a competent scientific practitioner and who could not.

Needless to say, the same general situation obtains today, although, as we have seen, it is far older than the social institution of professionalised science.

Yet it is well to remind ourselves that the professionalised state of modern science means that there is wide agreement in our society as to who is an expert bearer of reliable natural knowledge; it does not mean that natural knowledge is solely located in the minds and texts of accredited scientists, nor is it necessarily accurate to assume that 'what the public think' about natural processes and objects is merely a simplification or dilution of scientists' expert knowledge. Compared to the abundance of academic material we now possess about the beliefs of tribal societies concerning the natural world, it is remarkable how little we know, and have sought to know, about the 'ethnoscience' of our own, modern western societies. Peter Burke's programme dedicated to the study of popular culture and its relations with 'high' culture has not yet made a significant impact on the history of science proper. Thus, with the exception of a small, but admirable, body of work in medical history and sociology, we have scarcely any understanding of the range of beliefs entertained by lay members of our society, how these beliefs may relate to those maintained by scientists and what purposes may be fulfilled by lay thinking about nature. Research by such medical sociologists as Cecil Helman strongly suggests that the public of modern western societies possesses a fairly elaborate set of beliefs about disease, its causes and indicated treatments. These beliefs are found to be not only qualitatively distinct from the beliefs of physicians but are actively deployed by patients to secure from their doctors the therapies that patients deem appropriate.[3] We are a very long way from understanding 'public science' in this sense, but we can at least recognise the historical submergence of lay beliefs about nature as a problem and as a legitimate topic of historical inquiry.

4. THE CULTURAL GULF ATTACKED

The cultural gap surrounding the mathematical physics of the Scientific Revolution was neither a pervasive feature of all sciences, nor was it universally considered to be either an inevitable feature of scientific progress or an acceptable and desirable state of affairs. Indeed, some commentators regarded a gulf of incomprehensibility between the common sense of the public and the culture of scientific intellectuals to be a sign that something was amiss with the latter. Paracelsus in the sixteenth century, and his numerous followers in the seventeenth century, argued that the sequestration of official intellectuals from everyday empirical experience and their socialisation into esoteric ways of knowing and speaking guaranteed that what they claimed to know was defective. Genuine natural knowledge for Paracelsians was founded upon sympathetic engagement with ordinary sensory experience. This was why miners, practical chemists and husbandmen were said to know more and know better than university professors and university-trained physicians. Proper knowledge was properly public

knowledge, generated by using the knowledge-acquiring techniques of ordinary members of society.

This structuring of the nature and legitimacy of the cultural relations between science and the public is recurrent. For example, Charles Gillispie has shown how the radical Jacobins of Enlightenment France contested the morality and validity of the official Newtonian science of the Paris *Académie des Sciences* by pointing to its divorce from the world of ordinary experience. Popular herbalist medical men criticised the knowledge and efficacy of 'allopathic' physicians in nineteenth-century America along similar lines. In nineteenth-century Britain the phrenological followers of Gall and Spurzheim (see art. 56, sect. 2.) questioned the scientific standing of academic psychology: a genuinely scientific study of the mind ought, they said, to be grounded in the observational competences available to the ordinary public, rather than depending upon the trained 'introspection' of university elites. And in the early twentieth century the phenomenologist Edmund Husserl identified a 'crisis' in the state of science. The 'Galilean' idealisations of modern mathematical science did not in fact pertain to or explain the world of lived experience. One could cite instances of this sort indefinitely. But the point should be evident: one of the most basic dimensions along which the knowledge of the scientific community and the knowledge of the public is arrayed has historically been a field of contest. There appears to be nothing inevitable about the existence of a cultural gulf dividing the knowledge or the ways of knowing of scientists and the public.

