Introduction

'Since the rise of Christianity, there is no landmark in history that is worthy to be compared with this'.[1] So Sir Herbert Butterfield acclaimed the Scientific Revolution of the seventeenth century, and such high estimates have assured that the science of the time has been subjected to intense and prolonged scrutiny. Not only have scientific ideas themselves been much studied. Attention has also been paid to their setting, since historians have long believed that the phenomenal intellectual fertility of this period must be linked to the social and economic milieu in which it occurred and must in turn itself have had broader effects.

Modern concern with such questions dates largely from the 1930s. Its most influential pioneers were the Russian physicist, Boris Hessen, and the American sociologist, Robert K. Merton, though an honourable place may also be found for the English historian, Sir George Clark, whose *Science and social welfare in the age of Newton* (1937) arguably says as much in its brief format as any work on a related topic since.[2] The views of these scholars differed markedly and the subject has always been characterised by lively controversy. Indeed contrasting viewpoints have been propounded on numerous topics – from the social and ideological forces encouraging creativity to the links between science and technology, the significance of scientific organisations and the acceptance of science and scientific norms in the community at large.

Some have attempted generalisations about science and society in early modern Europe as a whole, but attention has focused mainly

[1] H. Butterfield, *The origins of modern science 1300–1800* (London, 1949), p. 174.
[2] Hessen,[167] Merton, [168] Clark.[172] Another early study of a different kind is Jones,[240] first published in 1936. Here and throughout the notes, citations of an author's name with a raised numeral refer to entries in the bibliographical essay, pp. 198–219.

on seventeenth-century England, the subject of Hessen's, Merton's and Clark's essays. This is not entirely surprising. Science in the Stuart era cries out to be linked to other features of what was by any account a formative period of English history: an age of political revolution and religious conflict, of economic development and social change. Many studies have been made of science and of these broader themes, on a larger or smaller scale and with more or less satisfying results, and the profuse relevant literature that now exists is surveyed in the bibliographical essay appended to this work. This is partly a reference guide, but it is also intended to set the scene for the reappraisal of each aspect of science's role put forward in the chapters that precede it.

The terms of reference of this book are limited. 'England' is fairly strictly interpreted throughout: there are some allusions to published work on Ireland and evidence from Wales and Scotland has occasionally been introduced to illustrate specific points, but no attempt has been made at a systematic survey of events in those countries. More significantly, it is confined to the Restoration, to the years between the return of the Stuarts in 1660 and the end of the seventeenth century.

Its relatively narrow focus is deliberate: so important a subject as the role of science in this formative period is much prone to facile oversimplification, and this book tries to do justice to the subtlety and complexity of the questions it raises. A study of Restoration England may be justified as intrinsically valuable. Not only were these the chief productive years of Newton, Boyle, Hooke and a host of other exponents of the 'new' experimental philosophy; they also witnessed the foundation of the first English scientific institution, the Royal Society. But, though primarily applicable to these decisive decades, many of the conclusions drawn here about the setting and impact of the new science have direct relevance to broader issues in England and Europe. They thus throw new light on many of the imponderables about the social dimension of early modern science that have long preoccupied scholars.

Moreover, though the book is mainly about the Restoration, an attempt is made – especially in the first chapter – to relate trends after 1660 to what had gone before. These earlier developments have recently been considered in detail – particularly by Charles Webster in *The Great Instauration* (1975) – and the angle taken here may help to balance this intensive work on the Interregnum. To be truly

convincing, views about science's role and appeal have to account for its equal success before and after 1660.

The Restoration was an ambivalent era, in which reaction against the events of the previous two decades was offset by more positive features: the affiliations of science have to be seen in terms of the balance, and sometimes the tension, between these. Many features of the Interregnum were rejected in a manner characteristic of a 'post-Revolutionary' regime. All legislation passed without royal assent was expunged from the Statute Book and there was a general reaction in favour of conservatism and royalism and against the possibility of new disorder. A deprecation of Republicanism and its corollaries was accompanied by a reversal of the liberalising tendencies of the earlier regime in politics, law and society: this was perhaps symbolised by the newly broad Statute of Treasons of 1661 and the reimposition of repressive and unpopular licensing laws presided over by the redoubtable Sir Roger L'Estrange. The general revulsion against Puritan fanaticism was epitomised by the vast popularity of Samuel Butler's *Hudibras*. Its most tangible and significant outcome was the restoration of the Anglican church in a form which, due to the heat of reaction among Members of Parliament and others, was more rigid and doctrinaire than the King and other architects of the Restoration settlement had originally intended.[3] These circumstances favoured a conservative element in the universities which had survived threats of reform and even extradition in the revolutionary years, while the free thought which the confusion of the Interregnum was seen to have encouraged was also widely deprecated.

