Ziman, J. M., *An introduction to science studies: the philosophical and social aspects of science and technology*, USA: Cambridge University Press, 1996.

1

'Academic' science

'Such...is the respect paid to science that the most absurd opinions may become current, provided they are expressed in language, the sound of which recalls some well-known scientific phrase.' *James Clerk Maxwell*

1.1 Different aspects of science

What *is* 'Science'? Our whole approach to the subject of this book depends on how we might be tempted to answer this question. But it is really much too grand a question to be answered in a few words. Conventional definitions of science tend to emphasize quite different features, depending upon the point of view. Each of the metascientific disciplines – the history of science, the philosophy of science, the sociology of science, the psychology of creativity, the economics of research, and so on – seems to concentrate upon a different aspect of the subject, often with quite different policy implications.

For example, if science is defined as 'a means of solving *problems*', this emphasizes its *instrumental* aspect. Science is thus viewed as closely connected with *technology*, and hence an appropriate subject for *economic* and *political* study. The implication that this instrument should be used wisely and well puts it into the open arena of social conflict.

Another definition of science – as 'organized *knowledge*' – emphasizes its *archival* aspect. Information about natural phenomena is acquired by research, organized into coherent theoretical schemes, and published in books and journals. Although this knowledge is often profoundly influential through its technological applications, there is much to be said for treating it as a politically neutral, public resource. The accumulation of scientific knowledge is thus a significant *historical* process, worthy of special study.

Or we may follow an old *philosophical* tradition by emphasizing the *methodological* aspect of science. Procedures such as experimentation, observation and theorizing are considered elements of a special *method* for obtaining reliable information about

the natural world. From this point of view, science may be regarded as essentially objective, and hence transcending all political considerations.

Finally, one might emphasize the *vocational* aspect of science by tacitly defining it as 'whatever is discovered by people with a special gift for *research*'. This draws attention to such important personal aptitudes as curiosity and intelligence, which are well worth *psychological* investigation. Such studies might suggest that scientists should be recognized as members of a distinct *profession*, of considerable political significance.

There is so much that can be said about science from each of these and from other aspects that there is a tendency within each metascientific discipline to treat its own special definition as self-sufficient. Thus, philosophers of science largely ignore its instrumental and vocational features, whilst many serious studies of the political role of science seem quite oblivious to its complex methodological and vocational aspects. It is instructive to read books about science in this light. It almost seems as if each discipline has in mind a different 'model' of science, constructed around just those particular features in which it happens to be interested.

In truth, science is all these things, and more. It is indeed the product of research; it does employ characteristic methods; it is a body of organized knowledge; it is a means of solving problems. It is also a social institution; it needs material facilities; it is an educational theme; it is a cultural resource; it requires to be managed; it is a major factor in human affairs. Our 'model' of science must relate and reconcile these diverse and sometimes contradictory aspects.

1.2 *The chain of discovery*

The four conventional definitions of science are obviously complementary, but how should they be connected? They are often supposed to fit together in a one-way chain, from the vocational aspect, through the methodological and archival aspects, to the instrumental aspect where science merges into technology. That is to say, scientific knowledge is generated by individual scientists in the form of *discoveries*, which must be validated by scientific methods before being published in archival form. This knowledge is then applied to the solution of whatever problems may have arisen in society (fig. 1).

The great advantage of the linear *discovery model* of science is that it divides the labour equitably between the major metascientific disciplines. At each stage, so to speak, the material is processed according to the principles of the corresponding discipline and passed on to the next stage. Factors that operate at one stage can be ignored further along the line: 'intuition' for example can be treated as an important factor in the context of discovery (chapter 2) but not in the context of validation (chapter 3) where 'logic' is supposed to rule supreme. In principle, the history of

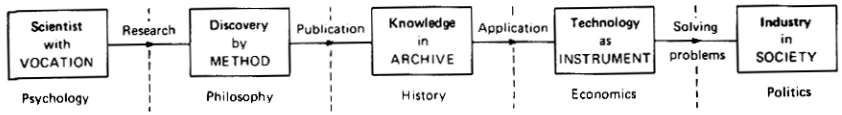

Fig. 1 The chain of discovery

science ought to deal with *all* stages in this process; in its narrowest traditional practice, it was often little better than a chronicle of publications, without significant reference to their particular psychological sources or general social context.