The strand of mathematical science represented a distinctively 'private' (or, at least, esoteric) form of culture, divorced from the experiences, competences and comprehension of the ordinary public or even from members of the ordinary educated elite. However, there was another strand of science, particularly important during the Scientific Revolution of the seventeenth century, and this stipulated the public character of science. The tradition of observational and experimental sciences which derived partly from the philosophical programme of Francis Bacon, implemented and publicised by Robert Boyle and his colleagues in the early Royal Society of London, was one that vigorously insisted upon the necessity of a public presence in proper scientific practice. Indeed, in its strong form this Baconian and Boylean programme identified the lack of that public presence and public participation as an adequate sign that the practice in question was not scientific. Alchemy, for example, was castigated for the privacy of its practice and the secrecy of its practitioners. Scholasticism was condemned for its esoteric language and for the refusal of its proponents to submit their claims to the test of ordinary (and artificial) experience; and some of those who endeavoured to model empirical science upon mathematical and demonstrative methods were labelled 'modern dogmatists', who wished to make ordinary experience submit to the transcendent domain of logical and geometrical inference. Was experience to be the test of knowledge, or was the evidence of the

senses to be subjugated to special, non-experiential procedures that dictated what nature 'must' be like, or was like 'in essence' or 'ideally'?[4]

The Baconian goal of 'the levelling of men's wits' had both epistemological and social dimensions. Having such a goal implied that the methods employed in empirical science and those that characterised everyday reliable observation and validation would overlap substantially; it also meant that the social boundaries between members of the scientific community and the public would be such as might easily be crossed. The style of writing and discoursing appropriate to the new experimental programme should, it was said, be such as facilitated public comprehension. Jargon, florid prose and esoteric language in general were to be rejected, precisely because such linguistic traits erected a boundary between the new enterprise and the wider public whose participation was being solicited. Yet, for all the rhetoric of seventeenth-century publicists which stressed the open and public character of their preferred science, the reality was far more complex and problematic. The 'public' that actually participated in the new experimental programme was a carefully selected and disciplined public. There is no accurate sense in which one could say that this was a form of practice open to all members of society. Even the much-advertised 'popularity' of the new science must, as Michael Hunter's research on Restoration science shows, be treated with caution. Moreover, from the latter part of the seventeenth century, the experimental enterprise co-existed with a revitalised and culturally aggressive mathematical programme. Mathematical practices in general, and the celebrated Newtonian mathematical philosophy of nature in particular, were definitely not public practices; nor, as has already been noted, were public comprehensibility or public participation said to be necessary for their truth and power to be granted. Seventeenth-century practitioners therefore lived with the tensions intrinsic and extrinsic to at least two forms of relationship between science and the public. Only occasionally did these tensions manifest themselves.

5. SCIENTIFIC NATURALISM AND THE COMMON CULTURAL CONTEXT

By the nineteenth century, certain of the divergences between public conceptions of nature and those said to be proper to legitimate science were being systematically addressed. The Scientific Naturalist movement of the mid-to-late Victorian period was characterised by efforts to eject from what counted as scientific thinking those elements that had previously linked public and scientific culture. Anthropomorphic, anthropocentric and teleological views of nature were identified by writers such as Huxley and Tyndall as fallacies of the public (or clerical) mind: wherever they intruded themselves, there an objective conception of nature was at risk. A human-scaled and human-shaped nature

– congenial to public common sense – was to be replaced with one in which human beings and human experience were themselves naturalised and had to find their place along with other natural processes, other animate and inanimate bodies. In the early modern period, the idea that man was the measure of all things formed a heavily-trafficked bridge between science and other forms of culture and between science and public discourse. That bridge was dismantled by the triumph of Darwin and other Naturalist scientists.

The consequences of the Naturalist victory, and of the secularisation of codified natural knowledge, for the relations between science and the public have not yet been systematically studied. R. M. Young has argued that one result was a 'fragmentation' of a previously 'common cultural context' linking scientists, clerics and laypersons. One could speculate that it was in this setting that lay perceptions of nature and natural processes were submerged and, ultimately, became invisible. The triumph of secular science consisted in the achievement by its qualified practitioners of hegemony and of professional legitimacy. Orientations to nature not accredited by the sanctioned scientific community did not have to be eliminated; it was sufficient, as F. M. Turner's work has shown, that they have no public forum and no political purchase.[5]

