THE COMPREHENSIBILITY OF THE UNIVERSE
A NEW CONCEPTION OF SCIENCE

CHAPTER ONE A NEW CONCEPTION OF SCIENCE

1 How Does Science Make Progress?

During the last century or so, natural science has met with astonishing success in increasing our knowledge and understanding of the natural world. Science has, it seems, made progress at an ever-accelerating rate.

The question arises: What has been responsible for this progressive success of science? Before the birth of modern science, with the work of Galileo, Kepler and others in the sixteenth and seventeenth centuries, knowledge grew in a rather slow, faltering way, an advance here being offset by a step backwards there. After Galileo and Kepler, the scene is transformed: scientific knowledge begins to grow apparently with ever-increasing rapidity, confidently embracing wider and wider ranges of phenomena. What has made this possible? Assuming that it is above all the exploitation in practice of so-called *scientific method* that makes this dramatic progress in knowledge possible,[1] what precisely *is* scientific method, and how does it make scientific progress possible? What is the methodological *key* to the unprecedented progressive success of modern science?

These questions are thrown into an especially sharp relief by the long-standing failure of scientists, and historians and philosophers of science, to provide an acceptable account of how scientific method does make the growth of scientific knowledge possible. Most strikingly and dramatically, there is the problem of induction - the problem of how it is possible at all to verify scientific theories by means of evidence. Ever since David Hume (1959, book 1) first posed the problem in something like its modern form in 1739, a succession of scientists and philosophers have struggled with the problem: Kant (1961), Mill (1973-4), Peirce (1931-58), Duhem (1954), Poincaré (1952), Russell (1948), Hempel (1965), Carnap (1950), Reichenbach (1938), Ayer (1956), Popper (1959), Lakatos (1970) and many others.[2] Even though there are a few thinkers who claim to have solved the problem - most notably Popper (1972: 1) in recent times - nevertheless the consensus is, in my view correctly, that none of the widely known attempts at solving the problem succeeds. As science has gone from strength to strength, attempts to *understand* how and why science has achieved such astonishing progress have not met with comparable success. Science makes progress, but philosophy of science, it seems, does not.[3]

In this book I put forward a view of science, similar to Einstein's in some respects, according to which science makes a hierarchy of increasingly contentless cosmological assumptions concerning the comprehensibility and knowability of the universe. Corresponding to these cosmological assumptions there are methodological rules which, together with empirical considerations, govern acceptance and rejection of scientific theories. The more contentful of these assumptions (and the methods that correspond to them) evolve with evolving scientific knowledge; the more contentless are permanent items of scientific knowledge, upheld independently of empirical considerations.

This view, I shall argue, solves the central problems of what scientific method *is*, and how and why it is so astonishingly successful in enabling science to increase our knowledge of

Nature. The view, which I call *aim-oriented empiricism* (for a reason which will emerge below), at the same time contains a diagnosis as to why other approaches to solving these key problems concerning the nature and rationality of scientific inquiry have failed. Aim-oriented empiricism, furthermore, has implications not just for the philosophy of science - not just for our understanding of science - but for science too. Not surprisingly, as a result of improving our understanding of science, we are able to improve science itself.[4] Indeed, as I have argued elsewhere, when the view is generalized there are fruitful implications not just for science, but for all of inquiry and, in a sense, for all of life.[5]

2 The Orthodox Conception of Science is Untenable

Aim-oriented empiricism differs from the orthodox view of science, upheld by most scientists, and many philosophers, according to which *the* distinctive feature of science is that laws and theories ought, ideally, in the end, to be accepted and rejected solely with respect to the justice that they do to the evidence, *no substantial thesis about the world being permanently upheld as a part of scientific knowledge independently of empirical considerations*. As Max Planck once put it "Experiments are the *only* means of knowledge at our disposal. The rest is poetry, imagination" (Atkins, 1983: xiv). Or, as Poincaré (1952: 140) put it "Experiment is the sole source of truth. It alone can teach us something new; it alone can give us certainty". Or, again, as Popper (1963: 54) has put it "...in science, *only* observation and experiment may decide upon the *acceptance and rejection* of scientific statements, including laws and theories".