But the discovery model is really much too simple, for it obviously neglects some very significant realities. It assumes, for example, that information flows only one way along the chain, as if there were no technological demands on basic scientific research. It also takes no account of the fact that scientists do not work alone; research is to a large extent a communal endeavour, where individual action is strongly influenced by social goals and norms.

These are not just minor deficiencies that can be made good later by more detailed analysis. In the last 20 years the whole field of science studies has been transformed by the realization that science can only be understood if it is treated as a *social institution*, both within its own sphere of activity and in its relationships with the world at large. In other words, the *sociology* of science must be included in this programme of study, along with more traditional metascientific disciplines such as philosophy and history.

1.3 *'Internal' and 'external' sociologies of science*

The programme of study outlined in this book is much more ambitious than a link-by-link journey along the discovery chain, for it implies a much more complicated conception of science as a whole. For clarity of exposition, it is convenient to proceed through the analysis in two successive stages, following the academic convention of distinguishing between the *internal* and *external* sociologies of science. That is to say, in chapters 2 to 8 we study the relationships between scientists as they go about research, and then in later chapters show how scientific work relates to the broader social context in which it is undertaken.

This order of exposition has been chosen solely for simplicity; it does not imply that 'internal' factors are somehow more important than 'external' factors. The reader who perseveres to the end of this book may well come out with quite the opposite view, which emphasizes the primacy of the whole social order, of which science is only one component.

Our starting point, therefore, is a 'model' of science where external forces are entirely neglected. In the traditional scheme, this would be equivalent to cutting the

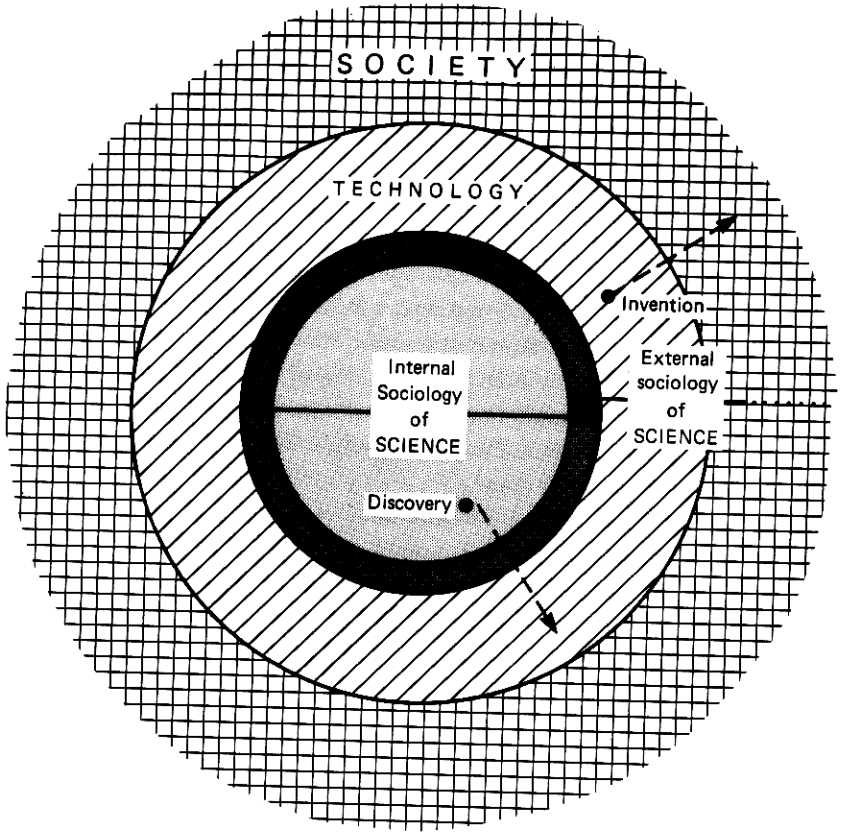

Fig. 2 Internal and external sociologies of science

chain of discovery between its archival and instrumental elements, as if scientific knowledge were accumulated solely 'for its own sake', without any thought for its possible applications. The boundary between 'science' and 'society' is envisaged as a semi-permeable membrane, through which knowledge only flows outward, from the scientific into the technological sphere (fig. 2). The goal of the 'internalist' programme is to account for what goes on in the region bounded by this membrane, philosophically, sociologically and psychologically, without reference to a wider world.