Aspects of this submergence have been discussed in Gillian Beer's work on the language of evolutionary science. She points to an apparent paradox, viz. that some of the key nineteenth-century texts that spelled out the divorce between properly scientific conceptions and public fallacies were, in fact, written for 'any educated reader' and worked with a language and a set of cultural assumptions shared between natural scientists and the educated public. Moreover, as the nineteenth- and twentieth-century public reception of Darwinian thought makes clear, a teleological account of evolutionary processes remains pervasively popular despite the agreement of the relevant scientists that it is grossly inappropriate.[6] It may be that our public language contains the ineradicable residues of the teleological, anthropocentric and anthropomorphic cosmology in which it was shaped. To the extent that scientific statements are couched in, or even appear to be couched in, ordinary public language, problems may be endemic. On the one hand, scientists may decide that certain scientific conceptions simply cannot be expressed in the public language. On the other hand, scientists' endeavours to use that public language may involve metaphors and analogies whose resonances they cannot expect to hold in place and control. In either case, the differentiation of scientific and public culture has precipitated serious problems of translation whose nature is largely undefined and whose remedies are unclear. Can the public comprehend science without learning the specialised languages and linguistic meanings of the scientific community? Are all attempts to 'popularise' science doomed to failure or fraud? Are modern science and its public divided by the illusion that they possess a common language?

6. SCIENTIFIC TESTIMONY AND THE PROBLEM OF PUBLIC TRUST

The problematic nature of the relations between the scientific community and the public goes back at least to the origins of systematical empirical science. Indeed, those relations are to be found at the very core of empirical knowledge; they are implicated in decisions about what is to count as knowledge. Within the rhetoric and the practice of seventeenth-century empirical science a fundamental problem of social relations was recognised and addressed. If, as was insisted, eye-witnessing was to be the hall-mark of proper scientific procedure, and if, as practical exigencies dictated, most of one's knowledge was to be founded upon testimony and trust, how did one go about evaluating testimony about empirical phenomena and processes? Who was to be believed and trusted in such matters? Although various candidate solutions to the practical problems posed by testimony were offered during the seventeenth century, the matter was dealt with for the most part by deploying criteria of creditworthiness that were routinely used by sectors of the public. For example, one might trust the word of a gentleman – in science as in social life in general. By the eighteenth century, and especially in France, the scientific enterprise was beginning to be much more clearly differentiated. The visible institutionalisation of science in the Paris *Académie* was both a means and a sign of the distinction that now existed between the man of science and the public. Within such a setting the question of what reports would count as knowledge, and therefore of how natural reality would be construed, were assessed according to whether such reports stemmed from the scientific community proper or from members of the public. Westrum has written of an especially telling episode in mid-to-late eighteenth-century France in which reports from the public retailing the fall of 'meteorites' were systematically discredited by members of the *Académie*, whose current thinking was that these phenomena did not exist, on the grounds that such lay persons were credulous and undisciplined observers. It is a state of affairs that still exists. Public claims about the natural world, where they conflict with what scientists reckon as true or plausible, are not in general seriously engaged with by the scientific community.[7] The costs of doing otherwise would, of course, be enormous. Sheer practicality necessitates the use of some sort of filter selecting which claims scientists can effectively consider. Nevertheless, the effect of such distinctions is to define out of the domain of science novel claims to knowledge that stem from the public – for the reason that this is their derivation. Further examples of the cognitive consequences of distinctions between the public and the scientific community could be cited *ad libitum*. Yet the general point is evident: membership and non-membership in the scientific community is continually being negotiated. The scientific community (and various sectors of it) and the public (and its special institutions and interest groups) are ceaselessly at

work in defining themselves, and the nature of the distinctions that divide them. In the course of so doing they also define what is to count as knowledge and the proper means of securing it.

