1 Where did science come from?

In the Introduction I tried to give some flavour of the controversies surrounding science, both as an activity in its own right, but also in its role in investigations of the social world. Before we can confront these matters we need to get some clearer views of what science is. This is the task of the next two chapters. In this chapter I want to look at a few episodes of what counted as science (particularly natural science) in past times in order to identify what kind of factors have been important in defining such practices as ‘scientific’. Second, I want to show, again with some brevity, how it was that studies of the social world came to be called science.

The dynamic of science

Science is not miraculous, nor is its contemporary manifestation the result of miraculous birth. As a social activity it is of human parentage and like all offspring it has evolved characteristics of its own, though it has retained many of those of its parents. If we stand in awe of science, we stand in awe of ourselves. The history of science is not simply a dialectical development of a relationship of human beings with nature, but also of scientists with their theories, and scientists with society. Society here is shorthand for religion, philosophy, ideology and politics. By this I mean that the romantic idea of the lone scientist pitted against nature is just one small part of the picture. Nature, as the scientist imagines it, is the product of scientific theories, themselves rooted in a philosophical world view. This in turn may have been shaped by politics or religion. Moreover world views may themselves have been shaped by the discoveries of earlier scientists.

We can summarise three interrelated characteristics:

1 *The relationship between metaphysics and science*. Early science was mystical and bound up with religious beliefs about nature and the universe. What we might see as recognisably scientific content was small. Yet throughout the history of science a desire to know the meaning of the

universe was a key motivation. Post-Renaissance science is ‘anti-mystical’, but must still depend on some metaphysical assumptions.

2 *The social position of science.* This comprises a number of characteristics. The first is the separation of scientific activity and everyday activity. The second is the relationship between science and society, in which the character or power of one has been a formative influence upon the other. The way in which society shapes science can itself arise directly, or indirectly (perhaps through moral prescription) from metaphysical belief. The third characteristic is power: the power of science can be utilised or challenged from society. The most famous early example of this was the trial of Socrates (*c*.470-395 BC), who was sentenced to death by the Athenian Assembly for impiety and corrupting youth through his ideas (Russell 1979: 103–7). This was the persecution of science, but perhaps more important has been what Tolstoy refers to as ‘the knowledge–power feedback loop’ (Tolstoy 1990: ix), as science became more effective, so it became more desirable as a tool of economic prosperity, or war, and this in turn led to further scientific development.

3 *The cognitive development of human beings.* The learning capacity and reasoning ability of scientists has developed and increased incrementally (with some setbacks) through the history of science. The cognitive abilities of scientists at each stage of science have been an important characteristic and sometimes limiting feature. The insights of one age become the methodological tools of another. Some of these developments (described below), such as ‘Thales’ leap’, Aristotle’s development of deductive logic or Galileo’s use of experimental method, are documented events, but like most discoveries about the world, these can mostly be seen as markers of the cognitive development of science at that time.

The emergence of unnatural thinking

In the beginning there was curiosity and a need to resolve problems, mostly those of survival. Humans learnt to hunt with primitive axes, which in turn gave way to arrows and once the effectiveness of hunting with arrows was established they were improved by using different materials, first iron and later bronze. But bronze required smelting and smelting required fire. The copper and tin themselves needed extracting and this, along with the smelting, required co-operation. Thus in early society we see evidence of technological success achieved through increasing cognitive abilities and social co-operation, some of the hallmarks of what was to become science.

As societies became more complex the role of ritual and metaphysical belief became more important. These beliefs informed and were informed by a desire and ability to measure and explain. The Babylonians, Egyptians, Greeks and Romans set great store in predicting the future, which can perhaps be seen as evidence of a desire to know beyond the material, but crucially for the development of science it led to the emergence of a cognitive élite. The 'scientific' development of early society served the pragmatic needs of survival, but perhaps the emergence of a metaphysical curiosity was a necessary precursor to a scientific one?

An abstract metaphysical curiosity was the hallmark of growing social complexity and of urbanisation. This in turn went hand in hand with commerce and required a reliable system of measurement; one which, as Tolstoy notes, provided 'a continuous running check on the validity of methods' (Tolstoy 1990: 58). This was also the point where a segregation occurred between the 'superior' activities of mind and the 'inferior' activities of manufacturing (*ibid.*). The cognitive élite in many early societies may have been a priesthood; certainly in societies such as Babylon, where astrological abilities were prized, those with such skills would have been an élite. Of course, the precise evidence from these societies is fragmented and disputed, but it remains that by the time such endeavours were recorded by the Greeks a division of labour between the material and the intellectual was well established.

From our vantage point in the twentieth century we have to understand that there was no separation in intellectual activities between the metaphysical and the development of the technological (though of course there was between these and the employment of technology). For example, the development of the Egyptian calendar allowed accurate prediction of the flooding of the Nile, thus allowing a more successful prosecution of agriculture. Yet although this was achieved as a result of astronomical observation, the constellations themselves were identified with the deities. Science and religion were one and the same. If the 'scientists' could predict the flooding of the Nile, then presumably the view that 'The sky was a flat or vaulted ceiling supported by four columns or mountain peaks, and the stars were lamps hung from the sky by cables' (Dampier 1966: 6–7) would have been taken equally seriously. Of course much of the science was wrong, though it did often lead to accurate prediction and is therefore better described as right for the wrong reasons. It did, however, demonstrate the ability for social co-operation in the pursuit of knowledge and the means to employ this knowledge practically, but also it was the desire to find meaning in the world. Finally, it was an activity that was conducted by a sub-group of society.

