PHILOSOPHY OF SCIENCE

An Overview for Cognitive Science

WILLIAM BECHTEL
PHILOSOPHY OF SCIENCE

An Overview for Cognitive Science
Tutorial Essays in Cognitive Science

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BECHTEL: Philosophy of Science: An Overview for Cognitive Science

BECHTEL: Philosophy of Mind: An Overview for Cognitive Science

GREEN: Linguistic Pragmatics for Cognitive Science
This volume is dedicated to the memory of

HANNA

who helped in ways she could not understand
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As one of the several contributing disciplines to cognitive science, philosophy offers two sorts of contributions. On the one hand, philosophy of science provides a metatheoretical perspective on the endeavors of any scientific enterprise, analyzing such things as the goals of scientific investigation and the strategies employed in reaching those goals. Philosophy of science thus offers a perspective from which we can examine and potentially evaluate the endeavors of cognitive science. On the other hand, philosophy of mind offers substantive theses about the nature of mind and of mental activity. Although these theses typically have not resulted from empirical investigation, they often have subsequently figured in actual empirical investigations in cognitive science, or its predecessors. Because the two roles philosophy plays in cognitive science are quite different, they are introduced in separate volumes. This one focuses on philosophy of science, whereas issues in philosophy of mind are explored in Philosophy of Mind: An Overview for Cognitive Science.

The strategy for this volume is to present a variety of views from philosophy of science that have figured in discussions about cognitive science. Some of these views are no longer widely accepted by philosophers of science. Nonetheless, they have been and, in some cases, remain influential outside of philosophy. Moreover, some older views have provided the starting point for current philosophical thinking that is done against a backdrop of previous endeavors, with a recognition of both their success and failure.

After an introductory chapter that introduces some of the other domains of philosophy that are pertinent to philosophy of science, this book falls into two main parts. Chapters 2, 3, and 4 explore general views about the nature of science and scientific explanation. Chapter 2 focuses on Logical Positivism,
a comprehensive view of the character of scientific theories and their status as claims to knowledge that was developed in the first half of this century. As I discuss in chapter 3, many of the doctrines of Logical Positivism have been criticized and the position is no longer widely accepted. But it continues to have wide influence in science. Its influence is particularly noticeable in the standard accounts of scientific method presented in the early chapters of introductory science texts. One reason Logical Positivism remains influential is that there has been no successor perspective that has gained comparable acceptance. A new perspective, however, is arising amongst those philosophers who have taken seriously the importance of actual scientific practice, particularly as revealed through the history of science. This new approach, which began with Thomas Kuhn's *The Structure of Scientific Revolutions*, (1962/1970), is discussed in chapter 4.

Chapters 5 and 6 explore an issue in philosophy of science that is particularly pertinent to practitioners of cognitive science. This is the question of the proper way of relating inquiries in different disciplines of science. A legacy of Logical Positivism, the Theory Reduction Model offers one widely discussed model for relating disciplines. It focuses on the relationship between the cognitive sciences and neuroscience and advocates the view that cognitive science theories should be reducible to neuroscience theories. This model, which has recently been defended in the influential text of Patricia Churchland, *Neurophilosophy* (1986), is discussed in chapter 5. A number of philosophers, however, have come to reject the Theory Reduction Model and have sought alternative views of the relationships between disciplines. One of these is discussed in chapter 6. It provides not only a different perspective on the relationship of cognitive science to neuroscience but also on the interactions of disciplines within cognitive science itself.

For those not previously acquainted with philosophy, some comments about how to approach philosophical material are in order. Although it used to be widely proclaimed that philosophical claims do not require empirical evidence, this view is much less accepted today. It remains the case, however, that philosophical claims tend to be fairly far removed from empirical evidence. Therefore, there tends to be much greater room for argument as to the virtues of particular claims than in many cases where empirical evidence is readily at hand. In considering the views discussed in this book, the reader should bear in mind the controversial and argumentative character of philosophical inquiry. This means that rather than simply accepting or rejecting a view, the reader should consider the possible kinds of arguments that might be made on behalf of or against the views presented. The reader, thereby, enters into the argument itself, and does not remain a passive observer. Although the accumulated efforts of philosophers provide a resource for anyone taking up these issues, the issues are not the exclusive prerogative of philosophers; scientists are encouraged to engage with the issues themselves and to reach their own conclusions.
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INTRODUCTION: WHAT IS PHILOSOPHY OF SCIENCE?