Despite being widely accepted and immensely influential, this *standard empiricist* conception of science (as I shall call it) is untenable, as we shall see in more detail in chapter two. The basic objection is simply this. In physics, any theory, T, however well established empirically, will apply to a vast range of phenomena never observed, most of which, indeed, will never occur at all. It is thus easy to concoct endlessly many rivals to T, which agree precisely with T as far as all observed phenomena are concerned but disagree with T, in arbitrary ways, for different specific unobserved phenomena. There will always be infinitely many such grossly *ad hoc* rivals to T, all equally successful empirically as T itself. It is easy, indeed, to concoct endlessly many *ad hoc* rivals to T that are empirically more successful than T is. If empirical considerations alone govern choice of theory in science, on what grounds are these infinitely many rivals to accepted theories rejected, independently of, or even against empirical considerations?

There is a reply to this objection. Most of those who defend versions of the orthodox view recognize that considerations that have to do with the simplicity, explanatoriness or unity of theories play an important role in science in determining what theories are accepted and rejected *in addition* to empirical considerations. This is true, for example, of Planck, Poincaré and Popper. The reason, then, that empirically successful, *ad hoc* rivals to accepted theories are rejected is that these theories, being *ad hoc*, violate requirements of simplicity.[vi]

But this reply fails (as we shall see in more detail in chapter two). It has at least two fatal defects. First, in persistently rejecting theories that violate requirements of simplicity, however empirically successful they may be, science in effect makes a persistent, substantial assumption about the world independently of empirical considerations, to the effect, at the very least, that the phenomena occur as if exhibiting simplicity (so that all *ad hoc* theories are false). This violates the central tenet of standard empiricism that no such assumption must be permanently upheld in science as a part of knowledge. Second, attempts to explain what the simplicity of a theory *is*, within the framework of standard empiricism, all fail. In chapter two we shall see that there are further objections to standard empiricism, in all ten problems which the doctrine cannot solve.

3 The Fundamental Epistemological Dilemma of Science

The collapse of standard empiricism means that it is impossible to do science without some permanent assumption about the nature of the universe being made independently of empirical considerations. If no such assumption is made, the empirical method breaks down. Science becomes drowned in an ocean of empirically successful *ad hoc* theories.

But what ought this assumption to be? And on what grounds can it be made?

It might seem that this assumption ought to be the least contentful that can be made that makes theoretical physics possible. This idea will be considered and rejected in chapter three; further arguments against it will be given in chapter six. A basic objection to the idea is that it turns out to be impossible to formulate an assumption which is *both* (i) sufficiently precise and contentful to be incompatible with all empirically successful *ad hoc* theories, *and* (ii) sufficiently imprecise and contentless for its acceptance to be justified on the grounds that, unless this assumption is made, science and the acquisition of factual knowledge more generally, become impossible. An additional objection is that an assumption which merely excludes *ad hoc* theories is insufficiently scientifically fruitful; what we really require is an assumption that promotes the growth of theoretical knowledge, which guides us to the development of good new theories.