For Lewis Wolpert (1992) the foregoing, though evidence of advanced technological thinking, does not amount to science. He maintains that science emerged only when there was a separation between what he calls 'natural' and 'unnatural' thinking. This separation, he believes, first took place in ancient Greece (Wolpert 1992: xii) and amounts to a cognitive disjuncture between common sense curiosity and scientific curiosity. Wolpert presents us with a number of simple scientific propositions which he believes to be counter-intuitive to the non-scientist. For example, the common sense view is that the natural state of any object is that it is at rest, but post-Newton scientists know that the natural state is for an object to move at a constant speed until stopped (Wolpert 1992: 3). Likewise few are aware that white light is composed of the colours of the spectrum. We can, he maintains, point to particular departures from unnatural thinking in classical civilisation and he accords the honour of being the first scientist to Thales of Miletos, who lived around 600 BC (Wolpert 1992: 35). The latter's contribution was to question the prevailing metaphysical ideas of the day to ask, 'What is the world made of?' His answer was 'water' – and of course wrong – but according to Wolpert, the fact that he could propose something that was so counter-intuitive prefigured such later successful propositions. Perhaps as importantly Thales provided a number of important mathematical insights, such as the observation that if two straight lines cut each other, the opposite angles are equal. As Wolpert remarks:

> Here, for the first time, were general statements about lines and circles – statements of a kind never made before. They were general statements that applied to *all* circles and lines everywhere ...
>
> (Wolpert 1992: 37)

Though generalisation was not new (Egyptian cosmology generalised), those that had a longevity beyond their historical setting were. Thales' contribution was, therefore, not simply lateral thinking, but some foundational mathematics, an essential tool for later science.

Wolpert's distinction is a useful one and offers a continuity with modern science: though still deriving from curiosity, science, however motivated, is rarely common sense. However, as Wolpert himself notes there is a circularity in the argument that science is 'unnatural'. If it were 'natural' and just a matter of common sense observation, then there would be no science to explain anyway. (I shall return to the question of curiosity in Chapter 2.) Moreover, what is known as 'Thales' leap' cannot be wholly attributed to one man's ability to think laterally, but also to the existence of a 'scientific', or at least proto-scientific culture and metaphysical foundation that allowed such a leap to be made.

Indeed it was not just Thales who leapt. Greek philosophical ideas were of immense importance to both science and to Western civilisation generally (see Russell 1979: parts 1 and 2). Perhaps the greatest contribution to science came from Aristotle (384–322 BC), though, like Thales, much of his science was 'wrong'; he too gave science an important tool, that of the syllogism. A syllogistic argument has two premises from which a conclusion is entailed. The conclusion can be deduced from the premises, as in the example below.

Premises:
All mammals are warm blooded animals
No lizards are warm blooded animals

Conclusion:
Therefore no lizards are mammals

Science, as we shall see, depends on deduction – on this kind of argument – though we must be careful here, for a conclusion following from premises does not entail the truth of the premises, but what deduction gives us is a rational structure to argument (see Weston 1992). With the formulation of this way of thinking we also have the beginning of rationality, that is, to deny conclusions once we have accepted the premises from which they are derived would be an irrational act.

Deductive logic is a *formalisation* of patterns of inference (people inferred before formal logic) and provided a framework for science. It is often said that post-Renaissance science produced the culture of rationality that is the hallmark of modern science, but of course to a great extent the opposite had to be true. For rational science to gain legitimacy at least some semblance of a wider culture of rationality had to exist in society (Tarnas 1991: 224–32). The relationship between science and rationality might be seen as a symbiotic one.

In the name of God

With the decline of Classical Greek civilisation and the rise of the Roman Empire scientific endeavour declined, at least in Europe. It continued to flourish in the Muslim world, however, and important advances were made, particularly in mathematics and specifically through the invention of algebra, but from the beginning of the Christian era to the late Middle Ages scientific discovery, as opposed to its utilisation, did not flourish in the West. The cognitive development of science was hampered by the metaphysical basis of science in early Christian civilisation and by the social structure that arose from the Christian hegemony. Nevertheless, because there was little scientific advance on the achievements of the Greeks did not mean that the period was intellectually barren. The medieval period was one of enormous accomplishment, but this was in many ways spiritual. The great architecture of the cathedrals, though displaying enormous technical skill, were dedications to a spiritual faith. Curiosity was not absent but found its expression in Christian endeavours to attain divine knowledge. The metaphysical centre of gravity, as it were, was the Holy Spirit (Tarnas 1991: 156).

The Christian Church's power – spiritual, ideological and political – extended to all aspects of life. Within its embrace was contained much of that which was progressive, innovatory, barbaric and conservative. Although the power of the Church in society was enormous, alongside it a new economic order was taking shape, one that grew out of the success of agriculture and widespread commerce and was centred on the towns. With urbanisation came important advances in technological ability, which in turn improved commercial efficiency, prompting more investment in technology (Tolstoy 1990: 100). The Church itself was, of course, a major participant in medieval commerce and the source of much of the technological innovation. Indeed much of the learning of medieval Europe was either monastic, or under the auspices of the Church. Philosophers such as St Thomas Aquinas, William of Ockham and Roger Bacon were all churchmen. The Church, then, both set metaphysical limits on science as well as being the repository of knowledge – including scientific knowledge.