This volume is devoted to introducing some of the basic issues in philosophy of science to the practitioners of the various disciplines of cognitive science: cognitive psychology, artificial intelligence, cognitive neuroscience, theoretical linguistics, and cognitive anthropology. Philosophy of science is a field devoted to analyzing the character of scientific investigations. It attempts to answer such questions as: What is a scientific explanation? To what extent can scientific claims ever be justified or shown to be false? How do scientific theories change over time? What relations hold between old and new theories? What relations hold, or should hold, between theoretical claims developed in different fields of scientific investigation? A variety of answers that philosophers have offered to these and other questions are examined in subsequent chapters of this book. Before turning to the concrete views philosophers have offered, however, it is useful to put the attempts to address these questions in perspective.

Since antiquity, philosophers have been interested in science for the reason that science seems to represent the most rigorous attempt by humans to acquire knowledge. This has led a number of philosophers to seek a criterion by which they could distinguish scientific endeavors and the resulting knowledge claims from other knowledge claims humans have advanced (e.g., ones based on mysticism, intuition). Philosophers, however, have not been the only people who have been fascinated by science and who have attempted to explain how it works. Historians have long been interested in the develop-
ment of science, partly as an area of intellectual history. More recently, social historians and sociologists have focused on science and the social context in which scientific investigation occurs. There have even been a few investigations by psychologists directed at the scientific endeavor itself. Although there have often been bitter controversies between philosophers, historians, sociologists, and psychologists of science as to which discipline's methodology provides the best tool to explicate the nature of science, there is beginning to emerge a cluster of practitioners from a variety of disciplines who take science as their subject matter. Increasingly, the term science of science is being used to characterize these investigations.

As the term science of science suggests, the inquiry into the nature of science, whether carried out by philosophers or others, is a reflexive endeavor, using the very skills that are employed in human inquiry to understand the human race's most systematic example of inquiry—science. This reflexive inquiry, especially as done by philosophers, has had profound consequences on science itself. Many scientists have been seriously concerned with the issues of philosophy of science. Such concern is particularly likely to be expressed in the context of open debates within the scientific community when questions arise as to proper scientific strategy or legitimate style of scientific explanation. (The recent history of psychology has witnessed such controversies in the battles between behaviorism and cognitivism, whereas cognitive science generally is currently witnessing such a battle between connectionists and those advocating rules and representations accounts of mind.) Some scientists who become concerned about philosophy of science issues may become contributors to the literature in philosophy of science (e.g., Polanyi, 1958). Most scientists, however, simply adopt a philosophy of science that is popular, or that suits their purposes, and cite it as authority. This proclivity to borrow positions from philosophy is rather common but poses serious dangers because what may be quite controversial in philosophy may be accepted by a particular scientist or group of scientists without recognizing its controversial character.¹ One of the objectives of this volume is to attempt to alleviate this situation in cognitive science by providing a brief, introductory account of the various competing philosophical perspectives on the nature of science. Then, if readers adopt a particular view of what science is, they will do so with some awareness of the alternatives and of some of the controversies that surround the position.

There are no sharp boundaries that divide the analyses of science advanced by philosophers from those offered by historians, sociologists, or psycholo-

¹ The fact that scientists have invoked a variety of positions developed in the philosophy of science literature requires that in this text I do not simply introduce the most prominent current positions, but also those that have been influential in the recent past and that still live on in the thinking of many scientists.
gists. In general, however, philosophers have tended to be more interested than practitioners of these other disciplines in the reasoning processes actually or ideally employed by scientists and have sought to identify criteria that give scientific claims their objective validity. Moreover, philosophers bring to their analyses of science a background that involved training in other areas of philosophy. As a result, they often call upon the conceptual tools developed in other areas of philosophy in analyzing science.² To provide nonprofessional philosophers the necessary background to understand and appreciate the claims made by philosophers of science, the remainder of this chapter is devoted to providing a brief introduction to other areas of philosophy that bear upon philosophy of science.

AREAS OF PHILOSOPHY THAT BEAR ON PHILOSOPHY OF SCIENCE

Philosophy as practiced in the modern Western world is probably best characterized as an attempt to develop systematic and defensible answers to such questions as: What are proper modes of reasoning? What are the fundamental categories of things? How can humans know about the natural world? How should humans behave? These questions define the basic domains of philosophy—logic, metaphysics, epistemology, and value theory. All of these bear to some degree on philosophy of science. The following is a brief account of the basic issues in each of these domains and of how these issues impact on philosophy of science.

Logic

The central issue in logic is the evaluation of argument. An argument is simply a set of statements, some of which serve as premises or support for others, that are called conclusions. Two criteria are relevant to evaluating arguments: Is the argument of such a sort that if the premises were true, the conclusion would also have to be true? and Are the premises true? An argument that satisfies the first of these criteria is traditionally called valid whereas an argument that satisfies both is called sound. The discipline of logic is primarily concerned with the first of these criteria, that is, with determining whether the argument is of a sort where the truth of the premises guarantees the truth of the conclusion. The truth preserving ability of an argument turns out not to depend on the content of what is stated in the argument but only on the

² A useful introduction to philosophical methodology is Woodhouse, 1984.
form of the argument. The concept of argument form can be explicated intuitively as that which remains when all the words or phrases bearing content have been replaced by variables, provided that the same substitution is made for all instances of words or phrases that have the same content. (For example the logical form of the sentence “It is raining and it is cold” might be “x and y,” where x and y are variables.)

