 Toward One Science
THE CONVERGENCE OF TRADITIONS
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Beliefs are like pieces in a puzzle. As rational beings, we like to think that our beliefs fit together to form a single coherent picture. But the wild mixture of ideas that confronts us is difficult to fit together coherently. Most of us accept the basic conceptions of western physical science. At the same time, we are confronted with scientific successes that have not come from the western tradition at all, but from knowledge traditions that became firmly established in other ground long before the homogenizing influence of the rapid and detailed communication of ideas. Acupuncture, an oriental technique based on a conception of the human body that is quite different from that of western medicine, produces predictable results. How are we to fit the two conceptions together? Meditative techniques which have been known for centuries in Asia produce results that are substantially the same and apparently more reliable than the new western biofeedback techniques for controlling blood pressure, heart rate, and brain-wave patterns. Can meditation and biofeedback be pieces of the same picture?

The lid seems to have come off in the past few years: some very tough-minded western scientists are beginning to wonder about extrasensory perception, hypnotic healing, biorhythms, and even astrology. At the same time, physicists are talking about particles of matter that aren't particles at all and about processes that violate all the rules of common sense.

We've brought it on ourselves, of course. It is western science that has been responsible for the developments in transportation and
communication that make contact among different knowledge traditions possible. And it isn't going to stop with human sources of new ideas: serious scientists are now trying to make linguistic contact with other intelligent species. We may one day be fitting together pieces of that puzzle which originated in the mind of a dolphin. And, as if that weren't enough, scientific associations have already held conferences about communicating with intelligent beings from other planets in other solar systems. Recent space probes have contained plaintive messages, to whom no human knows, identifying us and our planet as the source of the objects.

There is yet another dimension to the puzzle of rational belief. The best theories of any scientific tradition change over a period of time. It becomes difficult to say just what the basic conceptions of physical science are. Not only are pieces of the puzzle coming at us from a variety of directions, they are also constantly changing, and the rate of change is increasing. What physicists had to say ten or fifteen years ago about the ultimate constituents of matter is no longer believed. New items keep coming into the discussion—pi-mesons, fermions, quarks, even "charmed" quarks. In the 1930s we had only protons, electrons, and neutrons. Not too long before that we could content ourselves with indivisible atoms. When can we expect the final word?

I'm convinced that there is a rational point of view that can tie together all these pieces and more into a coherent picture. I'm going to begin by sketching the outlines of what I take to be the major pieces of the puzzle. Doing this will raise questions that will have to be dealt with in the later chapters where I will examine each of the major pieces in more detail and suggest a point of view from which they can be seen to form a single, coherent picture.

Science is something that people do. It is not a particular set of assertions or theories, but a set of activities that may or may not produce organized theories.

The formal theories of the organized sciences are, at any given time, the chief repositories of human knowledge. But scientific activity doesn't stop. Theories change over a period of time. Historically, the theories characteristic of one geographical population are different from those of others, both in what they explain and in how they explain it. What ties it all together is the activity: human beings explain things as naturally as spiders spin webs, and for much the same reason. Organized into complicated intellectual communi-
ties, we explain things in order to survive. As a species, our primary defense and our primary weapon, our primary device for feeding and protecting ourselves, is our intelligence. We solve problems, and we pass along our solutions in organized ways, encoded in the theories of our sciences.

But we can't begin fitting together the scattered pieces by studying theories. That would be like studying the activities of spiders by looking only at the webs that they spin. Fascinating as the webs are, they can't by themselves give us a comprehensive picture of what spiders do, not even of the activity of web spinning, its purpose, and its function in the life of the spider. If we were studying that activity, we would have to begin by getting clear about just what sort of organism a spider is, how and why it came to be that way, why spiders spin webs in the first place, and why different sorts of spider spin different sorts of web.

A similar range of questions confronts us concerning the human activity of doing science. Is there something about the nature of human beings that makes it necessary for us to explain our experiences? Is there a way of looking at the community activity of scientists that can explain why the science that developed in northern Europe is different from the science that developed in China and India? Is it possible that two quite different scientific theories about the same subject matter might both turn out to be right? Can there be such a thing as a global science in, say, psychology, that will cross national and cultural boundaries in the way that contemporary physics does?

I'm going to argue that the answer to all of these questions is yes. But the argument isn't brief. To tackle it seriously, I will have to turn to the sciences themselves for major portions of the argument.

Scientific theories explain and predict the kinds of event that fall within their scope. What I am about to develop is a theory about science, drawing on the best available theories of science to support the line of argument. Like any theory, this one is subject to criticism and revision, and it is always subject to replacement by a better theory. The activity of doing science goes on as a vital part of human experience. Particular theories, including theories about theories, come and go. They serve their purpose until they are replaced.

There is something a bit wrenching about trying to fit alien ideas together with familiar ones. It's rather like the shock of maturing. One of the first things we notice about a child as he begins to mature
is that his attitudes and behavior gradually shift from totally self-oriented patterns to what seems to be a wider and wider sense of identification with other people. He recognizes that there are other beings like him; that he isn't unique, and that he isn't, for any practical purpose, the center of the universe.

A similar "maturing" has taken place in the recorded history of scientific theories. The earliest recorded explanations of people and the world ran on the assumption that human beings are unique in the universe. Each area of inquiry that we recognize as a distinct field or discipline has gone through terrible conflict when the assumption of human uniqueness has come under question. But the assumption has eventually been dropped in each field. In this sense the disciplines of western science have matured relative to their own subject matter.

In astronomy, for example, we can trace the shift from the view that the earth is the center of the universe to the view that the sun is the center of the universe, and on to the current view that the universe may have no identifiable center at all. The wrench of the maturation was enormous. Only a few hundred years ago people actually died for believing that the universe did not center on mankind. Most of us now are comfortable with the view that there is nothing special or unique about our planet or our position in the universe. We know that there are many stars of the same sort as our sun and, in all probability, many planets of the same sort as our planet, and we know that it's highly likely that intelligent life has developed on some of those planets. The changing theories in astronomy have matured us in that sense.