What were the metaphysical limits and how was this different to Classical Greece? In terms of scientific development the end of Classical Greek civilisation was also its apex. A product of this early scientific world view, or indeed possibly contributing to such a view, was a growing philosophical secularism, a shift from astrology and theism, first to the pantheism of the Stoics, but eventually in Epicurus to a philosophy which denied the existence of gods as the creators of nature. Epicurus' view was that gods were simply part of nature as humans are and that there is a finality in death (Dampier 1966: 39). Such views as this were not to be expressed again widely in the West until the Renaissance; the medieval world view was militantly anti-secular and this extended to learning. All sanctioned learning was in the service, or at least context, of theistic knowledge, whereby philosophical ideas – often the inspiration to scientific activity in Greece – were in the service of theology. Yet the very early Christian Church made a conscious effort to fuse together Christianity with Greek philosophy. The result was successful in terms of the ideological longevity of Christianity, yet, rather like Chinese whispers, what survived of the philosophy in medieval Europe was a faint echo. Aristotle's work survived, though in imperfect form and mainly expressed through his logical principles, themselves the basis of attempts to 'prove' the existence of God (Russell 1979: chapter 13), or through his physics of the direct perception of substance, essence, matter, form, quality and quantity. This, in Wolpert's term, was a 'natural' physics, which accorded with experience, but was wrong.

The doldrums into which science had sunk were dominated by mysticism sanctioned by ideology, limiting the cognitive development of science to the bounds of theology. Indeed, as we shall see in the case of Galileo, to enquire too much into the nature of reality was impiety, even heresy, not just because it challenged the hegemony of the Church, or a Church-dominated intellectual and political élite, but also because it undermined the spiritual security of the afterlife (Dampier 1966: chapter 2).

Galileo and the birth of modern science

Galileo (1564–1642) has often been called the ‘father of modern science’. His work in dynamics and astronomy was certainly foundational for the version of science as we know it, but just as importantly for our purposes, he personifies the clash between secularism and mysticism, Enlightenment and medievalism and specifically between science and the Christian Church. Before considering Galileo and his ideas it is necessary to briefly say how the transition from the theistic medieval world came to pass.

Tolstoy (1990) calls the period between the fall of the Roman Empire and the Renaissance a period of transition between the science of the classical world and the modern one. The social and technological bases of modern science were laid down in this period of transition, and even though theology set limits to philosophy, ideas of great importance to later science evolved. One particular example is Ockham’s Razor (named after a Franciscan monk, William of Ockham, *c.*1285–1349), the principle of parsimony, usually expressed as ‘entities should not be multiplied beyond necessity’, a principle important in choosing between scientific theories and a matter I will return to in Chapter 2.

The head on clash between science and religion came with the challenging of theological *a priori* truths with observation *and* reasoning – Wolpert’s ‘unnatural thinking’. Galileo’s difficulties with the Inquisition are perhaps the most celebrated example of this. Two things are of importance here: first, what it was Galileo was challenging and what that challenge was, and second this as an exemplar, not of the formal defeat of Galileo (for that is what happened at his trial), but as the beginning of the end for Christian theology as a ruling ideology in the West.

I have noted above the importation of Aristotelian thought into Christian philosophy and science. With some modifications Aristotle’s mechanics and cosmology had become the Christian world view. Galileo challenged both. Aristotle’s physics appealed to common sense. The world, it was said, was made up of four elements: earth, fire, air and water. Fire moves upwards and earth moves downwards, thus the natural place of rocks is the centre of the earth, of water resting on the earth and of fire between the air and the surface of a sphere separating the earth from the heavens. It follows from this that motion will continue until the object moves to rest as close as it can to its natural place. The heavier a solid object, the more quickly it will fall to its natural place of rest – the centre of the earth. Galileo demonstrated that objects of different weights (assuming the same air resistance) will fall to the earth at the same speed. These experiments in dynamics and the claims that followed from them were not the focus of the dispute with the Church, but instead cosmological claims were. Aristotle’s four earthly elements (he added a fifth heavenly one of the aether) were characterised by rectilinear and discontinuous motion, whereas the moon, the sun, the planets and stars were continuous and circular, a fact which was observationally demonstrable, as was their motion around the earth. These bodies were 'perfect and incorruptible' (Dampier 1966: 30) and thus evidence of a final mover – that of God.

Aristotelian cosmology was, like the medieval mysticism it served, of an *a priori* kind, that is, observations had to fit the existing metaphysical schema, and to challenge that schema was to challenge God. Perhaps it was because even prior to Galileo's published work the ideas of Copernicus and Galileo's contemporary Kepler were gaining ground and even finding wider intellectual acceptance, that the church took such exception to Galileo's views. Nicolaus Copernicus (1473–1543), in his *Commentariolus,* had first publicly proposed a heliocentric view of the universe, and this view was developed through the observations of Tycho Brahe (1546–1601) and later energetically championed by Johannes Kepler (1571–1630), but although each reasoned mathematically from observation and, in the course of so doing, abandoned an Aristotelian or Ptolemaic *a priori* anthropocentric cosmology, their views were simply regarded as 'hypotheses' and attempts to save the philosophical status quo. Galileo's contribution was not then seminal, but it was crucial in so far as his observations utilised a new and powerful technology – that of the telescope. He showed that the moon was mountainous and not a perfect sphere, he demonstrated the existence of the moons of Jupiter. The cosmos he showed to be vast, not just spheres in a relatively near aether. What is crucial, however, is that his reasoning began from observation and did not depend on immutable philosophical principles. His trial then was not an argument about the truth or falsity of particular premises, but was a clash between two metaphysical standpoints. Alfred North Whitehead put it rather well when he noted that 'Galileo keeps harping on how things happen, whereas his adversaries had a complete theory as to why things happen' (Whitehead 1997: 59).

