Philosophy of Science

An Overview for Cognitive Science

William Bechtel

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PHILOSOPHY OF SCIENCE

An Overview for Cognitive Science

Tutorial Essays in Cognitive Science

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This volume is dedicated to the memory of

HANNA

who helped in ways she could not understand

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Preface

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 Postivism 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 obervser. 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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The Locus of Philosophy of Science

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 development 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-

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[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):

English gloss		not A	A and B	A or B	If A, then B	A if and only if B
Notation 1:		$-A$	$A \cdot B$	AvB	$A \rightarrow B$	$A \leftrightarrow B$
Notation 2:		$\bar{A}$	$A \cap B$	$A \cup B$	$A \supset B$	$A \equiv B$
A	B					
T	T	F	T	T	T	T
T	F	F	F	T	F	F
F	T	T	F	T	T	F
F	F	T	F	F	T	T

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."[3]

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.

[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 "$-A \rightarrow (A \rightarrow B)$", which says that if A is false, then if A then B is true. If "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 "$(A \cdot -A) \rightarrow B$". 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 $(x)(Fx \rightarrow Gx)$, 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 questions 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 factors in an explanatory theory. But such questions are not peculiar to psychology. 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 distance (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 contemporary 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 symbols 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 they 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 formality 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 assumptions, 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.

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