Throughout this book, we shall refer to this as the *academic* model of science. Although it is very far from realistic as a model of contemporary science, it is the notion of the nature of their activities that many scientists, and some metascientists, still have. It also has an important *historical* significance, for it might be considered a fair description of the natural sciences of, say, a century ago, before the rise of

industrial research. It is instructive to study these historical cases, together with a few modern disciplines, such as cosmology or pure mathematics, which are not yet closely coupled to technologies, for evidence on the way such a system works in practice: it is often possible to explain the actual behaviour of scientists in such circumstances by an appropriate combination of cognitive, personal and communal factors, almost as if they were indeed isolated from society at large.

Academic Science is thus the characteristic model for the 'internal' sociology of science. In the 'external' sociology of science, on the other hand, the usual assumption seems to be that science is a 'black box', whose internal mechanisms can be ignored. Study is concentrated on the technological effects of knowledge that has percolated outward from 'pure' science, through the 'membrane', and then been applied to the solution of practical problems. The *instrumental* capabilities of science in the service of political, military or commercial forces are thus regarded as paramount. This 'externalist' conception of *industrial science* as primarily a component of *technology* is developed in chapters 9 and 10.

In the final analysis, however, these elementary 'internalist' and 'externalist' accounts of science and technology must be reconciled and properly connected. This calls for a complete revision of both the academic and industrial models. As the sociologists of knowledge have demonstrated from historical research (chapter 8), the 'membrane' separating science from society is largely an illusion; the influences that are always flowing across this mythical boundary have profound effects on either side. It is a cliché that these influences have become so powerful in recent years that science is transforming society around us. What is not always realized is that the inner workings of science itself are being changed out of all recognition by the enormous social forces acting on it, and penetrating to its philosophical and psychological core. The theme of chapters 11 and 12 is the *collectivization* of science into a system of *Research and Development* organizations, whose economic and political characteristics are taken up in chapters 13 and 14.

The subject matter of modern metascience cannot therefore be considered static. The disciplines brought together under the heading of 'science studies' are concerned with a dynamical system that is undergoing dramatic historical change whilst we study it. This change is taking place both within science and in its cultural context. Thus, for example, as indicated in chapters 15 and 16, scientists are now expected to play a much wider variety of social rôles, and society interacts with science in many more ways than in any previous culture. In these final chapters we thus begin to see more clearly some of the contemporary answers to the very first questions posed in this book – what *is* science, and how does it work as a social institution, as a vocation, as a source of belief, and as an instrument of power?

A very important question that might be asked at any stage of the argument is whether the word 'science' is being used in its narrowest or its broadest sense: does

it mean the study of 'natural' phenomena by 'objective' techniques, or should it be extended to the interpretation of social systems and psychological events where 'subjective' factors cannot be avoided? For example, should we apply our 'internalist' sociology of science to sociology itself, or discuss the efficacy of 'pure' social psychology in the 'technology' of education? Questions of this kind are certainly of the greatest interest and importance, for they uncover many of the unconscious assumptions that we make when we refer to a body of knowledge as a 'science'. But if we were to try to raise such questions in the earlier chapters of this book, we would probably get some very misleading answers. It seems better to leave this whole issue to the final chapter (§16.4) when we have arrived at a fuller picture of science and its social function, and can decide the most fruitful approach to this very subtle theme. For clarity and simplicity of exposition, almost all the examples of scientific thought and action in the main text are drawn from the 'laboratory' sciences, such as physics, chemistry or biology, or from their technological applications in engineering, medicine, etc., but this is not to be interpreted as an opinion that these are the only genuine scientific disciplines. On the contrary, as argued in §16.4, my own inclination would be towards the wider view, which would include the social and behavioural sciences in the notion of 'science' at every stage in the discussion.