Biologists, too, have contributed to our maturation. They now view human beings as one species among many somewhat similar species—similar because they all evolved under roughly the same conditions of life on this planet. It has even been suggested that from an intellectual point of view, human beings might not be the most highly developed species on what we like to think of as our own planet. Dolphins have brains that are comparable to ours in size and complexity. Some researchers actually believe that if we can find a way of comparing human intelligence with dolphin intelligence, we might come out second best.

Even psychology, perhaps the most human-centered discipline of all, has moved away from the assumption that human beings are unique. If we share a genetic history with other species, then we can learn something about human thinking and behavior by studying those other species. Complex human behavior should be echoed, in simpler form, in other species that aren't as complicated neurologically as we are. So the study of how rats learn to solve problems and of how chimpanzees can learn rudimentary symbolic languages becomes relevant to human psychology.

What I suggest in this book is that the shift away from egocentricity involves at least one more important step before we can claim to have a mature view of scientific knowledge. The attitudes of many western scientists and philosophers toward science itself reflect the belief that the western tradition of science is somehow uniquely correct. I will argue that western science itself indicates that these attitudes are untenable, that the western approach to knowledge is neither more nor less correct than that of other traditions and that, even if we ultimately succeed in integrating the best knowledge of all human traditions, human knowledge is not the only possible sort of knowledge.

An attempt to fit together beliefs that originate in disparate knowledge traditions cannot begin with the surface statements that represent the present state of those traditions. Even to integrate statements from two different fields within western science entails digging below the surface. A theory about human science has to begin with the questions of why human beings do science at all and why they do it in a particular way at a given time and place.

Right away, these questions raise more questions: How do theories change within a scientific tradition? Why do they change, and who decides which changes are going to stick? How does a scientific tradition develop? What is there about the "nature" of human beings that leads ultimately to doing science? To get at questions like these, we have to start at square one and talk about how any species—and the human species in particular—comes to have the characteristics it has.

It is comfortable to think that human beings can shape and control the world. Civilization, from its very beginnings, rests on the ability to control and direct nature. Century by century, we have learned to manipulate natural forces and events to our advantage. We are able to meet conditions as they change, and we are able to flourish on every part of the planet. We are the most flexible species on earth.

But if you take your biology seriously, the opposite is also true: the world has shaped us. Century by century, the facts of life on this planet have made us into the kind of creatures we are. The world
determines what we need to do in order to flourish, and beyond that, the characteristics of this planet have shaped the physical equipment we have to do it with. The shaping takes place in the process that Charles Darwin called natural selection.

One tends to think of natural selection, with its strong emphasis on survival, as having to do with the "hardware" of organisms: teeth and claws, legs and spinal columns, lungs and opposable thumbs. But of equal importance to an organism are its sensory equipment and the nervous system that guides its activities in response to the stimuli that the sensory equipment picks up. The most significant development for human beings is not a natural set of physical weapons like tusks or claws, but rather the physical apparatus that makes thought and language possible. We are the species that lives by its wits.

Coupled with the development of sensory and neural apparatus is the development of techniques for using that apparatus in systematic ways to deal with the environment, techniques that are made possible by the physical characteristics that the species has and that at the same time are constrained by those physical characteristics.

The development of techniques—typical patterns of behavior, if you like—is evolutionary in the same way that the development of bodily characteristics is. This matter is somewhat problematic for biologists, psychologists, and physiologists at the present time. Although the way in which a particular behavioral trait is passed along is not always clear, it is important to recognize that techniques do develop as adaptive behavior and that these techniques are passed along as characteristic ways of solving problems.

Spiders spin webs to catch their food. Wolves travel in highly organized packs. Birds migrate to feeding and nesting grounds. Beavers build dams. Human beings explain things. Singly and in organized groups, they develop elaborate theories to explain why events happen as they do. By explaining past events, human beings are able to manipulate future events to their advantage, both in the obvious cases of finding food and shelter, of breeding and defense, and in the more complicated cases of traveling over long distances, forming communities, and developing means to support such communities. The more complicated patterns of behavior are in large measure solutions to problems that arise at least in part from earlier solutions to more basic problems.

Here, in broad outline, is one piece of the puzzle concerning human science: certain sorts of activity, which we identify in ourselves as conceptual activity, are best understood as part of the naturally selected techniques by means of which our species manages to survive. Now we are still a long way from talking about the formal development of scientific theory, let alone talking about integrating theories from scattered knowledge traditions.

There are still more questions. How are workable solutions to problems sorted out from unworkable ones? How can natural selection explain the solving of problems that affect whole populations? And all of this precedes our getting at the main questions I'm after here: What counts as a scientific approach to a problem as distinct from an unscientific one? How can we combine the most successful scientific explanations available to us into one coherent picture of reality?

If we are going to talk seriously about how human beings explain their experiences, we will need to consider the sorts of experience we can have. Human beings experience the world with a particular sensory apparatus: we have eyes that are sensitive to radiation in a narrow band of the electromagnetic spectrum and other senses that are stimulated within given ranges. We don't "see" all wavelengths of reflected radiation or "hear" all frequencies of atmospheric vibration. Taken together, the human sensory ranges constitute a particular point of view from which we experience the world around us.

Organisms have the particular sense organs that they do for reasons that a biologist can explain by making reference to the peculiarities of the planet on which those organisms evolved. The size of the planet, its distance from its sun, the composition of its atmosphere, all serve to determine the character of the most readily available "information"—sensory stimuli that can be of use in detecting food and danger. It is no accident that most life-forms on this planet have sensory apparatus that react to roughly the same sorts of stimuli within roughly the same ranges. The differences in sensory ability from one species to another are easily enough explained in terms of the relatively local conditions under which particular species developed and the special local needs that made, for example, the chemical senses of taste and smell more important than the visual sense to dogs, and the visual sense more important to human beings.
Our brain and neural system developed as they did, step by step, because each step in the development enhanced our ability to interpret the available stimuli and act on them in order to meet our needs. The facts of human life on this planet could have been different from what they have been. If the available “raw information” had been different or if what we needed to know had been different, our means of gathering and processing information would have been different too.