In Galileo's trial we seen dramatically how science, metaphysics and the social world, here represented by the Church, come dramatically into conflict. In his use of deduction and induction we see the cognitive advances of earlier science becoming the technical ability of a later one, and in his willingness to publish we see the use of science to shape thought. However, perhaps the most important departure arose through the deployment of experimental method. I mean this both in the technical importance of this way of doing science, but also in the way it helped the scientist to regard the world as comprising objects to be manipulated, as separate to the scientist and the everyday. Actually scientific objectivity was born of Galileo in two ways, both in his view of the world as objects to be known by the scientist, and in his refusal to allow the ideological orthodoxy to determine the interpretation of his findings. Though these have since become conflated in science, it remains that they marked an important departure from a common sense 'ought' view of nature to a scientific 'is' one. Whether we can strictly delimit these is another matter and one I will return to in Chapter 6. This way of looking at the world has become an important part of the scientific attitude, but also it lies at the basis of claims that science is 'other', divorced from the humanity which created it.

Newton and the 'clockwork' universe

If Galileo's fame is at least partially iconic, the same is not true of Isaac Newton (1642–1727). Indeed such has been the impact of Newton on science and Western thought in general that many have seen the era of science that his discoveries heralded as being *the* scientific era, or at least a paradigm, as Kuhn ([1962] 1970) termed it, within which all other science, or thinking about science operated. The scientific world view was largely that which came in to being as a result of how Newton described and explained the physical world.

Newton's description and explanation of movement has been frequently likened to a clockwork model of the universe. A clock is dependable, predictable in its movement and obeys a straightforward everyday notion of cause and effect. Newton's work spanned gravitation, mechanics, optics and mathematics, though his three laws of motion are perhaps the ones which most influentially shaped the scientific world view. His first law states that bodies not subject to a force will continue to travel in straight lines. His second states that if a force is applied to a body, its momentum will increase in the direction of the application of the force; for a body whose mass does not change, the resulting rate of increasing speed is equal to the force divided by the mass. His third law states that for every action there corresponds an equal and opposite reaction.

Perhaps the law that led most directly to the appellation 'clockwork' being given to the explanation of movement is his law of gravitation. This states that two spheres, for example the sun and the earth, exert upon each other forces of attraction varying inversely with the square of the distance between their centres. This law, though independent of his laws of motion, can be said to provide a force function, which in conjunction with the latter provides an explanation of how gravitational force is expressed in the motion of objects. These relatively simple axioms gave rise to a model of the solar system that was dependable and predictable (Tolstoy 1990: 168) and until this century lay at the basis of our understanding of the cosmos, but just as importantly they provided both an exemplar of how science should be done and a model of what the world is really like.

I do not wish to create the impression that certainty was born of Newton, but rather that Newton's discoveries were taken by many as a demonstration of the possibility of certainty in science. They ushered in an age of great optimism in philosophy and confidence in science. Indeed, that science and philosophy remained substantially a unified venture, i.e. that many 'scientists' were 'philosophers' and vice versa, meant that the advances in science directly influenced those of thought, which in turn fed back into science. Though the scope and success of Newton's work was unrivalled in its time and perhaps until that of Einstein in the twentieth century, the world he inhabited was not intellectually lonely and there was an important cross-fertilisation of ideas. He corresponded with Leibniz and Bernoulli, he knew Locke and Pepys and had an enormous influence on the US President Thomas Jefferson, himself first a scientist and second a politician (Holton 1993: 110).

Newton's success and much of his fame undoubtedly arose from the predictive and explanatory success of his methods. Though there was nothing really new about his approach – it was one advocated by Aristotle and Roger Bacon (Losee 1980: 55) – it was nevertheless superior to theirs in that it depended on the experimental confirmation of consequences deduced from axioms. For example Newton's third law stated that for every action there is an equal and opposite reaction. If these axioms hold true we can deduce the effect of one body on another; if our deductions are correct the bodies should be observed to behave accordingly. A consequence of this apparently foolproof way to knowledge was a reification of this approach to science and eventually a reification of science itself. The popular view of Newton is that his method amounted to a claim to certain knowledge, i.e. that the deduction of key axioms and their confirmation, through experiment, would allow a calculation of every possible state the universe could be in. As well as 'clockwork', the phrase 'mechanistic' is often used to describe the Newtonian universe. The doctrine of metaphysical determinism (that is, everything that happens in the universe is determined by prior conditions and that it could be no other way), though not new, was given empirical authority because of the success of Newton's predictions. Thus the French mathematician and physicist Pierre Laplace (1749–1827) believed the entire universe was composed of 'different arrangements of atoms moving in accordance with Newton's laws of motion' (Tallis 1995: 12). It follows from this that if all such arrangements as exist now can be known with certainty, then all possible future arrangements can be determined.