There have been two basic accounts of logical form in the history of philosophy. One goes back to Aristotle and gives rise to what is called syllogistic logic. The second was developed in the later 19th and early 20th centuries, principally through the work of Frege and Russell, and constitutes what is commonly referred to as symbolic logic. Syllogistic logic can be construed as a logic of classes, and uses information about what class an object belongs to or information about class inclusion to determine other relationships. The basic form of reasoning employed is the syllogism in which two statements about membership relations between objects and classes of objects are used to support an additional statement. The following is a typical valid syllogism:

All humans are mortal.
All Greeks are human.
Therefore, all Greeks are mortal.

Although syllogistic logic proved useful for capturing a variety of valid forms for arguments, there were a significant number of arguments that could not be captured. Modern symbolic logic was developed in order to overcome this shortcoming. There are two components of symbolic logic. The first is commonly spoken of as sentential logic or propositional logic, and the second is called quantificational logic or predicate calculus. Sentential logic takes simple complete sentences or propositions such as “it is raining” as units. It then uses truth functional connectives to build more complex, compound sentences. A connective is truth functional if the truth or falsity (truth value) of the compound sentence can be ascertained just by knowing the connective employed and the truth value of the component sentences. Although the connectives of sentential logic are defined in terms of precise rules that deviate from those governing the corresponding English words, the main connectives are generally expressed using the words “not,” “and,” “or,” “if ——— , then . . .,” and “if and only if.” Through a device known as a truth table, one can show how the truth values of various compound sentences depend on those of the component sentences (represented by the letters A and B). The truth value of a sentence is indicated by placing a T or F in the appropriate place in the table. The truth tables for sentences formed using the basic connectives just listed are shown here (a common symbol for the connective is indicated below the English statement for the compound):
The truth table for most of these connectives is just what one would expect. The troublesome one is the “if A, then B” connective, which is somewhat counterintuitively assigned the truth value true whenever A (the antecedent) is false. Part of the motivation for this interpretation can be captured by considering under what circumstances the statement could be recognized as false. The only such circumstance is where A is true and B (the consequent) is false. One important point to notice, though, is that given this interpretation of the “if ———, then . . .” connective, it is not proper to think of it as equivalent to implication. Logicians, rather, speak of it as the “material conditional.”

Derivations in sentential logic use premises and conclusions consisting of either simple statements or compound statements constructed from simple statements using these truth functional connectives. There are many such forms of valid derivations. One of the most important of these, known as *modus ponens* or “affirming the antecedent,” is the following:

If A, then B.
A
Therefore, B.

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3 There is a connection between the material conditional and implication. If a conditional statement is a tautology, that is, a statement that cannot be false, then one can speak of the consequent as implied by the antecedent. But in ordinary conditional sentences, this does not hold. This treatment of the “if , then . . .” connective results in a number of theorems that some logicians have found paradoxical and so labeled the *paradoxes of material implication*. One theorem is the statement “— (A — B),” which says that if A is false, then if A then B is true. If “—— then . . .” is read as “— implies . . .”, then one gets the paradoxical sounding statement “not A implies that A implies B”. Another example of a paradox of material implication is the theorem “(A — A) — B”. Reading this using implies yields “the contradiction A and not A imposes any statement whatsoever.” Logicians have differed as to whether there is anything really paradoxical here and whether any change is needed to remedy the situation. Those who defend the material conditional simply insist that it ought not be read as “implies.” (For a criticism of the material conditional based on the paradoxes, see Anderson & Belnap, 1975, and for a defense of the material conditional, see Hughes & Cresswell, 1968.)
Another very important form, known as *modus tollens* or "denying the consequent," has the following form:

If A, then B.
Not B.
Therefore, not A.

Treating these and some other basic forms as rules that license inferences from statements of the form of the two premises to statements of the form of the conclusion yields a system of *natural deduction*. In such a system you begin with a set of premises and apply a series of such rules to derive an ultimate conclusion.

Of course, not all forms of argument are valid. There are, in fact, two invalid forms that closely resemble the valid forms above. The first, known as *affirming the consequent*, has the following form:

If A, then B.
B
Therefore, A.

The second, known as *denying the antecedent*, has the form:

If A, then B.
Not A
Therefore, not B.