Now what does this suggest about nonhuman intelligence? Suppose we can make sense of the claim that dolphins are as intelligent as we are. Is it at all likely that they “think” the way we do? Perhaps before long we will be able to find out whether or not the rapid, complex sounds that dolphins make constitute a language that is as sophisticated as human language, and, if it is such a language, we should eventually be able to get some idea of its structure and organization.

But consider this: The interpretation of visual stimuli employs a larger portion of the human brain than does the interpretation of stimuli from the other senses, and it seems to be the case that the visual sense provides the organizational scheme into which information from the other senses is fitted. With dolphins, the situation appears to be different. Their “organizing” sensory system, by all indications, is their sonic echoing apparatus (which, with a similar sense that bats have, gave us the idea for radar and sonar). What kind of natural language could be based on such a sense? What sort of object would they converse about? What sort of properties would they discern those objects to have?

There is one more question before we set this subject aside. If the characteristics of available sensory stimuli and indeed the characteristics of human intellectual activity are structured by the particular facts of life on this planet, what sort of intelligence could we expect to find in members of species that developed on other planets where the facts of life are likely to have been quite different?

I will return to these questions several times, but they have to be kept on the margin of the main line of discussion. We just don't know enough yet to develop reasonable answers to them. But they are similar to a group of questions that we must ask about human beings: To what extent have different circumstances and different needs influenced the sort of language developed by human populations? To what extent do circumstances, needs, and languages affect the problems that are systematically addressed by a human community and the knowledge that develops out of the solutions to those problems?

Even if we restrict our attention to a single species and to the particular equipment it has for dealing with its needs, we find that solutions to problems differ from one physically similar population to another. Any given set of physical characteristics makes possible a wide variation in the techniques that a species can develop. Some species of shore birds differ from flock to flock and sometimes even within a flock in their characteristic techniques for opening shellfish. Some species of spiders show regional differences in the style of web that they spin, again without any discernible difference in the spiders.

Within the human species there are populations that differ with respect to the character of the languages in which they encode information and that have differed, from one major geographical region to another, in the kinds of information that they tend to systematize and pass along to their offspring. It is no accident that different sorts of language and different bodies of organized knowledge developed in different parts of the world. Local conditions of terrain, climate, availability of water, food supply, presence or absence of predators have all influenced the sort of problem that must be addressed first as well as the technique that will be effective in dealing with a given problem.

Now that first problem is important. We can't know precisely, of course, the first problems for which our remote ancestors in a given part of the world developed solutions, but we do know that the established techniques—the accumulated body of successful solutions to problems—serve at any given time to influence the sort of approach that will be taken to a new problem. Over a period of time a characteristic style of conceptualization or local idiom will develop.

Without major physical differences in sensory, neural, or other apparatus, for that matter, human beings have learned to deal with the world conceptually and linguistically in several distinct ways. Each geographically separated population has preserved its successful solutions to problems and has passed them along to successive generations. It is only very recently in human history that these separated populations have come in close contact with each other. The enormous successes of western physical science have been
responsible in large measure for the contact. And because of this, the western physical sciences have come to be the primary models for what a science should be. The demand has been made in various ways for psychology, sociology, and even biology to be "more like" physics and chemistry.

More questions, immediately. What makes a theory successful? What does a scientific theory do for us? Why should we expect all successful theories to resemble each other?

Because knowledge traditions that have developed elsewhere in the world differ in so many obvious respects from the conceptions of western physical science, they are viewed with suspicion by many western scientists. What I hope to convince you is that science is one kind of activity that can be carried out in many different styles; that the style of western physical science is already beginning to overlap with the style of eastern thought; and that the differences between the characteristic approaches to knowledge developed in geographically separated populations are differences that reflect the ways in which those populations learned to deal with the problems that confronted them.

You can't learn to do what you lack the equipment for, however. There are conceptual characteristics of human beings that reflect, so far as we can tell, the boundaries of what our sensory and neural equipment make possible.

What exactly are the limits of possible variation in human thought? We will have to turn to psychology and philosophy to trace the contours of the next piece of the puzzle. The physiology associated with conceptual activity is still something of a mystery, and at present the best evidence we have about how people think is to be found in what people say and in what they are able to do conceptually.

Can you imagine a four-dimensional physical object? “Imagine” must be taken very literally here, as in imaging or picturing. The answer is probably no, and it is probably the same for every human being, even though we can “do the math” for four-dimensional objects. Geometry that deals with objects of more than three dimensions has been around for a long time. Just what kind of limitation are we talking about? We certainly don’t see objects in four-dimensional space (which is different from saying that there are none); our visual imagination simply doesn’t seem to allow us to have images of four-dimensional physical solids.

When physicists talk of multi-dimensional objects and spaces or of particles that don’t have spatial dimension, position, velocity, or even (in the case of the photon) mass, they are talking about objects that we can describe mathematically but that we cannot experience with our senses or visual imagination. But why not? There isn’t anything in the math itself that says we can’t. Physicists talk freely about gravity as three-dimensional space curving in a fourth dimension, and they seem to be able to make perfect sense of it. They can even argue among themselves concerning the accuracy of each other’s descriptions of objects in four-dimensional space.

Whatever we can say about four-dimensional objects, they are not objects of common sense. This is a matter I will return to later, but let me give a minimal characterization here of what I take to be common sense experience of objects.

First of all, the physical objects we experience exist in three-dimensional space. And, second, events in which those objects figure happen in an irreversible sequence in time. Here again we can talk of reversible time sequences in our physical theory, and we can construct fictional accounts of travel backward and forward in time, but these things are really beyond common sense experience. Finally, it seems to be a precondition of our making sense of events that every event must have a cause. Later I will discuss just why it is that these three basic characteristics of human experience, along with several other characteristics, seem to be universal. For now, I will take space, time, and causality as the minimal list of features common to all our sensory experience.