1.4 *Three dimensions of 'academic' science*

For the moment, however, we are concerned with 'academic' science. Even the most aloof and idiosyncratic pure scientists are not really 'purely seekers after truth'. Their contributions to knowledge are seldom made quite personally and independently of one another. They often work closely together in their research, and almost always refer to themselves as members of an academic *discipline*, and of a corresponding scientific *community*: that is to say, they are quite aware of their social interactions with one another as *scientists*.

These interactions take many different forms. We observe communal *institutions*, such as university departments, learned societies and scientific journals, involved in a variety of communal *activities*, such as scientific education, the publication of scientific papers, debates on controversial scientific questions, or the ceremonial award of prizes for famous discoveries. More abstractly, we notice significant communal *influences*, such as educational curricula, research traditions and research programmes. Every scientist is called upon to play various communal *rôles*, such as graduate student, research supervisor or eminent scientific authority, and is subject to communal *norms* of behaviour, such as 'universalism' or 'disinterestedness'.

Some of these forms of communal interaction have long been obvious. Historians of science have always been interested in the creation of communal institutions and the activities that they foster. No serious history of science in seventeenth-century

Europe, for example, would overlook the foundation of the national scientific academies that brought together so many of the important scientists of their day.

But this interest has tended to be marginal. The fundamental principle of the recent revolution in the metasciences is that these communal institutions, activities, influences, rôles, norms, etc., are not just a background for the logic of scientific method, or to the mystery of scientific creativity; they are *constitutive* of science as we know it. It is not possible to understand the status of scientific theories, or how these get thought of in the first place, without asking how scientists relate to one another in the course of their scientific work.

Any study of the collective actions and relationships between the members of a human group is bound to raise questions about the attitude of the observer and the framework within which the observations are to be interpreted. There are sociologists who insist that this attitude should be as detached and uninvolved as possible, as if one were an anthropologist observing the daily life and occasional festivals of a newly discovered tribe. This *ethnographic* approach has much to recommend it in principle. For the lay outsider, scientific research is an unfamiliar activity imbued with meanings that are only intelligible to the participants, and thus analogous to the symbolic rituals of a mystical sect. Sociological research in this spirit has clearly demonstrated that scientific people and scientific organizations are not at all different, in many essential characteristics, from other people and other organizations of comparable size in comparable cultures.

In practice, however, this very refined approach to human affairs calls for superhuman powers of intellectual detachment and sophistication. The sociology of science is difficult enough to write about in ordinary language, without the additional handicap of trying to purge it of any of the terms that the actors would normally use to describe their own actions to one another. Indeed, there are other schools of sociology that insist that social activity must be interpreted *hermeneutically*, by empathic comprehension of what it means for those taking part. Whatever we may think about this subtle issue in the theory of the social sciences, we are bound to adopt the latter point of view, at least provisionally, in an introductory account of the subject.

The traditional ways of theorizing about academic science usually implied that it had the distinct psychological and philosophical aspects of the discovery model of §1.2. Together with the sociological aspect, these give us three distinct categorial frameworks of abstract description – three different terminologies and conceptual schemes into which the observed phenomena might perhaps be made to fit. The psychology of research uses *personal* terms, such as 'motives', 'perceptions' and 'intelligence'; the philosophy of science uses categories of *knowledge*, such as 'theory', 'contradiction', 'causality'; the sociology of science is about *communities*, with 'institutions', 'norms', 'interests', etc. Each of these schemes has been developed

independently in its own 'dimension' up to a high level of intellectual sophistication. The difficulty is that science is a complex activity which exists, so to speak, in all three of these dimensions at once and cannot be understood properly if it is described in three separate 'aspects', without consideration of their interrelations.