The forms can be recognized as invalid by substituting "it rains" for A and "the game will be cancelled" for B. Now assume in each case that the premises are true and consider whether the conclusion might be false. Because it clearly could be false, the argument form is not valid.

*Quantificational logic* expands on the power of sentential logic by exposing the inner structure of the basic statements used in sentential logic and showing how a variety of valid forms rely on this structure. The structure in question is the basic subject-predicate structure, as is found in the sentence "the sky is blue." To represent this structure, replace the subject terms (those referring to objects) with lower-case letters from the beginning of the alphabet and predicate terms with upper-case letters from the middle of the alphabet. Thus, the earlier sentence may be represented as "Pa," where P = "is blue" and a = "the sky." The predicate term in this case covers only one object, and so is termed *monadic*. It is also possible to have relational predicates that take two or more objects. For example, "taller than" is a relational predicate and the sentence "Carol is taller than Sarah" may be represented Tab.
In addition to representing statements referring to specific objects, quantificational logic allows for generalizations that assert either that a statement is true for any object or for at least one. Thus, the statement “All dogs have hearts” can be symbolized as $(\forall x)(Fx \rightarrow Gx)$, which is read “For all $x$, if $x$ is a dog, then $x$ has a heart.” Similarly, the statement “There exists a white dog” is symbolized as $(\exists x)(Fx \cdot Gx)$, which is read “There exists an $x$ such that $x$ is white and $x$ is a dog. In natural deduction systems for quantificational logic there are specific rules governing when it is permissible to introduce or remove these quantifiers. These rules give quantificational logic a power deductive structure. (For an introduction to symbolic logic and many issues concerning logic relevant to cognitive science, see McCawley, 1981.)

The interest in logic, however, goes beyond the ability to use it to produce detailed proofs. There are interesting properties that can be proven of logical systems themselves. Many of these proofs of what are called metatheorems were developed as part of an endeavor to use logic to provide a foundation to arithmetic. Frege, for example, set out to show that all the truths of mathematics could be rendered in terms of arithmetic and that all the principles of arithmetic could be rendered in terms of logic. (This project is known as the reduction of mathematics to arithmetic, and arithmetic to logic.) Frege had to abort his program when Russell pointed out a contradiction in the system Frege had developed. Logic requires consistent systems because if a system is inconsistent it is a trivial exercise to derive any statement from it. One of the basic things that must be established for any logical system, therefore, is that it is consistent. The demonstration that Frege’s system for deriving arithmetic from logic was inconsistent undercut the interest in that system.

The program of reducing arithmetic to logic turned out to be impossible, but pursuit of this program resulted in number of important findings. For example, in addition to consistency another important property of a logical system is completeness. A complete system is one in which the axiom structure is sufficient to allow derivation of all true statements within the particular domain. Kurt Gödel established that quantificational logic is complete—any statement that must be true whenever the premises are true can, in principle, be derived using the standard inference rules for quantificational logic. But the fact that a system is complete does not mean that a procedure exists to generate a proof of any given logical consequence of the premises. If such a procedure exists the system is decidable. Sentential logic is decidable, and so are some restricted versions of quantificational logic. But Church proved that general quantificational logic is not decidable. In general quantificational logic, the mere fact that we have failed to derive a result from the postulates does not mean that it could not be derived; it may be that we simply have not yet constructed the right proof. Of even more significance to the program of grounding mathematics in logic was Gödel’s proof that, unlike
quantificational logic, there is no consistent axiomatization of arithmetic that is complete. This is referred to as the *incompleteness of arithmetic* and is commonly presented as the claim that for any axiomatization of arithmetic there will be a true statement that cannot be proven within the system. (For detailed treatments of these theorems, see Quine, 1972, and Mates, 1972.)

Some of these theorems about logic have played important roles in the development of computer science. Other claims of logic, which are commonly accepted as true but which are not or cannot be proven, have figured prominently in motivating the use of computers to study cognition. An example is Church’s thesis, which holds that any decidable process is effectively decidable or computable, which is to say that it can be automated. If this thesis is true, then it follows that it is possible to implement a formal system on a computer that will generate the proof of any particular theorem that follows from the postulates. The assumption that this thesis is true has buttressed the use of computers in studies of cognitive processes. Assuming that cognition relies on decidable procedures, this thesis tells us that these procedures can be implemented on a digital computer as well as in the brain. (For a challenge to this assumption, see Smolensky, in press.)

Symbolic logic has played a more general role in artificial intelligence. Many have assumed that the procedures of symbolic logic characterize much of human reasoning, and because these procedures can readily be implemented on a computer, many investigators have tried to develop simulations of human reasoning using computers equipped with these inference procedures. For our purposes here, however, the interest in logic is that numerous philosophers have tried to explicate scientific theories as logical structures and the structure of scientific explanations in terms of formal logical derivations. We see this prominently in chapters 2 and 5.