Newton himself had been more circumspect, claiming only that we can establish the relations between phenomena using his methods and we cannot prove that the relation could not have been otherwise (Losee 1980: 94). This view was held by empiricist philosopher David Hume (1711–1776), who maintained that although we can observe that relationships between things or events are regular, that *A* appears to 'cause' *B*, there is nothing in *A* or *B* themselves to suggest that relationship is a necessary one. That

> … even if our faculties were fitted to penetrate into the internal fabric of bodies we could gain no knowledge of a necessary connectedness among phenomena. The most we could hope to learn is that certain configurations and motions of atoms have been constantly conjoined with macroscopic effects.
>
> (Losee 1980: 101)

Hume's philosophical scepticism, though enormously influential since in the work of empiricists such as Mill, Russell, Mach and Hempel, has done little to dent the external view of science as a mechanistic enterprise implying 'the belief that everything was fixed. The future was contained in the present which was pre-destined by the past' (Appleyard 1992: 64).

The rise of social science

Had it not been for the success of the science and its resulting technology, inspired by Newton and his followers, studies of the social world might have taken on a very different character, at least initially. Thinkers from the seventeenth century (in particular) such as Thomas Hobbes and Giambattista Vico had emphasised the 'voluntaristic' nature of human beings (Manicas 1987: 29). Conscious, self-reflecting and creative, they required a different approach to being studied than did the objects of the inanimate world, one based on understanding and interpretation rather than explanation and prediction. Of course we cannot know whether under different historical circumstances this approach might have caught on, but it is nevertheless clear that a 'scientific ' approach to the study of the social world arose not because of its efficacy in its own right, but because science was in fashion and manifestly successful. The alternative hermeneutic approach, begun by Vico and continued by Schleirmacher and Dilthey (May 1996: 32–7), took on the role of the opposition with only Max Weber succeeding in any kind of compromise (Weber 1949; 1978b).

There was, however, an important, though not always stated, difference between the natural and social sciences in the nineteenth-century – even at their most avowedly scientific. The latter were not just about how the world 'is' but how it 'ought' to be. Indeed John Stuart Mill referred to the 'social' sciences as the 'moral sciences' (Mill 1987), implying their prescriptive character, though in this Mill was not advocating subjectivity. The success of science post-Newton convinced those (such as Mill) concerned with the conduct of human affairs that they could be known scientifically, and indeed that 'scientific' programmes could be devised to make social life more equitable and efficient. Mill believed that all of the sciences, including the 'moral sciences', were 'progressing towards the abstract and deductive character of classical physics' (Thomas 1985: 52). The natural sciences derived from physical laws, but the social sciences, he held, derived from the laws of mind, where the latter are in the final analysis dependent upon the former (Thomas 1985: 65–7). It was believed, then, that knowledge acquired through experience could lead to deductions and accurate predictions and was a principle that could be successfully translated from the physical to the social world. As Voltaire put it:

> it would be very singular that all nature, all the planets, should obey eternal laws, and there should be a little animal, five feet

> high, who in contempt of these laws, could act as he pleased, solely according to his caprice.
>
> (cited in Dampier 1966: 197)

Thus the ‘scientific world view’ (and in France particularly the Laplacian version of this) not only influenced a model of social science, but also a model of society which in its turn also influenced the infant social sciences.

This mixture of explanation and prescription was epitomised in the work of Auguste Comte, whose project R.A. Nisbet describes as replacing Catholicism with positivism (Nisbet 1970: 15), an attempt to fuse moral prescription with the rationality of science. However, despite his fame as the founder of ‘positivism’ there was more prescription than science in his world view. Though it is a matter of emphasis. In this, the history of the social sciences is even more genealogical than the natural sciences in that one can trace ideas back in more than one way. For example Comte is variously seen as emphasising science, or a kind of hankering for a pre-scientific conservatism (Nisbet 1970: 17–19). Though usually referred to as the father of positivism, his ‘positivism’ was an important, though partial determinant of the Durkheimian kind (Lukes 1981) and had little to do with the logical positivism of the Vienna Circle (Kolakowski 1972).

Max Weber similarly sought to put the social sciences on a ‘scientific’ basis, though his starting point was that of individual agency and the need to interpret actions so arising before making causal inferences (Weber [1922] 1947). However, in holding to methodological separation between the moral commitment of social policy and the value freedom required in its sociological operationalisation (Weber 1974) he was closer to science than interpretation. Nevertheless in a re-description of the work of any of these thinkers, and more especially those more ‘politically’ active thinkers in the Marxist tradition, one could emphasise ideological considerations and historical contingency as much as a desire to be ‘scientific’. Indeed despite Weber’s injunction that sociology should be ‘value free’, value laden language, such as ‘grand figures’ and ‘perfection that is nowhere surpassed’, permeates most of his work (Strauss 1963: 433). I shall return to this question of value freedom and objectivity in Chapter 6, but for the present I want to look at the apotheosis of science in social science, the era of positivism.

Positivism in natural and social science

There is much confusion about positivism in social science, or rather there is much confusion amongst social scientists about positivism. For many it is simply a term of abuse to indicate quantification, or the importation of ‘scientific’ method into social science (see for example Denzin 1983; Guba and Lincoln 1982), but of course if positivism was just science in social science then this would not explain why it was that for much of the twentieth century there has been a vigorous debate about positivism in the philosophy of the natural sciences (Losee 1980: chapter 11).