7. WHAT SCIENTISTS WANT FROM THE PUBLIC AND HOW THEY TRY TO GET IT: THE PROBLEM OF LEGITIMACY

When members of the scientific community explicitly address themselves to the public at large, what is it that they want, and how do they go about achieving it? In historical settings where science is neither well institutionalised nor recognised as a valuable enterprise in its own right, members of the scientific community commonly desire public acknowledgment of their legitimacy. They want it recognised that the systematic pursuit of natural knowledge is an acceptable and, ideally, a laudable activity; that its products are innocuous or even valuable. Such recognition is seen as a pre-condition for acquitting the day-to-day goals of men of science, e.g. the disinterested pursuit of knowledge and the free deployment of cognitive and manipulative skills. But in a pre-institutionalised setting this value and legitimacy had to be argued for and won. R. K. Merton's 1938 thesis about the connection between seventeenth-century English science and Puritanism centrally concerns this aspect of the relations between science and the public.[8] Merton showed that English virtuosi and natural philosophers publicly argued for the legitimacy of the new science by displaying its compatibility with dominant modes of culture and their sentiments, in this case with Puritan strands of religion. The systematic pursuit of natural knowledge, it was argued by spokesmen of science, was in no way inimical to or incompatible with religion. Indeed, religious purposes were to be as effectively (or even more effectively) realised by the study of God's Book of Nature as by more traditional religious practices. (See art. 50, sect. 3.)

From the seventeenth century up to and including much of the nineteenth century, members of the scientific community continued to assert the public legitimacy of their enterprise via 'natural theology', an exercise predicated upon the argument that legitimate religious functions could be well served through the scientific study of nature and the public deployment of scientific findings. If religious authorities, and the public that accepted religious canons, could be convinced that science was useful in these ways, then the much-wanted recognition of the legitimacy of science might be secured. From the Boyle Lectures (starting in 1692) to the Bridgewater Treatises of the 1830s, the culture of natural theology was one of the main vehicles by which scientists addressed the public and advertised the cultural and moral goods that scientific activity might deliver. A consequence of these transactions between science and the public was the entrenchment in scientific culture of those orientations (such as

teleology) that were deemed to be essential to the public religion. Only with the vigorous campaign of the Scientific Naturalist movement of the 1860s, 1870s and 1880s was the culture of natural theology broken down. Another sort of argument addressed from the scientific community to the public became current, designed to secure another desideratum. As we have seen, a secularised nature that no longer sustained religious verities was presented to the public. Strictly speaking, the public and practitioners of other forms of culture were told that they were to have no moral interest in this secularised nature. Scientists (now properly so called) were the only experts with a legitimate interest in, and with legitimate rights to pronounce upon, the domain of secularised nature. The public were told to expect substantial utilitarian benefits from the activities of authentic scientists (indeed, they were told that they had already enjoyed such benefits); but they were at the same time instructed that the only proper role that could be served by the public was to encourage and support the programmes of work and conceptions decided upon by autonomous scientists. If the public were substantially to interfere with the autonomy of the scientific community, it would not in fact receive the benefits that might accrue from science: they would kill the goose that lays the golden egg. The objectivity of knowledge would be corrupted, and the useful outcomes that could only arise from objective knowledge would not be realised. A more docile public emerged together with the role of the professional scientist and the secularised nature in which he operated.

8. CHANNELS OF COMMUNICATION BETWEEN SCIENCE AND THE PUBLIC

Until the nineteenth century the channels linking the public to scientific pronouncements were, in general, diffuse. We know that certain natural theological exercises were preached to specific congregations, and we now have some knowledge of the audience for science in a range of relatively inclusive scientific societies and academies from the seventeenth to the nineteenth centuries. But we still have little knowledge of the readership for texts that represented the findings of sciences to a wider audience or that appropriated scientific findings for public purposes. Karl Hufbauer has made one of the few systematic attempts to ascertain the readership of given scientific (and quasi-scientific) works, in this instance via subscription lists for a range of eighteenth-century German chemistry texts.[9] However, there has not yet been a concerted response by historians of science to the programme of research on the culture of publishing and reading associated with the work of Robert Darnton on the *Encyclopédie* and Elizabeth Eisenstein on print culture and Copernicanism. We need more studies of the vehicles used to communicate between science and the public, not least because the conventions and distribution of these vehicles

may have had an important bearing upon public perceptions of scientific claims and therefore upon their careers.