It is important to appreciate just how unavoidable and fundamental is the dilemma[vii] confronting the entire scientific endeavour that we are considering here - a dilemma whose very existence is obscured by the acceptance of standard empiricism. If science is to be possible at all, some kind assumption must be made about that of which we are most ignorant: the ultimate nature of the universe.[viii] But even worse, it is above all here, where we are most ignorant, that it is vital, for the success of science, that we make as good an assumption as possible, one which does the best possible justice to the real nature of things. For it is this basic cosmological assumption that will determine our methodology, what kind of theories we are prepared to consider. If, for example, we believe that a society of gods governs the natural world then, in seeking to improve knowledge of and control over natural processes, it will be entirely rational (relative to this belief) to adopt such methods as prayer, sacrifice, consultation of prophets, oracles, omens and dreams. But if we believe that a pattern of physical law governs natural processes, quite different methods will need to be adopted, namely those of putting forward precise hypotheses concerning possible laws governing phenomena, to be tested against observation and experiment. Metaphysics determines methodology. This makes it of paramount importance that a good basic metaphysical conjecture is adopted, one which corresponds near enough to how the universe actually is. A bad basic metaphysical conjecture, hopelessly at odds with the actual nature of the universe, will lead to the adoption of an entirely inappropriate set of *methods*, and the result will be failure - failure, possibly, of a peculiarly persistent kind. The wrong kind of hypotheses will persistently be put forward, which will be assessed in the wrong kind of way. Thus, if the world is in reality governed by a society of gods but we are convinced it is governed by a fixed, unified pattern of physical law, our whole approach to improving knowledge and control of Nature will be misguided. Instead of trying to find out what it is that pleases and angers the gods, so that we may encourage the former and avoid the latter, we will put forward and test hypothetical laws governing natural processes. Our efforts in this direction will succeed only insofar as the gods choose to behave in a precisely regular fashion. But if the gods are anything like gods traditionally have been believed to be (wilful, vain, childish), our attempt to reduce them to patterns of lawful regularity is likely to provoke them into behaving with unpredictable outrage. Our specific laws will be refuted but, convinced that laws of some kind must govern phenomena, we will try to discover more successful laws; we will not conclude that our whole approach is wrong. Equally, of course, if things are the other way round, and we are convinced phenomena are controlled by gods in a world that is actually governed by some utterly impersonal pattern of physical law, our whole approach to improving our knowledge of and influence over natural processes will be inappropriate. There will be some apparent successes, as when the tribal witch doctor or shaman apparently succeeds in curing disease or causing rainfall by calling upon the gods; these successes will help to keep alive the basic creed. Many failures need not at all, however, cast doubt on the basic creed, for the creed will contain explanations as to why such failures should occur: anger of the gods at undisclosed crime, or evil thoughts, within the tribe, for example. Indeed, if the creed determines the methodology whereby beliefs are developed and assessed, beliefs that clash with, or cast doubt on, the basic creed will be excluded *a priori* as it were. In this way, it may be very difficult indeed to escape from a bad choice of basic metaphysics, even though it leads to a programme of improving knowledge and control of natural processes that meets with only very limited success.[ix] (It is in part for this reason that it took so long for humanity to create modern science.[x])

The dilemma, in short, amounts to this. In order to proceed at all we must make some assumption about the ultimate nature of the universe; in order to proceed successfully we must make an assumption that is near enough correct; if our assumption is badly wrong, not only will progress in knowledge be seriously impeded but, in addition, it may be very difficult for us to discover our basic mistake: and yet it is above all here, concerning the ultimate nature of the universe, that we are horribly ignorant, and are almost bound to get things hopelessly wrong.

Aim-oriented empiricism, the view defended in this book, emerges as the solution to this dilemma. It can be summarized like this. We need, first, to make explicit that cosmological assumption that may be regarded as being implicit in our current methodology, and then extract from this a hierarchy of increasingly attenuated metaphysical[xi] cosmological assumptions concerning the comprehensibility and knowability of the universe, until we arrive at assumptions which are such that doubting them cannot help the growth of knowledge, whatever the nature of the universe may be. At each level in the hierarchy of assumptions we adopt that one which holds out the greatest hope for the growth of knowledge, and which seems best to support the growth of knowledge. If currently adopted cosmological assumptions, and associated methods, fail to support the growth of empirical knowledge, or fail to do so as apparently successfully as rival assumptions and methods, then assumptions and associated methods are changed, at whatever level appears to be required. In this way we give ourselves the best hope of making progress, of acquiring authentic knowledge, while at the same time minimizing the chances of being taken up the garden path, or being stuck in a cul de sac. The hope is that as we increase our knowledge about the world we improve the cosmological assumptions implicit in our methods, and thus in turn improve our methods. As a result of improving our knowledge we improve our knowledge about how to improve knowledge. Science adapts its own nature to what it learns about the nature of the universe, thus increasing its capacity to make progress in knowledge about the world.

[1.] Other factors - economic, technological, cultural and political - of course contribute to making scientific possible; but without the crucial requirement of an appropriate methodology being put into practice, these other factors will be impotent.

[2.] See Kyburg (1970), Hesse (1974), Watkins (1984), Glymour (1980). The books by Kyburg and Watkins have extensive bibliographies on works concerned with the problem of induction.

[3.] Some contemporary historians and philosophers of science appear to have abandoned all hope of understanding how scientific *progress* in knowledge is possible. They seek merely to describe and explain, in sociological terms, scientific *change*. See for example Barnes and Bloor (1982).

[4.] For earlier expositions of aim-oriented empiricism see Maxwell (1974, 1976b, 1977, 1979, 1984a, 1993c).