Though Comte coined the term 'positivism', *logical* positivism, unlike the Comtean kind, emphasised the methodological aspect of science, rather than the philosophical. In fact natural science was much more influenced by the empiricism of Hume (Gillies 1993: chapter 1) and Mill than the continental variants in Comte and Durkheim. Logical positivism was associated principally with the Vienna Circle, a group of philosophers and scientists including Moritz Schlick, Rudolph Carnap and Hans Reichenbach, and with the English philosophers G.E. Moore and A.J. Ayer (Kolakowski 1972: chapter 5). Much influenced by Hume, an important doctrine, especially early on, was that of verification expressed in the formula 'the meaning of a statement is the method of its verification' (Kolakowski 1972: 213). That is, unless we can state how it is a proposition can be verified it is meaningless. Verification of hypotheses can occur only through observations, and the means by which the verification can take place is through observation statements. If something is not observable then it is not verifiable, and if it is not verifiable then we are not entitled to make claims about it (Carnap 1969: 108–9). A problem with this, recognised by the logical positivists, was that an improvement in experimental technique could render a meaningless statement meaningful overnight. This doctrine was then relaxed somewhat to mean that a statement could in principle, if not actuality, be verified (Kolakowski 1972: 213). Apart from observation statements only analytic statements in logic and mathematics had a part to play in science, but of course these are tautological, can give only structure to propositions and can reveal nothing new about the world. Statements other than analytic or verifiable ones were not seen to be scientific; they were instead metaphysical and meaningless. This, of course, would include a great deal of theory, yet to be verified, or shown to be untrue. Only reluctantly were they admitted to play any part in science and then only as conventions adopted by scientists that constrain and structure scientific enquiry. The job of observation statements was to propose how theoretical statements could be tested. If verified they were admitted as meaningful, if not they were considered meaningless.

Like Caesar, logical positivism was killed, or at least mortally wounded, by one of its close associates, Karl Popper (Popper 1986: 87–90). Popper's objection was mainly that whilst the observation statements might refute a theory, they could never confirm it. Instead he developed his alternative of falsification, which I will discuss in the next chapter. A second related objection was directed towards the empiricism itself and the insistence of the logical positivists that observation statements and theory statements must be separated in order that the former can confirm or refute the latter. Popper's objection was that observations are never made except in the context of one theory or another (Popper 1989: 24–30). Though not confined to Popper, this criticism has been the principal one levelled at logical positivism ever since.

It is hard to gauge the influence of positivism on natural science; really the relationship was more symbiotic. Ernest Mach and Hans Reichenbach, for instance, were physicists and philosophers; both were advocates of positivism (Losee 1980: 159–88). Yet it was the physics of the late nineteenth and early twentieth centuries that so influenced the philosophy. Perhaps then, historically, it was the last and most fawning celebration of science, believing, as did Comte, that the clarity and objectivity of the scientific method were the tools of a wider societal salvation. Though the influence on social science is even harder to gauge, it is possible that logical positivism was more influential on method than the positivism of Durkheim and certainly that of Comte.

Comte's importance was more that of an historical figure than in any lasting substantial contribution (Craib 1997: 25–6). Durkheim's influence on the explanation of social structure and on the use of official statistics in *Suicide* (1952) is tangible and important, but it was the mood of positivism in the natural sciences, especially its empiricist character, that was most influential. Comte and Durkheim asserted the possibility of the scientific nature of the study of the social world and the latter demonstrated its feasibility in *Suicide,* but it was the importation of empiricism into method, both implicitly and explicitly, that characterised the positivist influence. The influence of positivism on social science is perhaps more readily explained by the importation of logical positivism into American social science at a time of its great expansion, in the 1930s. Of course one could perhaps claim the opposite, that it was the importation of logical positivism that led to the success of social science. Either way the age of positivism in social science coincided with the growth of American dominance, particularly of sociology, itself motivated by the tremendous advances in science and engineering in the first quarter of the century in that country. There were criticisms, notably from R.S. Lynd and C. Wright Mills, but these fell on deaf ears in a profession 'trained in statistical methods, with mutually reinforcing motivations to win promotion and produce the "facts" needed by mayors, presidents and corporations' (Manicas 1987: 226).

Indeed positivism, or more specifically a commitment to methodological empiricism, was to dominate American social science for a generation and by extension that in the rest of the English-speaking world also. As a philosophical underpinning to science, social or natural, it is discredited and lives on only as a demon, and one suspects a convenient one, in the minds of certain interpretivist social 'scientists' (Philips 1987: 36–7). Nevertheless, it has left a threefold legacy. First, and I believe beneficially, as Michael Scriven noted, it was a knife that cut away much of the constricting metaphysics in philosophy, 'performing a tracheotomy that made it possible for philosophy to breathe again' (cited in Phillips 1987:

39). The ensuing rigour was hugely influential on 'scientific' social science and is one that remains. Second, less beneficially, it bequeathed a naïve empiricism to social science. This was Popper's complaint and is even more forceful when stated in relation to observations in the social world. Such observations depend on the derivation of categories, themselves a product of earlier experience. The measurement of class, for example, arises out of a theory that classes exist and have properties. As we know their existence in particular forms is postulated and often disputed (for a discussion of the 'reality' of class see Pawson 1989). Thus the measurement of class is in no sense a neutral observation. Nevertheless the assumption often remains in much of survey research, particularly that carried out by government agencies, or sponsored by them, that only what is observable can be measured and the measurement itself is an objective one of a real phenomenon in the world. A view that manages to be both naïvely empiricist and realist at the same time (Williams 1998: 12–13).

The objections of Popper and others aside, it was not the case that logical positivism was an unsophisticated doctrine – its exponents were very aware of developments in the physics and mathematics of the time. For instance in stressing the importance of observation in physics, Albert Einstein and Werner Heisenberg both qualified as 'positivists' (Popper 1985: part 1, section 12), as did the mathematician, often credited with prefiguring complexity theory (see Chapter 7), Henri Poincaré. However, like Chinese whispers the sophistication of the methodological debate in science became rather changed by the time it reached social science. The result was that whilst 'frontier' science was shifting the methodological (and indeed metaphysical) ground towards probability (in both senses that the laws that govern the way the world is are themselves probabilistic and that scientific knowledge itself is probable and not certain) and contingency, the social sciences seemed content to retain a deterministic model of causality more influenced by Laplace than Poincaré.