In the seventeenth century, periodicals like the *Philosophical Transactions* of the Royal Society of London and the *Journal des savants* distributed scientific information and opinion among a broad community of the philosophically interested, though much scientific interchange continued to be conducted by letter and without the intervention of print. Nor should one forget the extent of face-to-face interaction in the seventeenth and eighteenth centuries between men of science and laypersons in public venues such as coffee-houses, taverns and exchanges. During the eighteenth century, itinerant lecturers in Britain staged scientific spectacles for public consumption, and Schaffer has shown how public demonstrations of phenomena created by the Leyden jar functioned as theologically important dramatic manifestations of God's power latent in nature.[10] By the eighteenth and early nineteenth centuries, printed channels for conveying scientific knowledge to the laity had vastly expanded: in Britain *The Ladies' Diary* (founded in 1704) and *The Gentleman's Diary* (founded in 1741) were important vehicles for mathematical communication; the *Gentleman's Magazine* (founded in 1731) contained significant quantities of medical information and the *Edinburgh Review* (founded in 1802) was the first of a large number of nineteenth-century British periodicals that defined the place of science in the wider culture and whose conflicting political and religious orientations offered readers divergent interpretations of the meaning of scientific claims. R. M. Young has shown how the fragmentation of the common cultural context may be traced in the changing place of science in the nineteenth-century general periodical literature.

The differentiation and specialisation of science meant that scientific knowledge no longer enjoyed a matter-of-course place in general culture. Yet that same differentiation created an opportunity for the explicit 'popularisation' of science, and, thus, for literary forms designed to convey otherwise inaccessible or impenetrable scientific knowledge to sectors of the public. From the late eighteenth century there developed, especially in Britain and America, a thriving industry devoted to the production and distribution of a vast number of 'popular' scientific texts, pamphlets and periodicals, ranging from moralistic tracts for the children of the lower orders to straightforwardly technical manuals for craft and industrial workers. The purposes of these various enterprises of popularisation and the portrayals of nature and of natural knowledge that they proffered have only begun to be assessed.[11] In our own century the roles of newspapers and magazines and of non-print media, notably photography, radio, television, film and museum exhibitions, in shaping (and representing) public perceptions of science, technology and medicine also remain largely unexplored, while serious studies of the role of 'science fiction' in the relations between the scientific community and the public are similarly scarce.

Scientific knowledge, in various forms, had been an element in the curricula of universities since their founding in the Middle Ages. However, the public reached by universities, even by the more open and accessible of these institutions, was small. The development in the nineteenth century of a 'schooled' society, and the integration of scientific knowledge into the curricula of schools, marked a fundamental change in the relations between science and the public. In Britain voluntary adult schools for skilled workers (the Mechanics' Institutes) offered almost exclusively scientific instruction from the 1820s, but it was not until much later in the nineteenth century, and into this century, that all children in Britain and elsewhere in Europe and America were receiving a compulsory education that contained significant elements of the natural sciences and mathematics. The nature and effect of this exposure has yet fully to be explored. However, it merits serious attention from historians of science, as school is certainly the major source of the modern public's knowledge of science and of how scientists go about securing their knowledge. The embedding of science into structures of authority like the classroom may have far-reaching consequences for shaping the public's sense of the certainty to be expected of science and of the manner in which scientific knowledge is made. Whether these sensibilities accurately correspond to the realities of science is debatable.

9. WHAT THE PUBLIC WANTS FROM SCIENCE AND HOW IT TRIES TO GET IT: THE PATRON AND THE STATE

If what the scientific community largely wanted from the wider public was recognition, legitimacy and support, what did the public want from men of science and the knowledge they were producing? And what consequences have there been for science of this public interest? As has already been suggested, a public persuaded that science was potentially useful knowledge might express their desire for the promised outcomes. (In this sense, public wants are not independent of the scientific community's historical work in identifying and cultivating those wants.) The public might want to see men of science actively at work addressing and satisfying technological and economic needs. Again, aspects of Merton's thesis deal with these relations between science and public interests and with their effects on scientific work. Merton documented certain 'foci of interest' that characterised the scientific proceedings of the seventeenth-century Royal Society. Scientific interest was not, he found, randomly distributed across the whole range of disciplines and problem areas; it was in fact concentrated in certain theoretical areas that, he argued, were those bearing the most evident relationship to pressing technical and economic problems. Sectors of the seventeenth-century English public came to believe that science might

possess answers to economic and military problems they desired to solve. As a consequence, men of science found it advisable, expedient, or simply interesting to work preferentially in these areas.