Our natural way of talking about science draws indiscriminately on all three schemes. This is very obvious from a simple example, such as the following account of a recent episode, as it might have been reported in a journal such as *Nature* or *Science*:

> 'Darwin's *theory* of evolution by natural selection is widely held to be well established.' (*knowledge*)
> 'Nevertheless, at several scientific *meetings* it has come under considerable criticism.' (*community*)
> 'According to some recent *experiments* by an Australian scientist, Dr Edward Steele, there is evidence for the inheritance of acquired characteristics.' (*knowledge/person*)
> 'Dr Steele was invited to continue this research in the laboratory of Sir Peter Medawar, the world's leading *authority* on immunology.' (*person/community*)
> 'There were, however, considerable difficulties over the *publication* of his later results.' (*knowledge/person/community*)
> 'Dr Steele was accused of breaking the conventions of scientific *controversy* by making personal attacks on the work of other scientists.' (*knowledge/community*)
> 'Although his own *sincerity* in this affair is not in question, the *originality* and professional competence of his experimental research is now seriously doubted.' (*person*)

These sentences evidently make a connected paragraph containing words that belong to all the different schemes or combinations of schemes in this three-dimensional framework (fig. 3). In the most complicated case, we use words that belong to all three schemes at once. Thus, for example, a scientific publication obviously conveys scientific information, and therefore has a cognitive or *philosophical* dimension. At the same time it is addressed to a segment of the scientific community, and therefore has a communal or *sociological* dimension. In addition, there is the *historical* axis, along which science may be said to evolve by a linked sequence of research publications. These 'dimensions', moreover, are not independent of one another: thus, for example, the psychological significance of a scientific paper to its author is closely connected with the philosophical status of the research results it claims. It would be quite misleading to gloss over such connections for the sake of theoretical simplicity.

All human activities have their personal and communal aspects. The complementarity of individual and collective descriptions is a commonplace of social theory.

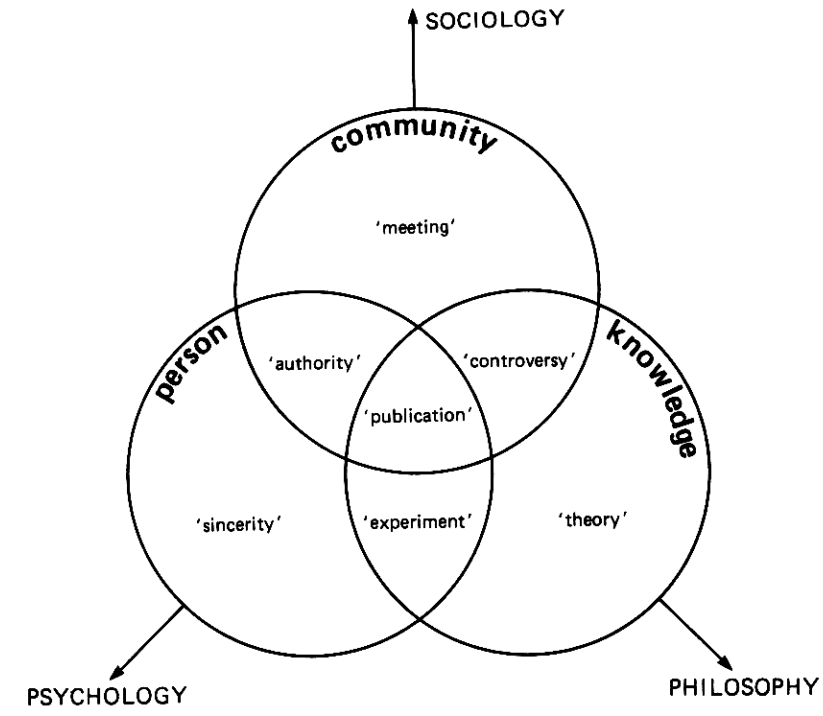

Fig. 3 Three dimensions of discourse about science

The peculiarity of science is the highly ordered and compelling symbolism of the knowledge by which it is both bound together and transformed.