Let’s grant, even, that all human beings have the same basic experience of common sense physical objects. The objects have the sensible properties of color, texture, smell, taste, and sound. They occupy three spatial dimensions, they endure for at least a period of time, and they are solid—at least solid enough for us to discern their boundaries as discrete objects. Might there be a uniquely correct way of describing a system of such objects that we could take as a beginning point for human knowledge?

Consider the walls of the room you are in right now as the boundaries of a physical system. (If you are reading outdoors, construct some arbitrary boundaries around yourself, marked off by trees or rocks, so that you have a room-sized space defined.) Having defined the physical space, then, we want to try for a neutral and correct description of the physical objects in the room.
But how many physical objects are there in the room?

That sounds like a silly question, doesn’t it? Nobody would really ask it outside a philosophy classroom. On the face of it, it might seem that finding the correct answer would simply involve a few tedious hours of counting the objects.

But it’s not that simple. Embarrassing problems come up almost immediately. Should you count your loose-leaf notebook as one object, or should you count each page separately? What about tables and chairs? Is the chair one object or twelve pieces of wood? One ring of keys, or five keys and a ring? Do you dismantle the lamps and count each part separately, or just count the lamps? Each of these choices could reasonably go either way, and each choice affects the outcome of the count. So there is more than one “correct” number of objects in the room. It depends upon what you decide to take as one physical object.

There might be reasonable arguments in some cases about the best way to count objects, but the problem comes down to this. The best way to count depends upon why you are counting the objects in the first place. A furniture dealer would count the chair as one object; a cabinetmaker might count the twelve pieces of wood separately. A zealous physicist might give you a fair estimate of the number of molecules, or even atoms, in the chair. What is the correct number of objects? Well, who is counting, and why?

Once you have decided on a way to count, you can talk about right and wrong answers to the question. But “physical object” and “thing” don’t give you a way of counting. You need to specify more about what is to be taken as a single object, and there is no uniquely correct way to do this.

Now move the question up a notch: How many different kinds of object are there in the room? The same sort of difficulty arises. There are indefinitely many ways of sorting out objects into kinds. How many colors do the objects have? Same problem. You have to make a decision about how to sort things out into kinds, if only the decision to use a particular scheme of classification that you get from someone else. You have to establish or adopt a particular way to draw the boundaries between colors. There is more than one reasonable way of doing each of these things within the limits of what we can do.

This is not to say that we can never differentiate between correct or incorrect counts or descriptions, only that there is no uniquely correct way of counting, classifying, or describing a system of objects. You might, in a given case, argue that one sort of description of a physical system is better than another for a given purpose, but there are many different sorts of description, each of which might be appropriate in some context or other and each of which determines a different “correct” count, classification, or description.

Descriptions are never neutral. There is no uniquely correct way of describing physical systems or events, and there is no uniquely correct way of explaining them either, since an explanation of why a thing has a given set of characteristics must depend upon what we take those characteristics to be. We describe and explain from a point of view, but there is no point of view that is common to all human beings in the way that the framework of space and time seems to be. So, even if there is something peculiarly correct about saying that the objects we experience exist in three-dimensional space, there doesn’t seem to be any peculiarly correct way of describing those objects. We can’t even speak here of a clear-cut “western” style or “eastern” style of description. So many reasonable variations have equal claim to accuracy that within a given local idiom we still can’t sort out one kind of description that is uniquely correct.

Now this raises a question that bothers some scientists a great deal. If there are a number of more or less arbitrary choices to be made before we can talk about the correct description, or even the correct number of objects in a given space, is it possible to claim objectivity for any of our judgments about the world? How can we talk about one science, or even one correct scientific theory, when there are indefinitely many ways of describing a physical system as ordinary as the objects in a single room?

The question of objectivity will recur several times as this theory about theories develops. For a start, we should sort out claims for objectivity from claims for neutrality. We cannot make judgments without a point of view, and there is no point of view that is absolutely neutral or, in some final sense, correct. That much has emerged from the questions about the numbers, kinds, and descriptions of objects in the room. The framework of space, time, and causality is basic to all human thought, the most sophisticated and the most commonplace, but it is only the beginning of the characterization of a context in which we can make sense of descriptions of the world and assess their accuracy.
A point of view can be characterized further by what I will call *presuppositions*. These can be expressed as assertions of a particular sort, about what kinds of thing there are, about what specific individual things exist, about what properties things of a given kind can have. Presuppositions define the contexts in which intelligent behavior and discourse can take place and in which solutions to problems, including the theories of the organized sciences, are passed along from one generation to the next.

More important, a context of presuppositions—a point of view—must be understood before we can decide whether or not a given description is accurate. Aside from what I will call the presuppositions of common sense—space, time, and causality, for a start—other presuppositions are subject to wide variation within what human beings are capable of doing linguistically and conceptually. They are determined by factors other than our sheer physical makeup: language, culture, local idiom, what we have learned to distinguish, what we need in a given situation. We can replace these presuppositions by others with some effort at relearning. Still other presuppositions can be replaced easily and define idioms or “manners of speaking” that we shift into or out of as day-to-day situations demand.

Quarks are held together by gluons. That’s what the physicists say. Are they correct? Does the assertion make any sense? How can we tell?

First, we would have to know something about quarks and gluons and about how the expression “held together” is to be understood in the context. Then, we would need to determine whether or not the assertion can be said to be correct before we can decide whether or not it is correct.

In Chapter 3, I will go into some detail about what is involved in making such determinations. But let me illustrate here part of what is at stake. Suppose I were to tell you that the drugstore at the corner of Broad and Norris in Philadelphia was robbed last night. Am I telling the truth or not? If you know the intersection, you know that there is no drugstore there. But you can’t properly say that my assertion about the drugstore’s being robbed is either true or false. To say that it is true commits you to saying that there is such a drugstore and that it was robbed. To say that it is false commits you to asserting that the drugstore at the corner of Broad and Norris wasn’t robbed last night, which still leaves you talking about a nonexistent drugstore. The appropriate way to treat my assertion is to reject it altogether: “That isn’t a drugstore, it’s a university,” or simply, “There is no such drugstore.” In asserting that a given object has such-and-such a property or that it figured in such-and-such an event, we normally *presuppose* that the object exists. If it does not exist, the assertion is *improper*.