From the Renaissance up to and including the eighteenth century, one of the most consequential social links connecting science and public concerns was patronage. In the relative absence of secure institutionalised positions and career structures for men of science, the role of the individual patron in the direction of scientific work was crucial. The patron offered support, subvention and encouragement, protected the man of science from enemies, and suggested topics of inquiry and trajectories of research. The study of patronage in science still lags somewhat behind the assessment of its role in the fine arts and literature. We need to know more about the structure and effects of the relationships between individual men of science and their patrons, for example, between Galileo and the Medici, Robert Hooke and Sir John Cutler, Thomas Hobbes and the Cavendish family, Cassini and Colbert, Leibniz and the Guelphs, William Herschel and George III, Priestley and Shelburne and Cuvier and Tessier.[12] It was in the nature of the patronage relationship that it was largely *ad hoc* and not standardised. The terms of contract might be explicit or informal, the patron's interests might affect the recipient's work strongly or not at all (it might, indeed, be the receiver of patronage who effectively controlled the relationship); or public concerns might correspond to those of the patron in a wide variety of ways. Newton, evidently, kept his disciples' noses firmly to his philosophical grindstone, and his influence with government and universities ensured that his patronage was intellectually compelling. In the early eighteenth century James Brydges, first Duke of Chandos, manipulated a vast empire of public works and influenced the shape of applied science practised by Desagulier, John Keill, Richard Bradley and many others. Darwin's presence on the *Beagle* was the immediate result of patronage and the indirect product of public interest in empire, while the scientific outcome of that appointment bore little connection with the public concerns that brought it about.

In eighteenth-century Scotland, the patronage relationship merged with a more diffuse nexus in which the cultural leadership of certain sectors of society was acknowledged by men of science, with effects upon the direction and nature of scientific work. In that setting, a powerful audience of improving Lowland landowners, persuaded that the pursuit of sciences relating to the terraqueous globe might aid them in their search for greater yields, profits and rents, influenced Scottish men of science to cluster their researches in geology, mineralogy and meteorology. C. J. Lawrence has argued that public concerns with explaining the state of Scottish society and legitimating certain versions of proper social order influenced eighteenth-century Lowland physicians and physiologists to produce a specific view of bodily organisation and its nervous integration.[13]

Since the eighteenth century, the patronage system has been progressively replaced by professionalised (frequently bureaucratic) career structures and formal relations between science and the public. Now it is the state that speaks for (or claims the right legitimately to speak for) the public and to voice public interest in the conduct of science. This state of affairs developed at varying rates and for different reasons in different national settings. The persistence of patronage and of pluralistic and diffuse connections between science and the state is evident throughout much of the nineteenth century in Britain. In France the old regime effectively forged a set of institutional structures and ties between science and the state that the Napoleonic reforms largely translated into a new idiom. The government of Prussia invented key aspects of the scientist's role virtually as a by-product of bureaucratic concerns with the reform of the universities.

But it was in the United States that one of the most intractable problems afflicting modern relations between science and the public was most directly confronted. The scientific community up to and including the nineteenth century had argued for public support largely on utilitarian grounds. Pure science, it was repeatedly said, would ultimately yield applied science and economic benefits. In a democratic society, the state was justified in spending public money on these grounds and on no others. The recipients of public monies had to be publicly accountable. (In the middle and later part of the nineteenth century there were considerable *constitutional* objections to Federal support for an enterprise that could not guarantee contributions to the national welfare, and there continue to be enormous problems securing resources for scientific studies whose useful outcomes are not acknowledged by the public or its representatives.) These terms of public support carried with them substantial troubles. The demand for accountability appeared radically incompatible with the autonomy that, scientists said, was the condition for the health of science, its capacity to yield objective knowledge, and, thus, to produce the knowledge upon which technological innovation could be based. The relations between science and the public in modern democratic societies would seem to be entangled in deep contradictions, partly deriving from the rhetorical structures historically used by the scientific community to justify itself to the public, partly the effect of engagements between a particular institution (science) and the enveloping public institutions whose interests may materially diverge.[14]

Throughout the nineteenth and twentieth centuries, and especially after the Second World War, the scale of state support for science vastly expanded, and in no areas more spectacularly than in those of direct or indirect military interest. It is now difficult to imagine what the social institution of science would look like divorced from its military ties. The effect of these links on the scientific community, including scientists' professed norm of openness, has scarcely been examined, still less their consequences for public perceptions of the

nature of science, its autonomy and its value. If the golden egg explodes and strews radioactive isotopes over the countryside, one may perhaps understand the public's willingness to consider doing violence to the goose who has historically claimed the egg as her own.