**Metaphysics**

Metaphysics seeks to determine what are the basic or fundamental kinds of things that exist and to specify the nature of these entities. Historically, interest in metaphysics centered on such issues as whether a supreme being or a creator god exists, whether there are mental phenomena or spiritual phenomena that are different from physical phenomena, or whether there is such a thing as free will (for sample writings, see Taylor, 1978). In more recent times it has addressed the question of the kinds of entities that we can include in scientific theories. For example, are mental events the kinds of things that should be posited in a theory of human action? The set of entities posited is generally said to specify the ontology to which the theory is committed.

It is important to note that the character of metaphysical questions is generally taken to be different than the character of ordinary empirical ques-
tions such as whether there are any living dinosaurs. With such empirical questions we rely on such techniques as ordinary observation to settle the issue. Ontological questions are thought to be more fundamental and not resolvable by ordinary empirical investigations. It was thought that to address the classical questions of the existence of God or of minds separate from bodies required a kind of inquiry that went beyond ordinary empirical investigation. Sometimes it was claimed that such issues could be addressed simply through the tools of logic. For example, the ontological argument for God’s existence tried to argue from the idea of God as a perfect being to the actual existence of God. It claimed this could be done by invoking the principle that if God did not exist, there would a more perfect being—a being just like God but who actually existed. Thus, the assumption that God does not exist is claimed to be contradictory, so God must exist. The modern ontological questions concern how we should set up the categories through which we conduct our empirical inquiry. The question of the appropriate categories arises prior to empirical observation and so cannot be easily settled by means of such observation.

To many nonphilosophers both classical and contemporary questions of ontology seem peculiarly remote and unproductive. Of what value would it be to have an answer to an ontological question? The very character of ontological questions suggests that they lack practical significance. If ontological differences do not entail physical differences, it would seem that one could hold whatever ontology one wanted and still deal with the physical world in much the same way. When the challenge is put in this way, philosophers often find themselves hard put to provide a satisfactory answer. A number of philosophers, in fact, have tried to divert attention away from metaphysical issues. The logical positivists, whom I discuss in the next chapter, claimed that most classical questions of ontology were meaningless, whereas Ludwig Wittgenstein (1953) tried to convince readers that when philosophers raised such issues they were letting their language go on a holiday, not raising real questions at all.

Other philosophers have sought to reduce the distance between ontological inquiries and empirical ones. Quine (1953/1961b; 1969a), for example, proposed that when we settle on a scientific theory we thereby settle the question of what ontological scheme we accept. Invoking the framework of quantificational logic, where all the terms referring to objects can be represented as variables in quantified expressions, Quine offers the maxim “to be is to be the value of a bound variable” (1953/1961b, p.15; i.e., the objects to which we attribute properties in our theories are the ones whose existence we accept). Although this attempt to place ontological questions in the context of scientific inquiry may seem particularly attractive when we consider how perplexing the issues are otherwise, we should not think that thereby we really avoid them. What this proposal overlooks is that many of the debates over
the adequacy of scientific theories have focused on the ontology assumed by 
the theory. This has been particularly true in recent psychology, where there 
have been active disputes over whether to count mental events as causal fac­ 
tors in an explanatory theory. But such questions are not peculiar to psy­ 
chology. In physics and biology as well, disputes between theories have often 
turned on ontological issues as much as on empirical issues. For example, 
there was a long controversy between Cartesians and Newtonians during 
the 17th and 18th centuries over the legitimacy of appeals to action at a dis­ 
tance (as is countenanced by the Newtonian concept of gravity). Embryology 
at the end of the last century was torn by a prolonged battle between vitalists 
and mechanists over the appropriate kind of explanation for developmental 
phenomena.

Citing these historical examples may engender the response that although 
at the time the ontological issues loomed large, these issues have now been 
resolved and what resolved them was the success of a scientific theory. There 
is something correct about this observation. These controversies do show 
that empirical considerations are relevant to settling ontological questions. 
But they do not show that the ontological questions are insignificant to the 
development of science and can simply be ignored. An examination of con­ 
temporary physics and biology shows that in these disciplines ontological 
issues are still central. In quantum physics, theorists are split over whether 
a unified account of the basic forces of nature is needed, or whether a dualistic 
account is acceptable. In evolutionary biology there is active disagreement 
over whether selection works only on individuals or whether it also works 
on higher level entities like groups or species (see papers in Sober, 1984, for 
an introduction to this debate). Similar controversies exist in cognitive science 
even amongst those who accept the legitimacy of mentalistic explanation. 
Barwise and Perry (1983), for example, proposed an approach to semantics 
according to which the semantic content is not totally represented in sym­ 
\n\nsbols within the cognitive system but depends on the context in which the 
cognitive system is embedded. They maintained, moreover, that the 
legitimacy of inference also depended on the context and could not be specified 
totally in formal principles governing the manipulation of symbols. In this 
\n\nthey seem to have violated an ontological principle, the formality constraint, 
which Fodor (1980) has articulated for cognitive science. According to the 
formality principle, all information that is to affect the system's behavior must 
be formally represented. Thus, the question is raised as to whether the for­

mality condition is a proper ontological principle for cognitive science. (For 
a sample of this debate, see Fodor, 1987, and Barwise, 1987.)