The assertion about the robbery isn’t nonsense, of course. We know perfectly well what it would take to make it proper. There would have to be such a drugstore. If there were, then it would be a straightforward matter to determine whether or not it had indeed been robbed last night.

Now, let’s take another kind of case. Suppose I were to say, “My typewriter isn’t happy today.” The difficulty here isn’t that I am talking about something that doesn’t exist. I do have a typewriter. Perhaps, with a little imagination, you might make some sense of what I have said as a figure of speech: a key is sticking, it needs cleaning or a new ribbon, something like that. But, as an assertion to be taken literally, we can’t allow it. Certainly it isn’t true, and if we say that it is false we are saying that my typewriter is happy today, which is just as problematic as the assertion that it isn’t. We have another improper assertion on our hands, because a typewriter just isn’t the kind of thing that can be either happy or not happy. So there is another sort of presupposition that must be taken in order for assertions to be proper: Whatever we are talking about must be something that can reasonably be said to have, or fail to have, the property that we attribute to it.

One more example, a little closer to our interests here. Suppose I were to suggest the following line of reasoning. The temperature of your body is approximately 98.6°F. Fahrenheit. Let’s be content with saying that it is somewhere above 95°F. It would seem reasonable, then, to say that the average temperature of your internal organs is somewhat above 95°F. No problem so far.

But as we move downward in scale and size, our attribution of an average temperature runs into conceptual trouble. We can reasonably speak, perhaps, about the average temperature of the cells which make up our internal organs, but not of the average temperature of the molecules which comprise the cells, and surely not of the atoms and subatomic particles which constitute the molecules.

The claim that a given molecule, atom, or electron has a temperature somewhat above 95°F fails, not because the temperature is below
95°, and not because you can’t find a place to stick the thermometer, but because molecules, atoms, and electrons don’t have properties of temperature, although some of their properties are of course related to the temperatures of the systems in which they exist.

It is easy enough with made-up examples to track down just how an assertion misfires. In more complicated cases, where one group of people makes an assertion and another group claims that it doesn’t make sense, it is not so easy.

Presuppositions can be understood as rules for making sense. Some of the rules will change over a period of time. If you think in terms of the classical conceptions of Newton’s physics, which are very much like what I have called the presuppositions of common sense, you can see perfectly well that the current theories about subatomic events just don’t make sense in Newtonian terms.

This isn’t a particularly new or startling point. Most of us are familiar with the fact that our view of physical reality has changed several times in the physical theory of this century. The dramatic impact of Einstein’s work and that of his successors has led some people to think that truth and falsity are matters that we can no longer discuss intelligently; that a given assertion can be “true for me” whether or not it makes a grain of sense to anyone else. This just won’t do, of course. Such a situation would make group solutions to common problems impossible. It would make science impossible on both local and global scales. So there are still more questions to be dealt with. If our assertions can be assessed only within a well-understood context, how can we choose the best context in which to frame our scientific theories? How can we ever compare two theories that are constructed within different contexts of presupposition?

If a Freudian psychologist starts talking about, say, Richard Nixon’s superego, a behavioral psychologist is likely to claim that the Freudian isn’t making sense. Another Freudian might disagree with the first about some of his assertions, but there wouldn’t be a question between the two Freudians about whether or not the assertions were proper. Now who is right here? The Freudians or the behaviorists? In such cases, we sometimes speak of the Freudian idiom or the behaviorist idiom. Do we just have to note the difference between the two idioms and let it go at that, or can we make some reasonable connection between the two? The same questions arise when we compare two theories about the same subject matter that are separated by time or by geography.

I suggested earlier that human beings need to explain, that the activity of theorizing about why things happen is as important to us as the activity of web spinning is to a spider. This isn’t to say that fully developed formal theories spring up in some spontaneous way—indeed, they do not, and I will describe in Chapter 5 how they do develop. What I am suggesting is that the kind of activity that has led to the formal theories of western science is something that all people do.

If you should hear a loud crashing noise just outside your room, you might decide that it has nothing to do with you and simply ignore it. You might, more likely, open the door to find out what happened, or you might prudently pause for a minute and consider what could have caused the noise before opening the door to investigate. What you wouldn’t do is suppose that there was no reason at all for the noise. Things don’t just happen in our experience. Every event is caused. When an event seems relevant to us and our well-being, we want to know what the causes are. When they aren’t immediately apparent, we develop hypotheses—suppositions about what the causes might be—and we sort out the plausible hypotheses from the implausible ones before acting on any of them. Here again, there are questions that we will have to try to answer: How do we decide which hypotheses are plausible and which are implausible? How do we choose among several plausible hypotheses?

Beyond explaining why particular events happened, we try to describe reality in general terms. But, as we saw earlier in trying to count and describe the contents of a single room, there are many different ways of describing things. Is it at all consistent to say that there is one reality, but many different ways of describing it? Can there be more than one correct way of describing reality?

Several years ago, a physicist, a psychologist, and a philosopher were jointly teaching a course called “Scientific Knowledge” to a group of fifty university freshmen.* On a particular day, the physicist was lecturing about light and color. He described how objects reflect light of different wavelengths and showed how given wavelengths of light are identified as given colors. He demonstrated how objects which appear to be one color under a particular kind of illumination appear to be quite a different color under other kinds of illumination.

*The physicist was Robert Weinberg and the psychologist was Charles Reed, both of Temple University.
Finally, the physicist pointed to a red shirt and asked, “What color is it really, all by itself? If you take the red shirt and put it in a drawer, what color is it?” The answer he wanted and got was “No color.” No color, because color is a property of light. When the shirt is in a drawer, it isn’t reflecting any light at all, let alone that portion of the visual spectrum identified as red light.

The philosopher objected immediately. Did the physicist seriously believe that all the shirts in his drawer were no-colored shirts; that they became red or blue or whatever only when the drawer was opened in a lighted room? Suppose he called a department store and ordered a red shirt. If it was delivered in a sealed package, would he send it back to the store unopened with the complaint that the shirt wasn’t red? Wouldn’t that be a little odd?