10. PUBLIC ORDER AS SCIENTIFIC TOPIC: CONCLUSION

Historically, the public have wanted much more from natural knowledge than technical and economic utility. Nature has traditionally been a theatre in which moral dramas are enacted and a classroom in which moral lessons can be learned. A socially (as well as technically) usable nature has been demanded of those entrusted with the task of producing representations of it. However, here it is not merely incautious but grossly inaccurate to speak loosely of 'the public's' interest. As with economic goods, the conception of moral goods inevitably divides the public into groups with differing interests. In the late seventeenth and early eighteenth centuries, Low Church Anglican apologists demanded a morally usable conception of nature in which God could be seen actively to intervene, while their deist opponents required a visibly self-sufficient nature. Such moral use of science divided the public into those who approved and disapproved of Newtonian natural philosophy, in whole or in part.[15] In the nineteenth century distinct geologies, with conflicting attitudes towards what counted as stratigraphical and palaeontological facts, catered for sectors of the public with different investments in the natural world and its uses in religious and moral argumentation. Perhaps the most celebrated public appropriation of codified scientific work is Social Darwinism. There were sectors of the public that rejected Darwin's naturalistic findings on moral and religious grounds; others held the text stable while contesting its implications for man and the moral order.

The triumph of Darwinism, and of the Naturalistic movement of which it was part, signalled the end of an era of public interest in the constitution of scientific knowledge. With the secularisation of nature, the relations between science and the public were, as the canonical account rightly suggests, fundamentally altered. A culture that represents nature as morally vacuous lays down the conditions for a radical distinction between those professionally concerned with the explication of secular nature and the general public with their moral concerns. The modern public were to have no business with the framing of scientific representations and with the conceptual content of scientists' work. The converse did not, of course, apply. In the late nineteenth century the eugenics movement offered a naturalistic account of the social order, an enterprise carried on in the late twentieth century by sociobiologists. Nor are naturalistic theories of public order confined to the specifically biological: much, if not the whole, of modern

social science is founded upon agreement that social order and the formation of public interests ought to be naturalistically analysed. There can be no more striking evidence of the changing relations between science and the public since the seventeenth century. Where once the public were powerful in relation to the making of scientific knowledge, there is now widespread assent to the proposition that public life is a legitimate topic for naturalistic scientific inquiry.