[5.] In my view, it is the broader implications of this new conception of scientific method and rationality for the whole of academic inquiry and, above all, for the task of creating a better world, that are really important. In this book, however, there is space only for an exposition and defence of the conception of science itself. For the all-important broader *implications* of this new view of science see especially Maxwell (1984a); see also Maxwell (1976b, 1980, 1984b, 1985a, 1986, 1987, 1990, 1992a, 1992b, 1993b, 1993d, 1994b, 1996, 1997).

[vi.] Here, and in what follows, "simplicity" is taken to include "explanatoriness", "unity" and other possible non-empirical considerations governing choice of theory in science, such as "elegance", "symmetry", "beauty", "comprehensibility",

[vii.] It deserves to be called "the fundamental epistemological dilemma of science". It is more fundamental than the problem of induction, which only arises if the need for science to make some kind of substantial cosmological assumption is denied.

[viii.] It is important to appreciate that even if we try to formulate an assumption that is as much as possible about local observable phenomena only, and thus as far as possible away from being about "the ultimate nature of the universe", such an assumption will, nevertheless, remorselessly, contain some assumption about the ultimate nature of the universe, to the effect that it is such as to permit local, observable phenomena to be as the assumption asserts them to be. However instrumentalistic or phenomenalistic one may seek to be in couching cosmological assumptions of science, such assumptions will carry some implications about the ultimate nature of reality.

[ix.] Even when the assumption that sustains the methodology is a falsifiable theory rather than an unfalsifiable metaphysical thesis, it still may be difficult to reject the theory in the light of empirical difficulties, as Kuhn has shown in his account of the resistance encountered within science to the overthrow of paradigms that have encountered anomalies: see Kuhn (1970: chs. VIII-IX and XII).

[x.] An additional difficulty involved in creating modern science has to do with the nature of the metaphysical conjecture that needs to be adopted for science to succeed, namely that some kind of impersonal unified pattern of physical law determines how events occur. This is an inherently difficult idea to make precise; as we shall see in chapter four, it requires, amongst other things, the mathematical theory of differential equations. It has disturbing consequences for the nature and value of human life, having to do especially with consciousness and free will. (How can there be consciousness and free will if everything is physically determined?) And the mode of explanation for natural phenomena that it makes possible is profoundly unintuitive for human beings. Human consciousness evolved within the context of social life, in part as a result of the need to understand others in terms of their desires, intentions, beliefs, feelings. This personalistic mode of understanding, being intimately bound up with our existence as conscious beings, is the "natural", intuitive way for us to understand things. It is not surprising, then, that humanity should (initially) try to understand the natural world in the same sort of way, in terms of the desires, intentions of gods. It has been extraordinarily difficult and painful for humanity to discover that the universe is not comprehensible in this personalistic fashion but, on the contrary, is only physically comprehensible in terms of some unified pattern of physical law. In many ways, indeed, the discovery has not yet been made; hence the need for this book.

[xi] A "metaphysical" thesis, as understood here, is a general, factual thesis about the world which lacks the *precision* of a physical law or theory, and thus fails to make the precise empirical predictions of a law or theory. In general, given a metaphysical thesis, B, it will be possible to make this precise (so that it becomes capable of making precise predictions) in infinitely many different ways. Thus B might be atomism: the world is made up of atoms, of some size and mass, which stick together in some way. This vague, metaphysical doctrine becomes a scientific theory as it is given greater precision and becomes, as a result, testable. This notion of "metaphysical" does not draw a sharp line between the metaphysical and the testably scientific. The "metaphysical" doctrine that there are only repulsive forces in the world is refuted by the observation that attractive and cohesive forces do exist: the "metaphysical", as understood here, cannot be equated with the "unfalsifiable" in a Popperian fashion: see Popper (1959: 40-42 and 78-86). On the other hand, most physical theories have an element of imprecision: a constant, such as the constant of gravitation, "G", in Newtonian theory, is determined only within a range of values. A theory with an imprecise constant corresponds to an infinity of different precise theories, each with its own distinct, precise value of the constant. Newtonian theory fits the definition of a metaphysical thesis! The distinction between the physical and metaphysical is thus, to some extent, a matter of degree. (Popper's distinction between the scientific and the metaphysical is also, it should be noted, a matter of degree.) As far as Newtonian theory is concerned, if the constant G is fixed as narrowly as possible, within the accuracy of current measurements, the theory is a level 2 *physical* theory; if the constant G is left completely undetermined, the theory becomes a level 3 metaphysical assertion, and further generalizations make it all the more metaphysical in character.