Yet the reaction was not so complete as to re-create the state of affairs before the Revolution. The Interregnum had seen great growth in the power and efficacy of government: newly heavy taxes like the excise had come to be taken for granted, intervention by the central government in the localities had become commoner, standing armed forces had been retained, and the civil service had grown in size and efficiency. These features, which Charles II inherited, added a new element to politics which had been lacking in his father's time, in the form of a powerful executive and the real possibility of the development of centralised efficiency in the direction of royal absolutism – a development familiar elsewhere in

[3] Whiteman in Nuttall and Chadwick,[10] pp. 19–88; I. M. Green, *The re-establishment of the Church of England 1660–63* (Oxford, 1978).

seventeenth-century Europe, particularly in France. Impulses towards absolutism, however, coexisted throughout this period with a chronic political instability which was equally characteristic of the time, for the Civil War had hardly solved any of the constitutional issues between King and Parliament over which it had been fought. Instead, these continued to be debated fiercely and inconclusively, and were made more intense by fears of the growing power of the executive. In the resulting tension, scientists ambitious to implement reforms took up a clear position which will be outlined in chapter 5: their loyalties were to strong government, and official support for them, though generally disappointing, reached a climax when royal power was on the ascendent in the 1680s.

The Restoration also had an important inheritance from the Interregnum in economic affairs. In contrast to the bleakness of the early seventeenth century, the English economy was booming in the years after about 1650. Its strength was due largely to the burgeoning re-export trade, which laid the foundations of England's more general commercial prosperity in the eighteenth century, but a lesser contribution came from agricultural improvement and industrial change. Current scholarship does not on the whole indicate that this was due to the policy of any particular regime. Attempts were made both before and after the Restoration to encourage it through the so-called Navigation Acts, however, and this economic vitality was greeted by contemporaries with a general patriotic enthusiasm.[4]

There was clearly an indirect link between science and economic life, for the prevalent innovative attitudes in science were mirrored in the fertility of invention shown by patent applications and in a widespread optimism about the potential for improvement.[5] Indeed there were hopes in scientific circles that the link might become direct, with national prosperity and useful, scientific knowledge advancing hand in hand. Thus it might be possible 'to render England the Glory of the Western World, by making it the Seat of the best knowledge, as well as it may be the Seat of the greatest Trade', with merchants patronising and assisting intellectual activity, while it was also hoped that the findings of the new science could improve techniques in agriculture and industry.[6]

[4] Wilson,[13] pp. 61–4, 163–4 and passim; Jackson in Jones,[2] pp. 153–4.
[5] K. G. Davies, 'Joint-stock investment in the later seventeenth century', *Economic History Review*, 2nd series 4 (1952), 283–5.
[6] Oldenburg to Rycaut, 30 Jan. 1668, Oldenburg,[121] IV, 133.

But – as chapters 3 and 4 show – modern scholars have been misled who have taken these hopes of the propagandists of the new science at their face value instead of finding out how far they were realised. The links between science and the mercantile community proved disappointing, and, though the interest of intellectuals in technological improvement is significant, the extent to which they contributed to economic development is questionable. If this has sometimes been recognised – particularly by economic historians – little attempt has hitherto been made to explore the reasons for it; these are examined in chapter 4 and they throw interesting light on the 'cultural topography' of the period.

The presumption that science and technology must have been closely linked has distracted attention from another crucial development that forms the background to science. This was the growth of a fashionable, leisured culture focused on London – the seat of government and law – which had such important consequences as the growth of the retail trade and a general increase in consumption which has sometimes been seen as contributing to the Industrial Revolution.[7] This is the setting of the culture of the 'virtuosi' and of a significant public audience for intellectual matters whose links with science will be considered in chapter 3. It was a culture which grew phenomenally in the late seventeenth century, while so did London social life, epitomised by the rapid spread of coffee houses from their first introduction there in 1652.[8] Though London was the centre of this – as it was the focus of most cultural and economic activity – it also made inroads in the provinces. The relations between London and the country and their significance for science will also be surveyed in chapter 3, where some attempt will be made to assess the receptiveness of English society to the new science at all levels.