The evaluation of theories often depends on judging the coherence of their 
ontological assumptions. Theories that make inconsistent ontological assump­
tions, or ones that contemporary researchers find unacceptable, are criticized 
in much the same way as theories that make false empirical predictions. Yet,
in some way empirical criteria must be applicable if ontological issues are to be settled. The link between ontological issues and empirical inquiry stems from the fact that although ontological issues often play a role in developing a particular kind of research program, the ability of such a research program to produce a progressive tradition of theorizing often affects subsequent judgments about the adequacy of the ontological position underlying the program.

The previous paragraph may suggest the false view that because ontological issues are partly settled by the adequacy of the research programs based on them, we need to wait for the verdict of history on the fruitfulness of such research programs to evaluate ontological positions. However, the dialogue is often much more interactive than this. From the collective experience of attempting to develop accounts of nature, we can evaluate whether particular ontological positions are likely to be satisfactory, or will lead to unsolvable problems. When we recognize that certain assumptions are likely to produce problems, we can anticipate them. Sometimes these very problems can be avoided by reshaping the theory within a different ontological framework. Then, in order to avoid the problems, it is useful to take seriously the ontological commitments being made and to reformulate hypotheses in a framework that will avoid the problems.

Metaphysical questions are clearly important to science, but, as I have noted, some philosophers of science, including the Logical Positivists, have tried to dispense with them as pseudo-issues. Nonetheless, other philosophers, whom I consider in chapter 4, have argued for a prominent role for metaphysical questions in determining the direction and progress of science. Further, even the Logical Positivists, in their model of theory reduction, provided a framework for unifying the ontologies of different theories, as we see in chapter 5. Thus, metaphysical issues are quite pertinent to philosophical accounts of science.

**Epistemology**

Whereas metaphysics is concerned with delimiting the fundamental categories of what exists, epistemology is concerned with the question of what knowledge is and how it is possible. Epistemological discussion often has been prompted by skeptical doubts that what we believe might be false. Although there have been skeptics throughout history who have challenged people’s knowledge claims, perhaps the most profound skeptical challenge is found in the 17th century philosopher Descartes (1641/1970), who began his *Meditations on First Philosophy* by directing as much doubt as possible toward our ordinary beliefs. He started with some common strategies for raising doubts. For example, he pointed out that we are all aware of having been deceived by our senses at some point (e.g., by perceptual illusions) and questioned how we can know at any particular time that we are not being similarly deceived.
Further, he noted how we have sometimes had dreams that seemed so lifelike that we thought we were awake and that even afterwards we could not distinguish from real experience. Finally, he proposed a hypothesis that, if true, would call nearly every belief we have into question. This hypothesis posits that we are the creation of an evil genius whose major preoccupation is to make us believe falsehoods. To accomplish this, the evil genius arranges for it to appear as if we lived in the physical world and had a physical body and knew other people, but this is all a grand illusion created as part of its attempt to deceive us. Once such doubts are raised, the task for epistemology is to overcome them and show that we do have real knowledge.

The general assumption that stems from the ancient Greek philosopher Plato is that knowledge is related to belief but has a special status. One feature of knowledge that differentiates it from belief is that what is known must be true, whereas what is believed may be false. At a minimum, therefore, knowledge seems to involve true beliefs. But this is not sufficient because we would not credit someone whose true belief was a lucky guess with knowledge. So commonly, knowledge is taken to be justified true belief. This raises the question as to what constitutes justification. Before we consider that question, however, we need to note that several epistemologists have challenged the definition of knowledge as justified true belief. They have proposed a variety of counterexamples that satisfy the definition but do not seem to constitute knowledge. A typical counterexample involves a case where a belief is true and where the person has information that seems to justify it, but where the relationship between the justifying information and the object of belief is inappropriate. For example, a person might correctly believe that there was an object 10 feet ahead where the justification was provided by perception. However, the scene might have been so arranged with mirrors so that, although there actually was an object 10 feet in front of the person, the object seen is an identical object that is behind the person. As a result, the person would not really know that the object was there (see Gettier, 1963). Defenders of the definition of knowledge as justified true belief have attempted to refine the definition of knowledge to handle such examples, resulting in a continuing sequence of counterexamples and redefinitions.