Surely, the philosopher argued, the shirt was really red, and all the physicist’s talk of reflected light simply explained why red things appear red under normal illumination. Color is a property of objects, he insisted, and our way of telling what color an object really is consists of viewing it under normal light.

Now the psychologist objected. Reflected electromagnetic radiation of given wavelengths is just reflected radiation, he said; it isn’t color. It may be a fact that certain dyes and pigments reflect radiation of given wavelengths more than others, but you can’t talk of color until you bring the human visual system into the discussion. Color properties are a function of the objects, the radiation they reflect, and the way in which that radiation is apprehended and processed by the human visual system. So color is neither a property of the light nor of the object. It is really a property of the complex perceptual experience.

Now who is right here? What color is the shirt really? What is color really? What is color a property of? Objects? Light? Experience? Could all three of them be right?

Every day, we literally stake our lives on the adequacy of our hypotheses and the theories that develop from them. In most cases, our theories are successful in guiding our actions safely. Whether or not a theory is successful in this sense does not depend upon the particular field, or even the particular tradition, in which it developed and became established. Our beliefs have far-reaching roots. A coherent pattern of beliefs can—perhaps must, at this time in human history—contain elements that originated in widely divergent traditions of knowledge. But how do we integrate such disparate ingredients?

This is a long list of questions, and each must be dealt with if we are to construct the coherent picture of rational beliefs that I spoke about earlier. To get at the questions in a reasonable way, we will have to begin with a general account of how human beings come to have the characteristics they do and how some of those characteristics have led to systems of organized knowledge in every human civilization. We will have to consider just how it is that we are able to make assertions about the world, and how we can choose between conflicting assertions. Beyond this, there are questions about how we can sort out the objects of our experience in systematic ways, develop theories to explain the characteristics of those objects, and predict what we can expect from those objects in new situations.

Finally, we will have to develop a general account of what it is to do science, whereby Aristotle’s physics, Newton’s physics, contemporary physics, eastern and western psychology, and other bodies of theory all emerge as products of the same kind of activity, to explain how they came to be so different from each other, and to suggest how they can be brought to bear on each other in a coherent way.

And that is what I propose to do in the chapters that follow.

FURTHER READINGS

Most of the topics raised in this chapter will be dealt with in more detail in subsequent chapters, and recommended reading will be given at those places.

For an interesting discussion of attempts to visualize in four spatial dimensions, see Ludwig Eckhart, *Four-Dimensional Space* (1968).
THREE
On Making Sense

Supposing, Believing, and Asserting

Science is essentially a public activity, and for that reason it is essentially a linguistic activity. Beliefs are shared, and passed along from one generation to the next, by means of speech and written language. Beyond this, language molds our beliefs in two ways. First, the particular language we speak and the particular vocabulary within that language that comes naturally to us provide habitual modes of sorting out and describing our experiences. And, second, the use of language makes it possible for us to discuss each other's beliefs critically and to evaluate our individual beliefs against the background of a critical consensus of beliefs.

Even before we come to communicating and criticizing beliefs, the use of language enables us to suppose—to form hypotheses that we neither believe nor disbelieve at the outset—and to try them out publicly. Critical discussion of what we suppose hones and refines what we come to believe.

Any exchange of information among human beings amounts to an assertion, or series of assertions, that something is or is not the case. You can, of course, make assertions without using language directly—by nodding your head, pointing or otherwise gesturing, flipping the lever on your car’s directional signal, or pressing a button. But words, gestures, or mechanical signals cannot be taken by themselves unambiguously. Speaking or gesturing must happen within a context in which it will be understood if we are to communicate our beliefs.

Logical questions can be raised within a well-understood context, to evaluate specific lines of reasoning, or in more rigidly defined contexts, to spell out the logical consequences of a particular statement of the laws and postulates of a theory. Logic is not, in general, concerned with hypotheses, beliefs, and assertions, but with statements (or propositions or sentences) which are assumed to be straightforwardly true or false, and with the evaluation of individual patterns of inference or argument. Such patterns are abstracted from the activities of asserting and critically discussing our beliefs. They are patterns that we detect in the “products” of the activities—the statements or sentences—that I likened earlier to the webs that are the products of a spider’s activity.

To evaluate a set of statements logically we must assume that they are all made on the same common ground—from the same point of view. Recall the example in Chapter 1 where we considered the variety of reasonable ways of counting and describing the objects in a given physical space. The objects on my desk at this moment can be counted in at least three different and defensible ways. The outcomes are seven objects, or twelve, or sixteen, depending upon what you choose to take as a single object. Logically, the three following statements are mutually exclusive:

There are precisely seven objects on my desk.
There are precisely twelve objects on my desk.
There are precisely sixteen objects on my desk.

No two of them could be true. But each of the three is accurate on its own ground—that is, within the context of a given way of individuating objects.

Each way of counting yields a different inventory of the objects on my desk (five keys and a ring on one inventory and one ring of keys on another, for example). Moreover, each of the three inventories is, on its own ground, an accurate inventory of the items on my desk. I know perfectly well that there are seven items on my desk. If I were to lay out for you how I counted them, so we were on common ground, you would get the same result. I also know perfectly well that there are other ways of sorting out the objects that would result in counting different numbers of objects.

Now this, in miniature, is the situation we face when we consider alternative descriptions of any state of affairs or alternative explanatory assertions about why a given state of affairs is the way we
describe it. We make assertions in such a way as to relate our own experiences to a common ground of conceptions that other people can understand—a point of view that makes rational discourse possible. Within such a point of view we can carry out the logical abstraction of statements and inference patterns, and discuss the effect that the truth or falsity of one statement would have on the truth or falsity of another made on the same ground. But frequently we have to step back from a particular context of assertion and explain or negotiate that common ground in order to be understood, prior to raising logical questions within the context.