1.5 *Academic science as 'public knowledge'*

The true realm of discourse about science must surely be of many dimensions. Nevertheless, most of what is really worth knowing in the field of science studies has been established under the banner of one or other of the conventional metascientific disciplines, with little support from the others. Each of the next few chapters could thus be labelled according to the discipline from which it mainly derives. Chapters 2 and 3, for example, are essentially a survey of the epistemological problems normally studied by philosophers of science, whilst chapters 5 and 6 on authority, rules and norms are obviously sociological in language and spirit. A conventional study programme would take up each of these topics in detail, interpreting it as far as possible within the framework of its characteristic discipline. But such a programme leaves one with numerous oversimplifications and inter-

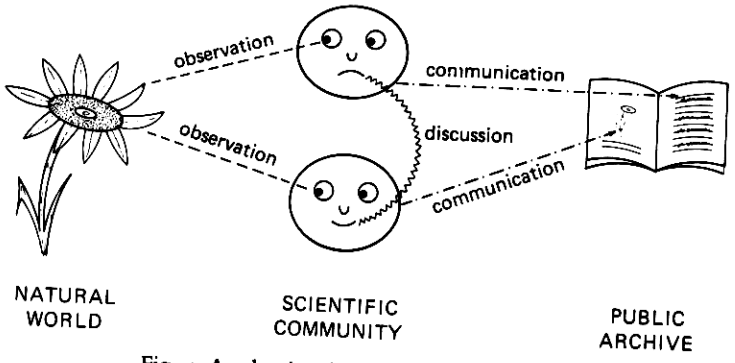

Fig. 4 Academic science as a social system

disciplinary loose ends. Epistemology, for example, is more dependent on sociology than we like to think: in practice the credibility of a scientific conjecture depends very much on the scientific status of the person who moots it! To correct these misconceptions and make good these missing links, we are bound to set up some general 'model' or multidisciplinary interpretative scheme of academic science, in which these diverse topics can be seen to be significant and relevant to the subject as a whole.

At a purely descriptive level, science can obviously be represented naïvely as a community of individual scientists observing the natural world, discussing their discoveries with one another and recording the results in the archives (fig. 4). This model correctly defines research as a social activity, but it lacks any dynamical principle beyond the personal curiosity of its individual members. This sort of scheme can be given much more force and coherence if it is organized around the following proposition:

Academic science is a social institution devoted to the construction of a rational consensus of opinion over the widest possible field.

This is not intended as yet another *definition* of science: it is a hypothetical characterization, of which every word is open to question, criticism and empirical testing. But it does span all the metascientific disciplines, and thus provides an active principle by which to link together many observed features of the 'academic' style of science. The obvious archival, methodological, communal and vocational features of science can be related to it without forcing or major inconsistency, and yet it is relatively undogmatic on the vexed question of the validity or 'truth' of scientific knowledge. It also suggests some very general demarcation criteria by which science can be distinguished from cognate social activities or institutions, such as technology, law, religion, art, education and humanistic studies.

The conception of science as simply 'public knowledge' is, of course, avowedly 'internalist'. It suggests no other goal for the enterprise than the search for knowledge

'for its own sake'. 'Externalist' influences are completely excluded. But this is precisely the attitude we have decided to adopt in the first part of this book. It is necessary to understand the traditional academic conception of science on its own ground, and in its own terms, before we can appreciate how far this might be from present-day reality.

This principle is also a temptation towards *functionalism*. It tends to suggest that the detailed characteristics of science as we happen to know it are somehow essential to its 'functioning' as a whole. One might then use this argument to justify existing practices – for example, the 'peer review' procedure by which anonymous 'referees' scrutinize scientific papers submitted for publication – although they may, in fact, have grown up more or less by accident, and could well be managed quite differently. Social institutions are both more ramshackle and more adaptive to historical change than such arguments allow.

In any case, whether or not one accepts 'maximum rational consensus' as the fundamental objective of academic science, this principle is very convenient as a provisional hypothesis around which to structure one's observations and conjectures about the way in which scientists really work. As in the natural sciences themselves, this is the proper spirit in which to undertake a scholarly investigation.