Science in the twentieth century

It is commonplace nowadays for scientists and science writers to complain about the lack of the public understanding of science (Sagan and Druyan 1996: 318–33). But perhaps it has always been thus – the peasantry of the Middle Ages was just as unenlightened about the workings of the universe as middle America is today. The difference is that our culture is now a 'scientific' one, that is we materially rely on science and its emergent technology, but also that the promise and threat of this lead more people than ever to have a view on science. What I described as the 'clockwork' view of the universe promoted by Laplace took seed in the public mind and, as I have suggested, was influential in social science. The view can be summed up by saying that science was the objective study of natural phenomena and depended on scientific method, which if applied rigorously would lead to certain knowledge. Alongside this a crude metaphysical view of the universe was reproduced through generations of school physics classes. It was vast, predictable and fixed, relative to us as observers, and was composed of planets orbiting stars, each possessed of gravitational properties which kept them in fixed unvarying relation to each other. This was the universal realm, but at the realm of the very small a similar behaviour was replicated with billiard ball atoms all behaving predictably in the miniature solar systems of molecules. Although a gross oversimplification of the Newtonian model of the universe, there is at least a common sense spirit of the original that in the intelligent lay person this understanding could be fairly easily converted into a more detailed and correct one. The point is simple: Newton's model was one that could be made intelligible through common sense imagery and this may be the secret of its longevity as a popular metaphysics.

The culture of science in the nineteenth century and the public culture that developed from it depended on successful prediction, which implied, if not determinism, then regularity. This in turn depended on a fixed time–space relationship of the observer to the rest of the universe. Space is an extended entity which contains all objects and events and time is a process which encompasses all other processes. This common sense metaphysical view began to break down within science during the nineteenth century, though there had long been some, such as the philosopher Leibniz, who disputed this 'mechanical' model (Gower 1997: 84–5). In the early years of this century Albert Einstein published two papers with consequences for science equal to those of Newton's work. Einstein, more than any, has perhaps come to symbolise the archetypal genius, but his science and its implications have not translated even into a common sense understanding in the same way as that of Newton did. There is an obvious reason for this, that his physics is completely counter-intuitive to our everyday experience. If every other period of science was, or could be made intelligible to an articulate citizen of the times, it is doubtful whether anything more than a 'hand waving' understanding of relativity theory, or his (and subsequent) work in quantum physics would be available to most of us. The physicist (and one of the originators of the first atomic bomb) Robert Oppenheimer, was pessimistic about the public's ability to understand the new science.

> Our knowledge today can no longer constitute, as knowledge did in Athens or 15th century Europe, an enrichment of genial culture. It will continue to be the privilege of small highly specialised groups, which will no longer be able to render it accessible to humanity at large as Newton's knowledge was rendered accessible.
>
> (Oppenheimer cited in Rouzé 1965: 33)

In the Newtonian or 'common sense' view time and space are fixed and discrete entities with bodies, such as the earth, moving through the 'aether'. This idea, as I noted above, is traceable to Aristotle. Experiments in the nineteenth century, particularly by Michelson and Morley with light waves, showed that the speed of light remains constant whatever the velocity of the observer. If the speed of light was constant for all observers whatever their velocity through space an aether could not exist. Einstein's Special Theory of Relativity, published in 1905 (see Einstein 1956), contains four important ideas: (1) time and space are actually closely linked dimensions; (2) the speed of light in empty space is the same for all observers, regardless of their own speed; (3) the speed of light itself cannot be exceeded; and (4) there is an equivalence of mass and energy (famously expressed as $E = mc^2$). The reasoning for each of these propositions is enormously complex and the result unsettling for one accustomed to a 'Newtonian' universe. It is that our motion is simply relative to the time frame we occupy. Imagine two spacecraft travelling in the same direction, one travelling 1,000 kph faster than the other. Provided there was no other immediate observable frame of reference (such as a planet or a star) to those in the slower spacecraft, the observed effect of the faster spacecraft passing by is no different than if that spacecraft had been stationary and the other spacecraft had passed at 1,000 kph. More mundanely a similar effect can be obtained if one is sitting on a train next to another in a station. Unless one can see beyond the second train to a 'fixed' object it is not possible to tell which train has pulled away. Thus what we see as our fixed position in the universe is not – it is a position simply relative to others.

The 'Special Theory' was an incomplete one, for it referred only to the 'special' circumstances of objects moving at constant speeds in straight lines. The 'General Theory' published in 1915 'generalises' the former to deal with gravity and acceleration, proposing that gravity is a property of space itself, not of bodies (such as stars and planets), and space itself becomes 'curved' as a result of the existence of bodies (Russell 1991: 194–203). Gravity is a consequence of space curved by matter. Finally, space, or more properly space-time, is expanding and can be likened somewhat to a balloon being inflated.