Presuppositions

If I expect you to understand my assertions, I have to follow rules for making sense. Some of these are structural, linguistic rules that we absorb as we learn how to speak and write. Others characterize conceptual common ground on which we carry out rational discourse. The latter are presuppositions which delimit the contexts in which we understand, compare, and debate each other’s spoken or written assertions. Changing problems, changing conceptions, and changing interests continually redefine the ground on which we assert and discuss our beliefs. Such changes also continually redefine the territory of the sciences on which the specialists carry out the critical debate that leads to consensus in the scientific community.

The presuppositions which characterize the context of common sense discussion change over a period of time and vary somewhat from place to place. Within what may be called the overall context of common sense, we can shift from one set of presuppositions to another, depending upon the occasion, or whom we are addressing, or the particular purpose of our assertions. This is exactly the sort of thing that happened in the several different enumerations of the items on my desk.

Whether we are talking about the loose and informal contexts of common sense or about the more rigorous contexts of scientific theories, we can distinguish several different kinds of presupposition which delimit the common ground on which we make and understand a given set of assertions.

*Formal* presuppositions are those I identified in Chapter 2 as descriptive of species-specific facts of human experience. Among them are the following:

All objects exist in three-dimensional space.
No object both has and fails to have a given property.
Individual objects occupy distinct, bounded, uninterrupted segments of space and time.
Time is irreversible.
Every event has a cause.

Such presuppositions constitute the foundation of common sense experience. They have remained unquestioned in a very solid sense, although, as I noted in Chapter 1, there have been some interesting suspensions of them for purposes other than describing experience: contemporary physicists view gravity as a curvature of three-dimensional space in a fourth dimension, speak of reversible time and causal sequences at the subatomic level, and allow that subatomic particles might violate the general presuppositions about individual objects. In general, we do not suspend formal presuppositions except at the far reaches of theoretical explanations. The exception is, of course, to be found in certain types of science fiction or fantasy, where the experiences of characters might include multidimensional space and travel "through time.*

*Ontological* presuppositions concern the kinds of thing we are willing to claim exist. This broad group of presuppositions can be broken down into subgroups in several ways. For now, we can observe that ontological presuppositions may be of a very general sort such as the following:

Physical objects exist.
Minds exist as distinct from bodies and the activities of bodies.
Chemical elements exist.

*If such formal presuppositions are species-specific—which means, according to Skinner, that they are genetically constrained and thus “innate”—then why did it take human beings so long to ferret them out? I think the reason has to do with the development of writing. If the estimates are correct, human beings have been using language for some 40,000 years and writing down their language for less than 6,000. There are oral traditions that have come down in fragmented form from before the time of written language, but there is nothing in the oral traditions that smacks of conceptual self-examination nor even of the rudiments of logic. When we do examine how we think, we pay close attention to the words and symbols that we record. This is as true of the Greek thinkers of 300 B.C. as it is of modern analysts. One is led to suppose, then, that questions about how this species thinks did not arise in any serious way until we were capable of writing down our ideas and lines of argument for our own later criticism and the systematic criticism of others.
Everything that exists is composed of earth, air, fire, and water. Subatomic particles exist.

Ontological presuppositions may also be of a less general sort, such as these:

- Oxygen exists.
- Skunks exist.
- Quarks exist.

From the examples, you can see that ontological presuppositions are likely to change over a period of time and that two people are likely to disagree about ontological presuppositions (the mind-body presupposition, for instance). But assertions like “The halogens—fluorine, chlorine, bromine, iodine, and astatine—form binary salts by direct combination with metals” can be viewed as true or false statements only within a context of presuppositions that gives them sense, including, among others, the presupposition that chemical elements exist. To argue about such statements, to test them for truth or falsity, and to draw inferences from them become possible only within a context of ontological and other presuppositions.

**Existence** presuppositions are about individual things, whereas ontological presuppositions are about kinds of things. In general, we presuppose that assertions about individual objects refer to identifiable existing objects. We can’t discuss whether or not Harry Truman’s eldest son was a Democrat because Harry Truman didn’t have a son. In literal contexts of assertion, we can’t claim that a drugstore that is a figment of the imagination either was or was not actually robbed, as we saw in the example in Chapter 1. We do, of course, talk about fictional, or hypothetical, or merely possible individuals, and we do make perfect sense of such talk so long as it is clearly understood that this is the ground on which assertions are being made. We can assert that Sherlock Holmes used cocaine, understanding that we are talking about a fictional character, and we can say that, if Harry Truman had had a son, he probably would have been a loyal Democrat. But the contextual shift from making assertions about actual individuals to making assertions about fictional or possible individuals has to be clearly understood if we are to carry on rational discourse.

**Categorial** presuppositions determine the properties we are willing to ascribe to things of given kinds. Human beings and other higher animals are said to have properties associated with awareness and emotions; inanimate objects in general do not have such properties. Typewriters may be in need of cleaning but not in need of psychotherapy. Human beings may be in need of both. Electrons and other particles below the molecular level do not have properties of temperature.

Categorial presuppositions are particularly subject to change over a period of time as both scientific and common sense points of view change. Until the twentieth century, almost all western physical theory presupposed that physical objects have properties of absolute rest or motion. In the context of contemporary physical theory, rest and motion are relational properties: an object can only be said to be at rest or in motion relative to another object.

There will be more to say about categorial presuppositions later, when other distinctions have been introduced to mesh with the ones just made. Sometimes, of course, we violate categorial presuppositions deliberately, not to produce nonsense but to produce figures of speech that have a function other than the straightforward conveyance of information.

One of the features of language that makes it difficult to lay out distinctions such as these in a way that will stick is that we can constantly shift the level of a discussion from assertions about sticks and stones to assertions about **assertions** about sticks and stones or assertions about language itself. Now this is a complicated business, and I don’t propose to draw you any further into a set of linguistic distinctions than I need to in order to set things up for a discussion of how and why scientific ideas differ from one time and place to another.

The rules that delimit contexts for making meaningful assertions—a set of presuppositions—can themselves be asserted in their own contexts or in the broader context of an explanation or negotiation about what the common ground for a discussion is to be. Presuppositions have a dual status then. They serve the semantic function of delineating contexts for meaningful assertions, and they themselves can be asserted within their own contexts. To complicate matters even more, they can, like any assertions, be logically abstracted as statements understood within their own contexts and assessed for truth or falsity.