Such social extensions to the new science are important, like its wider ambitions to serve human life, but they should not obscure the fact that the most important social dimension of the new science was academic – concerned with the institutions which provided facilities and encouragement for this and other scholarly pursuits, and the

[7] Werner Sombart, *Luxury and capitalism* (English translation: Ann Arbor, 1967), esp. ch. 5; E. A. Wrigley, 'A simple model of London's importance in changing English society and economy 1650–1750', *Past and Present*, 37 (1967), 44–70.

[8] F. J. Fisher, 'The growth of London as a centre of conspicuous consumption in the sixteenth and seventeenth centuries', *T.R.H.S.*, 4th series 30 (1948), 37–50; Michael Foss, *The age of patronage: the arts in society 1660–1750* (London, 1971), ch. 4; Ellis,[149] ch. 4 and passim.

traditions and pressures that made up contemporary intellectual life. Indeed it is symptomatic of the crudity of much study of science's social relations that little attention has until recently been paid to such matters except through rather caricatured generalisation.

Misunderstanding has often been induced by the one novel feature of the Restoration, the advent of a specifically scientific institution, the Royal Society, which is often seen as synonymous with contemporary science and largely responsible for its achievement. Chapter 2 will consider the legitimacy of this, evaluating the Society and assessing its role in the organisation of intellectual life. Then chapter 6 will reconsider the position of the universities, for, whatever the importance of the new society, these were the chief centres of learning. The extent of their enthusiasm for and hostility to the new philosophy has been much debated, and this question will there be appraised in connection with the scholarly traditions of the time, whose vitality is sometimes underestimated. These can be (and were) argued to have had as significant 'social' functions as science, despite the disdain of some scientists and their latterday followers, and a vigorous controversy took place about the merits and implications of the new science which has long been familiar, if not always well understood.

There has been equal misapprehension about what contemporaries found perhaps most worrying in science's social relations, for a conviction of the close links between thought and action is manifest in the anxiety felt both within and without the scientific community about the danger of 'atheism'. The philosophical heterodoxy which had flourished in the Interregnum showed no sign of abating under the new regime and was widely considered subversive to moral values and social stability. Such fears had a marked effect on the public image and internal development of science, which will be surveyed in chapter 7: for while some saw scientific pursuits as conducive to infidelity, others argued that the study of God's handiwork was the best cure for unbelief.

The aim of this book is thus to use a close reading of manuscript and printed sources to show how Restoration science related to contemporary society in terms of support and apathy, facilities and impediments, motivation and reservations. To set the scene, however, we must first establish the character of science at the time. A proper appreciation of the broader role of Restoration science is impossible without understanding the nature and definition of

science, the sometimes conflicting tendencies within it, and the forms in which it was most familiar to contemporaries – which are not necessarily the same as those in which it has been most familiar since. Only then can we understand developments during the Puritan Revolution, and, more important, the position which natural philosophy aspired to and achieved after 1660.

1

Restoration science: its character and origins

FRANCIS BACON AND THE SCIENTIFIC REVOLUTION

In 1668, Joseph Glanvill, Rector of Bath and a vigorous polemicist on behalf of the new science, published a book called *Plus Ultra*. The work was 'occasioned by a Conference with one of the *Notional* Way' – by which he meant the scholastic philosophy – that he had taken part in locally and to which he wished to give wider circulation by the printed word. The sub-title of the work proclaimed its theme: 'The Progress and Advancement of Knowledge Since the Days of *Aristotle*. In an Account of some of the most Remarkable Late Improvements of *Practical, Useful* Learning', and in it Glanvill described and defended the achievement of the science of his time. Thus it provides a helpful approach to the ideology of Restoration science, its definition and content, for Glanvill was in close contact with several leading researchers and was quite well-informed on the subject.