NOTES

1. The 'canonical account' described here is obviously a pastiche of approaches employed by many writers. An author whose view comes closest to the canonical account is Joseph Ben-David, see esp. his *The scientist's role in society: a comparative study* (new ed., Chicago, 1984; orig. publ. 1971), and 'Organization, social control, and cognitive change in science', in Ben-David and Terry Nichols Clark (eds.), *Culture and its creators: essays in honor of Edward Shils* (Chicago, 1977), pp. 244–65.
2. Thomas S. Kuhn, 'Mathematical versus experimental traditions in the development of modern science', in Kuhn, *The essential tension: selected studies in scientific tradition and change* (Chicago, 1977), pp. 311–65.
3. Cecil G. Helman, ' "Feed a cold, starve a fever" – folk models of infection in an English suburban community, and their relation to medical treatment', *Culture, medicine and psychiatry*, 2 (1978), 107–37; Charles E. Rosenberg, 'The therapeutic revolution: medicine, meaning and social change in nineteenth-century America', *Perspectives in biology and medicine*, 20 (1977), 485–506.
4. Steven Shapin and Simon Schaffer, *Leviathan and the air-pump: Hobbes, Boyle, and the experimental life* (Princeton, 1985); Shapin, 'Robert Boyle and mathematics: reality, representation, and experimental practice', *Science in context*, 2 (1988), 25–61.
5. Robert M. Young, *Darwin's metaphor: nature's place in Victorian culture* (Cambridge, 1985), chaps. 2 and 5; Frank M. Turner, 'The Victorian conflict between science and religion: a professional dimension', *Isis*, 69 (1978), 356–76; Morris Berman, ' "Hegemony" and the amateur tradition in British science', *Journal of social history*, 8 (1975), 30–50.
6. Gillian Beer, *Darwin's plots: evolutionary narrative in Darwin, George Eliot and nineteenth-century fiction* (London, 1983); also R. M. Young, (1985) ch. 4.
7. Ron Westrum, 'Science and social intelligence about anomalies: the case of meteorites', *Social studies of science*, 8 (1978), 461–93; *idem*, 'Science and social intelligence about anomalies: the case of UFOs', *Social studies of science*, 7 (1977), 271–302.
8. Robert K. Merton, *Science, technology and society in seventeenth-century England* (new ed., New York, 1970), esp. chs. 4–6.
9. Karl Hufbauer, *The formation of the German chemical community (1720–1795)* (Berkeley, 1982); *idem*, 'Chemistry's enlightened audience', *Studies on Voltaire and the eighteenth century*, 153 (1976), 1069–85.
10. Simon Schaffer, 'Natural philosophy and public spectacle in the eighteenth century', *History of science*, 21 (1983), 1–43.
11. See, for example, James A. Secord, 'Newton in the nursery: Tom Telescope and the philosophy of tops and balls, 1761–1838', *History of science*, 23 (1985), 127–51; Greg Myers, 'Nineteenth-century popularizers of thermodynamics and the rhetoric of social prophecy', *Victorian studies*, 29 (1985–86), 35–66.
12. For selected examples, see Dorinda Outram, *Georges Cuvier: vocation, science and authority in post-revolutionary France* (Manchester, 1984), esp. chap. 5; Richard S. Westfall, 'Science and patronage: Galileo and the telescope', *Isis*, 76 (1985), 11–30; John Gascoigne, 'Politics, patronage and Newtonianism: the case of Cambridge', *The historical journal*, 27 (1984), 1–24.
13. Steven Shapin, 'The audience for science in eighteenth-century Edinburgh', *History of science*, 12 (1974), 95–121; Christopher Lawrence, 'The nervous system and society in the Scottish Enlightenment', in Barry Barnes and Steven Shapin (eds.), *Natural order: historical studies of scientific culture* (Beverly Hills, 1979), pp. 19–40.

14. George H. Daniels, 'The pure-science ideal and democratic culture', *Science*, 156 (1967), 1699–1705.
15. Margaret C. Jacob, *The Newtonians and the English revolution, 1689–1720* (Ithaca, N.Y., 1976); *idem*, *The radical enlightenment: pantheists, freemasons and republicans* (London, 1981).

FURTHER READING

Roger Cooter, *The cultural meaning of popular science: phrenology and the organization of consent in nineteenth-century Britain* (Cambridge, 1984).

Charles C. Gillispie, 'The *Encyclopédie* and the Jacobin philosophy of science: a study in ideas and consequences', in Marshall Clagett, (ed.), *Critical problems in the history of science* (Madison, Wisconsin, 1959), pp. 255–89.

Gerald Holton and William Blanpied, (eds.), *Science and its public: the changing relationship*, Boston studies in the philosophy of science, vol. 33 (Dordrecht, 1976).

David Layton, *Science for the people: the origins of the school science curriculum* (London, 1973).

Roy S. Porter, 'Science, provincial culture and public opinion in enlightenment England', *British journal for eighteenth-century studies*, 3 (1980), 20–46.

Steven Shapin and Barry Barnes, 'Science, nature and control: interpreting mechanics institutes', *Social studies of science*, 7 (1977), 31–74.

Susan Sheets-Pyenson, 'Popular science periodicals in Paris and London: the emergence of a low scientific culture, 1820–1875', *Annals of science*, 42 (1985), 549–72.

Terry Shinn and Richard Whitley (eds.), *Expository science: forms and functions of popularisation*, Sociology of the sciences, volume IX, 1985 (Dordrecht, 1985).

Larry Stewart, 'Public lectures and private patronage in Newtonian England', *Isis*, 77 (1986), 47–58.

Frank M. Turner, 'Public science in Britain, 1880–1919', *Isis*, 71 (1980), 589–608.