The above is simply a brief description and just tells us minimally what 'relativity' is; it doesn't explain how Einstein reached such conclusions. A successful understanding requires a working knowledge of Galilean and Newtonian mechanics and Euclidean geometry. Euclidean geometry applies to flat surfaces in flat space-time, but the General Theory proposes that since space-time is curved, it therefore depends on a non-Euclidean geometry. It replaces the three dimensions of space with a fourth dimension of space–time. For most of us, even if we had understood Galilean and Newtonian mechanics, it is still hard to hold a mental picture of what this implies. And this is only part of the story. The early years of the century were marked by a new understanding of the composition of matter. The new science of quantum physics arose out of the work of Max Planck, who theorised that energy is absorbed or emitted not as a continuum, or continuously variable entity, but instead in discrete units; what he termed ‘quanta’ (Hoffman 1963: 31–7). Relativity theory showed that matter and energy were interchangeable, and the outcome of these findings was a new understanding of matter as composed of discrete quanta of energy. In 1913 Niels Bohr went on to propose a model of the atom which showed a limited number of possible orbits for its constituent electrons. The new view of the atom, emerging over the next years, was of a number of subatomic particles behaving in distinct ways, depending on the type of atom. But later there came a twist in this story. In 1935 Werner Heisenberg proposed his ‘uncertainty principle’. That is, the ‘fundamental’ particles, of which atoms are composed, behave with uncertainty. What is meant by this is that it is impossible to measure both the position and velocity of such particles simultaneously. Such measurement can be obtained only probabilistically. Indeed, attempts to measure one appear to have an ‘effect’ upon the other. This, it is claimed, is not the result of our inability to measure, but a property of the world itself (Rae 1986).

Relativity theory and quantum physics were not just fanciful ideas, but led to predictions which could be empirically verified. They changed the face of physics fundamentally. Knowledge of the energy–matter relationship led to the development of the atomic bomb, the General Theory of Relativity revolutionised cosmology and in turn led to the ‘big bang’ theory, whilst quantum physics became domesticated into quantum mechanics (Ikenberry 1962). Though science in other ages had the resources to describe the universe, the science of the twentieth century was the most ambitious science ever. In presenting theories of the history and composition of the universe from its origins to now and from fundamental particles to large scale structures spanning millions of light years (Sagan 1980), it embodied greater empirically confirmed detail than ever before. Physics, of course, is not all of science and any account of twentieth-century science would probably have to include the discovery of the structure of DNA by Watson and Crick in 1951 (Watson 1968) or the development of ‘chaos’ theory in mathematics (Gleick 1987), but it is mostly physics, since relativity and quantum theory, that has captured the public mind, either in fear of its consequences or in awe of its possibilities. Stephen Hawking’s *Brief History of Time* (1988) was one of the best-selling non-fiction hardback books ever and it is a brave attempt to make the counter-intuitive science I spoke of intelligible (though of course the purchase of a book does not imply that it is always read, let alone understood!).

Paradoxically the interest in popular science is probably greater than ever at a time when science has reached a level of conceptual and mathematical complexity, such as to put it out of reach of most citizens without at least some knowledge of basic science and mathematics. Whilst the names of Einstein and Hawking are known far beyond their discipline, the everyday mundane world of the laboratory is mysterious and often misunderstood. The science of the twentieth century is truly unnatural.

So what is science?

In this chapter I have tried to show how throughout its history, science (or what has been called science) has been the product of a dynamic interrelationship of metaphysical, social and cognitive factors, not wholly determined by nature, society or prevailing philosophical beliefs. Some characteristics, such as a desire to explain and predict, have always been present, but of course these are present in other areas of life than science. We can point to certain periods in science, for example, the development of experimental method, or the mathematics of the calculus, as being crucial to the nature of modern science, but an encompassing historical definition of science escapes us because in each period what counts as science is different. Of course we could argue that the ensemble of beliefs, knowledge and methods that is science today is what science is. But there are three problems with this. First, it is actually very hard to produce an ensemble that would fit all sciences (and for the moment let us exclude social science). Even if we took the view of Ernest Rutherford that physics was *the* only science and the rest were 'stamp collecting' (Blackett 1973: 159) we would still have to invent a name to encompass the activities that have led to discoveries such as the structure of DNA, the existence of continental drift or the destructive effects of chlorofluorocarbons (CFCs). Second, we would have to explain how it was that past discoveries, that remain part of the current knowledge base of science, could have been discovered in a pre-scientific culture. Third, we would have to show that what counts as science now will continue to do so. If we are inductivists (that is we believe future experiences are likely to resemble past ones in important ways) then we have no grounds for assuming this, since science has changed and dramatically so even in this century. If we are anti-inductivists (see Chapter 2) we would say that we have no grounds to know if this will be the case anyway.

Is the corollary of this that science is anything you want it to be? That Christian science or astrological science are just as much science as physics? Clearly on that basis social science could be admitted to the club. I think the appellations science in the first two examples are simply instances of a desire to claim the authority of science, and I do not think science is whatever is called science. Yet there is more to it than this. In my view science is the ensemble of knowledge and practices that best reflect and operationalise a critical attitude to the discovery of the world at that moment in time. Under this rubric the very worst natural 'science' would not be science, but much of the better social science would be. However, much turns on what counts as the critical attitude to discovery and at any point in the history of science this will be embodied in its methods. It is to these I now turn.

Suggested further reading

Fuller, S. (1997) *Science,* Buckingham: Open University Press.

Horgan, J. (1996) *The End of Science,* London: Little, Brown.

Losee, J. (1980) *A Historical Introduction to the Philosophy of Science,* Oxford: Oxford University Press.

Tarnas, R. (1991) *The Passion of the Western Mind: Understanding the Ideas that Have Shaped our World View,* London: Pimlico.