After defining knowledge, the central question for epistemologists has been to specify what kind of justification is required for knowledge. Within the history of epistemology several approaches have been pursued (e.g, Plato and Descartes both argued for some form of a priori justification for knowledge), but most contemporary epistemologists adopt one of two basic approaches to justification—foundationalism or coherentism. The foundationalist approach compares knowledge with an architectural structure. The support for most knowledge claims are a set of foundational claims, with other pieces of knowledge being derived from these. The challenge confronting the foundationalist is to identify the foundational claims. Generally, foundationalists
appeal to perceptual beliefs. One approach, now generally not in favor, proposed that there were direct objects of perception, called sense-data, that consisted of simple perceptual qualities, like patches of color. The view held that we directly perceive and so have completely justified beliefs about these sense-data, and that all other knowledge is logically derived from them. This approach has been abandoned, partly because philosophers came to question the idea that we had direct awareness of sense-data and partly because the prospects of ever deriving knowledge of worldly objects from such primitive foundations began to appear impossible. Contemporary foundationalists generally appeal to a criterion such as being indubitable or self-warranted to identify foundational beliefs (see Chisholm, 1976, 1982). A recent variant on this approach has been to seek a foundation in a reliable belief making process (see Goldman, 1986).

The coherentist approach rejects the whole idea of external foundations and instead appeals to the relationship between beliefs to find justification. The idea is that a set of beliefs either cohere with each other or are inconsistent with each other. Some of those that cohere provide justification to each other such that, even if no one of these beliefs can be supported independently from the rest, the whole network stands together (see Lehrer, 1974). The coherentist generally faces two challenges. One is to explicate what kind of relationship between a set of beliefs is required to make the whole set warranted. We can imagine simple sets of statements, all of which might be false but which cohere well with one another. The coherentist needs to establish criteria to specify which of such sets of coherent beliefs are to count as justified and hence as knowledge. The second challenge is to show why anyone should take the coherence of a set of beliefs, however that coherence is characterized, as providing knowledge. (For an introductory set of readings in contemporary epistemology that introduces both foundationalism and coherentism, see Chisholm & Schwartz, 1973.)

Generally, the weakness of the foundationalist approach coincides with the strength of the coherentist approach and vice versa. The foundationalist tries to identify some beliefs that take us outside of our belief structure and put us in direct contact with the external world, but faces the difficulty of identifying which beliefs can stand on their own as knowledge claims. Most of our beliefs, even our perceptual beliefs, seem to be interlinked and to depend on each other. The coherentist obviates this need by always focusing on the interconnection of beliefs. However, the coherentist then faces the problem of explaining why coherence should provide us any indication of how nature is. At the current time, sophisticated versions of both approaches can be found in the epistemological literature and each side has tried to coopt some of the strengths of the other. In epistemological debates, however, one essentially witnesses a conflict between inconsistent intuitions as to what is critical in making a belief into knowledge.
Issues of epistemology are obviously of great relevance to philosophy of science, especially insofar as scientific claims are taken as paradigmatic claims to knowledge. The tradition of Logical Positivism, discussed in the following chapter, adopts the foundationalist approach and tries to justify our knowledge of scientific theories by showing how such theories are grounded in perception. Critics of the Positivist program, as we in chapters 3 and 4, have attacked the idea of an objective observational base to ground scientific theories, thereby raising fundamental questions as to how scientific beliefs are to be justified.

Before leaving this topic, I should note that some notable philosophers such as Quine (1969b, 1973) have concluded that the classical endeavors in epistemology are fundamentally misguided. Often, this challenge takes the form of denying that we can ever answer the skeptic who asks us to justify our knowledge in a way that is immune from further doubt. One way to abandon classical epistemology is to reject the claim that what is known must be true and focus instead on justified beliefs. This, however, raises objections from those who find a logical inconsistency in saying “Smith knew that it was raining, but was wrong.” The other way to abandon classical epistemology is to dismiss the concept of knowledge as useless and focus only on the question of what justifies belief. Generally, those who make this move also tend to adopt a quite different attitude toward justification. Rather than looking for kinds of justification that guarantee truth, they look for modes of justification that increase the likelihood of reaching true judgments, or at least judgments that one will continue to affirm as true in the future. Within this context, empirical information about how human beings process information and make judgments become relevant. Various parts of cognitive science, including cognitive psychology and artificial intelligence, as well as historical accounts of how humans have performed on reasoning tasks, can provide pertinent information. Hence, such an approach to epistemology is commonly spoken of as naturalized epistemology. One particular approach that has received a good deal of discussion in recent years involves comparing the belief acquisition process to the process of evolution, with the idea that more adequate beliefs are comparable to well-adapted species and that the mode of acquiring adequate beliefs involves a winnowing process much like natural selection. (See Campbell, 1974a, Popper, 1972, Toulmin, 1972, Hooker, 1987 for positive treatments of this idea; Thagard, 1980, for a critical response; and Bradie, 1986, for an evaluative overview.)