Further reading for chapter 1

To appreciate the theme of this book, the reader should have access to works on the scope of modern science and on its historical development. It is impossible to make a short list of recommended books on this limitless subject, since the choice must depend on each reader's existing knowledge and interests. For a readable general account, one might turn to

J. D. Bernal, *Science in History*. London: Watts, 1954

although his particular interpretations of historical events and contemporary circumstances are often more controversial than he indicates.

For information on particular topics, one might look first in

H. T. Pledge, *Science since 1500*. London: HMSO, 1966

or C. Singer, *A Short History of Scientific Ideas to 1900*. Oxford: Clarendon Press, 1959

For an account of the formation of the modern scientific attitude, one could start with

H. Butterfield, *The Origins of Modern Science 1300–1800*. London: Bell, 1957

or A. R. Hall, *The Scientific Revolution 1500–1800*. London: Longmans, 1954

These are but entry points to an immense literature, dealing with particular periods, particular scientific disciplines, or the life and works of particular scientists. Books and articles dealing specifically with historical aspects of the social relations of science will be noted in later chapters. A compact, but well-ordered and reasonable survey

of all this literature, with special reference to the 'internalist–externalist' debate, is given by

R. MacLeod, 'Changing Perspectives in the Social History of Science', in *Science Technology and Society*, ed. I. Spiegel-Rösing & D. de Solla Price, pp. 149–96. London: Sage, 1977

An elementary schematic account of 'Science Studies' is given by

J. M. Ziman, *Teaching and Learning about Science and Society*. Cambridge: Cambridge University Press: 1980 (chapters 5–7)

A more scholarly survey, with full biography, is given by

I. Spiegel-Rösing, 'The Study of Science, Technology and Society (SSTS): Recent Trends and Future Challenges', in *Science Technology and Society*, ed. I. Spiegel-Rösing & D. de Solla Price, pp. 7–42. London: Sage, 1977

The social model of academic science introduced in §1.5 is discussed at length in

J. M. Ziman, *Public Knowledge*. Cambridge: Cambridge University Press, 1967 (especially pp. 1–29)

Another elementary model, which emphasizes external factors from the beginning, is given by

L. Sklair, *Organised Knowledge*. London: Hart-Davis, MacGibbon, 1973 (pp. 57–63)

The most readable example of an ethnographic study of scientific work is

B. Latour & S. Woolgar, *Laboratory Life*. London: Sage, 1979 (pp. 43–104)

2

Research

'...in the discovery of secret things and in the investigation of hidden causes, stronger reasons are obtained from sure experiments and demonstrated arguments than from probable conjectures and the opinions of philosophical speculators of the common sort.' *William Gilbert*

2.1 Scientific knowledge

The purpose of science is to obtain *scientific knowledge*. That is to say, scientific work is directed towards acquiring a special type of information, either for immediate practical use or for publication in textbooks, encyclopaedias, learned journals, etc., under various headings such as physics, chemistry or biology. A typical item of scientific information might be, say: 'The benzene molecule contains six carbon atoms arranged in a ring'. This is clearly somewhat different from the sort of knowledge usually to be found in novels, law reports, sermons, or political manifestos – for example, that 'it is love that makes the world go round', or 'the greater the truth, the greater the libel'.

But what are the distinguishing features of *scientific* knowledge as such? This traditional philosophical question is important because it may decisively affect our actions to know that a particular piece of information is 'scientifically' warranted (cf. §16.3). It is also one of the key questions about science as a human activity, for it asks about the fundamental objectives of research. If, for example, it is said that the goal of science is to make 'discoveries', then we must have some idea what sort of thing a scientific discovery is supposed to be. If, further, we insist that scientific knowledge is only to be gained by a special 'method', then we naturally enquire whether this method makes this sort of knowledge peculiarly valid.

These are such deep and hotly contested issues that even the choice of the starting point for discussion may seem to prejudge the outcome. In the present chapter, we try to take a 'naturalistic' approach, talking about the contents of scientific knowledge, especially in the context of *discovery*, in terms that scientists themselves might use in describing their work. In the following chapter, this 'folk' description