Perhaps most important is Glanvill's implicit definition of 'science', for it is essential to remember that this word was not then commonly employed in this connection and that its use invites misunderstanding: 'natural philosophy', or, to be more precise, 'the experimental philosophy', both have the more authentic ring of the seventeenth century. In fact it should be remembered throughout this book that 'science' and 'scientist' are used purely for convenience, to avoid constant recourse to more cumbersome words, and the reader should beware of anachronistic overtones due to the transformation of natural science in the centuries since.[1] The com-

[1] 'Science' is occasionally used in something approaching its modern meaning in the seventeenth century: see, e.g., Birch,[118] I, 317. The commoner usage, however, is to mean 'Knowledge' and its branches generally: e.g., Glanvill,[66] sig. B6v, p. 25. See also below, p. 192.

moner contemporary phrase 'natural philosophy' is a clue to the correct status of the new science, as a department of philosophy from which it was only gradually separating itself. 'Experimental philosophy', on the other hand, best defines the type of intellectual activity that Glanvill set such store by, indicating how it was as much in method as subject-matter that the 'new' philosophers distinguished themselves from their predecessors.

Plus Ultra is also helpful as a reminder of how Glanvill and others conceived the aims of their enterprise. Glanvill called the learning that he was chronicling '*Practical*' and '*Useful*', and (like others) he was alive to its potential for increasing the '*conveniences* of *Life*' as well as 'for the *advancement* of *Knowledge*'.[2] Indeed this hope for the amelioration of life is intrinsic to the science of the time and almost all scientists considered technology germane to their interests, recognising the intellectual value of pursuits formerly considered rather menial. But they were aware of a distinction between pure and applied knowledge, and their concern for technology – which some considered more important than others – will be examined in a later chapter. The relative paucity of information on applied science in *Plus Ultra* illustrates how this, though not negligible, was peripheral to the intellectual revolution that Glanvill believed he was chronicling. He and others like him considered it their chief task to 'understand the *Artifice* of the *Omniscient Architect* in the composure of the *great* World, and *our selves*', and he dealt with a range of subjects very close to modern science – mathematics and astronomy, biology and anatomy, chemistry and statics, optics and pneumatics.[3] Theoretical investigations might be expected to have technological 'spin-offs', but these had to be kept subordinate to the more important job of reshaping ideas about the functioning of the natural world.

In all of the subjects he discussed, Glanvill and those whose achievements he described aspired to 'solid' knowledge: the most marked contrast they were conscious of was between the rapid and real advances in the natural sciences during the previous century, and the slow progress of knowledge that they associated with the former dominance of the philosophical synthesis evolved by the medieval schoolmen on the basis of the works of Aristotle. Whatever Aristotle's own scientific prowess, Glanvill attacked virulently the

[2] Glanvill,[66] p. 64. [3] Glanvill,[66] p. 25 and passim. See below, ch. 4.

a priori 'notional' way of reasoning produced by the methods of teaching associated with scholasticism, which attached little significance to accurate observation and experiment or novel systematisation. Worse still was the common idolisation of Aristotle's achievement, which implicitly denied the possibility of any improvement of the synthesis that he had bequeathed.

Glanvill and his colleagues had a more optimistic view, and though there was an element of caricature in their simple contrast of the old and the new, this only enhanced its polemical strength. Nothing could be more striking than Glanvill's sense of the potentialities of the new science in its aspirations, its methods and its techniques. His aim (as he put it) was 'to encourage the *freer* and *better* disposed Spirits, to *vigour* and *endeavour* in the *pursuits* of *Knowledge*; and to raise the *capable* and *ingenuous*, from a *dull* and *drowsie acquiescence* in the *Discoveries* of former Times; by representing the great *Encouragements* we have to proceed, from *modern Helps* and *Advancements*'.[4] Most generally, he was referring to improvements of recent centuries like the printing press and the mariner's compass. More specifically, he referred to such novel techniques as the invention of logarithms and the improvement of scientific instruments which facilitated precise observation and mensuration – the microscope, the telescope, the thermometer, the barometer and the air-pump, all of which had been developed in the early and mid seventeenth century and were becoming increasingly common in Glanvill's time.

Glanvill went on to list some of the achievements of the new science over the previous century, both on the continent and in England, not least those which such novel techniques had made possible. He wrote in great detail about the astronomical discoveries of Johann Kepler and Galileo Galilei and their successors. He had much to say about the improvements of mathematical knowledge and their potentialities, and he drew attention to improvements in optics. He mentioned modern work in chemistry, 'by which *Nature* is *unwound*, and *resolv'd* into the *minute Rudiments* of its *Composition*', alluding to the work of Robert Boyle on this subject as also on statics and pneumatics.[5] He referred to advances in anatomy by continental and English researchers, laying stress on William Harvey's demonstration of the circulation of the blood and the

[4] Glanvill,[66] sig. B3. See also below, ch. 6. [5] Glanvill,[66] p. 11.