Value Theory

Several of the areas of philosophy that I have surveyed already have a normative dimension. The term normative implies concern with standards that ought to be adhered to, not simply describing how things are. Logic, for ex-
ample, is generally viewed as normative in that it seeks the standards for good arguments, although epistemology is normative in that it aspires to standards for evaluating whether someone has knowledge or only belief. Many of the other domains of philosophy, however, are even more clearly concerned with values or with analyzing the source of values. These include ethics, which attempts to identify norms that should guide human behavior; political philosophy, which analyzes how one might determine what kind of state should be created; and aesthetics, which analyzes what should count as works of art. I am clustering all of these areas together under the label value theory.

One of the central issues common to all areas of the value theory is the question of whether one can rationally adjudicate questions of value and establish norms. Hume argued that one cannot logically derive a normative claim, a claim about what should be, from a descriptive claim, a claim that something is the case. This suggests that normative statements cannot be rationally defended. A central task pursued by many philosophers interested in value theory has been to try to show that Hume (1740/1888) was wrong and that we can derive normative statements from purely descriptive information, or at least rationally defend our value statements. Others who have acquiesced and accepted Hume’s judgment have tried to show what status should be accorded to value statements if one does not try to rationally justify them.

For the most part, questions of value theory are quite removed from the concerns of philosophy of science. There are, however, some points of intersection that should be briefly noted. A number of scientists, especially in more theoretical and mathematical disciplines of science, often speak of the elegance of a particular theory, suggesting that theoretical accounts of nature ought to adhere to an aesthetic standard. One version of this perspective is the view that a simpler account of nature is to be preferred to a more complex one if they are empirically equally adequate. The interaction between moral and political theory and philosophy of science has also developed in recent decades, especially as it becomes more clearly recognized that knowledge can have consequences. Thus, there have been a variety of arguments that some issues, such as genetic bases of intelligence, should not be scientifically investigated because of the potential harm that might come from knowing the answers to such questions. In this regard, some have argued that scientific investigation needs to be construed as a form of human action and subject to the same moral criteria as any other human action. The result is that philosophy of science will need to include discussion of moral issues that might arise from scientific research. This is not, however, a matter that is further pursued in this text.

CONCLUSION

Philosophy of science is focused on such questions as: What constitutes a
scientific explanation? and How are scientific knowledge claims to be justified? As such, philosophy of science draws upon other areas of philosophy, especially logic, metaphysics, and epistemology. In subsequent chapters I examine a number of influential views of science advanced by philosophers and note some of their strengths as well as raising a variety of objections. As was noted at the outset, this inquiry has consequences because scientists often use perspectives from philosophy of science either to support their own work or criticize that of their opponents. As we proceed to look at a variety of answers in subsequent chapters, it is important to bear in mind that these issues are controversial and that there are a variety of different views on most important questions in philosophy of science. The answers philosophers have offered to these questions are fallible and philosophers should not be used as final authorities to resolve important questions in science. Rather, their views ought to be carefully examined and evaluated by all scientists who invoke them in making decisions about their scientific endeavors.

Before proceeding, however, a final qualification is needed. Twentieth century philosophy in Western countries has been broadly split into two traditions. What is commonly called analytical philosophy has been the dominant tradition in most of the English speaking world as well as much of Scandinavia and parts of Germany. A prominent focus of the analytic movement has been the logical analysis of language and statements, including scientific statements, made in language. Existentialism and phenomenology, on the other hand, have dominated philosophical work on much of the European continent. These traditions have been much more concerned than the analytic tradition with the subjective elements of human existence and have attempted to describe these systematically and explore their implications for a variety of human endeavors, including scientific inquiry. This is not the proper place for a detailed discussion of the relative merits of the two approaches. Both have shown considerable interest in science, but from adopted quite different perspectives toward science. The views discussed in this text are primarily drawn from the analytic tradition. However, the approach to philosophy of science pursued by this tradition has been so transformed in recent decades that it no longer bears clear affinities to its philosophical heritage of logical analysis but is more concerned with giving a faithful account of actual scientific practice.
References


REFERENCES


REFERENCES


REFERENCES


Gall, F. J. (1835). *Sur les fonctions du cerveau et sur celles de chacune de ses parties* (W. Lewis, Trans.). (Originally published, 1809)


REFERENCES


McCawley, J. D. (1981). Everything that linguists have always wanted to know about logic. Chicago: University of Chicago Press.


REFERENCES


REFERENCES