Perhaps the best way to illustrate how presuppositions can be both semantic items and assertions is by analogy with definitions. In formal contexts, we often stipulate definitions of particular terms. In the Commonwealth of Pennsylvania, for example, the term "single-
man" is defined for contractual purposes as "an adult male [human being] who has never been married." Definitions are not statements, but there are statements which reflect them and which are true in the contexts where the definition applies. So, in any legal context in Pennsylvania, the statement "A singleman is an adult male who has never been married" is a true statement. The definition makes the statement true. In another context, where the Pennsylvania definition does not apply—say, a singles bar in Tijuana—the statement might not be true.

Presuppositions are not definitions of terms. They are the rules that determine what does and what does not make sense in a given context, what can be said to be true or false. But like definitions they can be expressed as statements which are always true within the contexts they govern.

Suppose you are discussing the motion of objects within the context of Newtonian physics. There, as I noted earlier, it is presupposed that objects are either in motion or at rest in an absolute (rather than relative) sense. You might assert that a given object, \( x \), is at rest at a given time. Within the context, one can determine logically what the statement "\( x \) is at rest at time \( t \)" implies and determine whether the statement is true or false, consistent or inconsistent, and so on. Further, within this same context, the general statement "Objects are either in motion or at rest" is always true, because it simply states one of the presuppositions that characterize the context. But within the context of contemporary physics, where motion and rest are understood as relational, the statement "Objects are either in motion or at rest" does not turn out to be always true; it requires some hedging in order for us to assess it at all.

To recall the analogy with definitions, if the term "singleman" is understood in a given context as "any unaccompanied adult male," then within that context the statement "A singleman is an adult male who has never been married" is false, even though it is true by definition in the context of legal definitions in the Commonwealth of Pennsylvania.

What I identified above as formal presuppositions are those which have been taken by philosophers and psychologists to be universal—common to all human beings and perhaps rooted in the very physiology of the human brain. There may be some argument as to which presuppositions belong on this list, but it seems beyond question that there are such presuppositions and that this list is a fair statement of the most important ones. With the exception of the presupposition—"No object both has and fails to have a given property"—the statements which express formal presuppositions are not generally taken to be "logical truths," but they do delineate the boundaries of common sense experience, whether or not it ever occurs to a given person that they do. While there isn't much that would count as argument for the formal presuppositions, it is possible to explain at least some of them, that is, to explain why they are basic to human experience. A behavioral psychologist would argue that human beings, and other species as well, consistently behave in such a way that it is taken for granted that every event has a cause. Failure to behave thus, when the event is a perceived sound or motion, for example, would make it less likely that an individual would be prepared to flee from danger or defend itself or to take an opportunity for nourishment. In evolutionary terms, there is overwhelming selective pressure in favor of those individuals who consistently behave as if every event does have a cause and against those who do not. That is precisely how species-specific or "innate" behaviors come to be universal.

The remaining kinds of presupposition—ontological, existence, and categorial—are clearly not species-specific, and they vary greatly from one cline to another. Moreover, as I suggested in Chapter 1, we can voluntarily drop one set of presuppositions and adopt another on either a temporary basis, as when we converse with a child, or a permanent one, as when we are "converted" to a new point of view.

Coherent Beliefs and Plausible Hypotheses

In 1632, when Galileo said "The earth moves," Pope Urban VIII said, roughly, "No it doesn't." That is what logicians call contradiction. Flat out, head-to-head contradiction. One of them had to be right, and the other had to be wrong. Now you might want to object immediately that, from the point of view of the theory of relativity, they were either both right, or both wrong, depending upon how you reinterpret what they said. A modern astronomer has to agree with both of them, in a way. When the astronomer describes the universe, he is likely to say that everything, including the earth,
moves relative to everything else. But when he makes the calculations to aim his telescope at some particular area of the night sky, he has to think in Urban's terms or at least use tables in his calculations that are designed from Urban's point of view.

But relative motion wasn't what Galileo and Urban were at odds about. In the context of their disagreement, there was no way around the confrontation. They weren't talking about the motion of one thing relative to another but of absolute motion, as we would call it now, in what they took to be well-understood absolute space. There was no way that a third party could reconcile the difference by saying that it all depended upon how you look at motion, that position and movement could only be discussed as a relationship between objects. The context of the disagreement presupposed that motion was absolute. Either the earth moved or it didn't. You could not consistently believe both. If you had tried to mediate the argument by saying something like "Well, the earth both moves and doesn't move," as the introduction to an explanation about the modern conception of relative motion, you would have been dismissed immediately as an incoherent babbler. On purely logical grounds, you simply can't assert both in one context, and to do so is to say something that is logically impossible. Understood literally, without the hedges of a new physical conception, you violate the rules of rational human discourse when you say that a given object both has and fails to have a given property.

The minimal thing that we must require of a set of coherent beliefs is that they be consistent. On logical grounds, two statements in the same context are said to be consistent if there is nothing about either of them that prevents the other's being true and inconsistent if they are related in such a way that they could not both be true. In the exchange between Galileo and Urban, the clash was direct: "Yes" on the one hand, "No" on the other. The question of consistency is not the historical question whether either one of them was correct in modern terms but, rather, a logical question about the effect that the truth or falsity of one statement would have on the truth or falsity of the other.

Inconsistency does not always depend on such direct Yes-No verbal confrontation or on putting the Yes and the No together in one logically absurd assertion. It just as often depends upon how we understand the concepts involved. For example, we all understand, I think, that in order to pass a test for a driver's license, you have to take the test. The point is so obvious as to require no explanation. So you couldn't consistently believe both of the following:

Schulz passed his driver's test.
Schulz never took a driver's test.

Even if Schulz had bribed the officials to say that he had passed a test he never took, that wouldn't give you a way of reconciling the two. You would probably put quotation marks around the word "passed" in order to underscore the anomaly, if you had to write the two sentences down. The two statements are inconsistent because of what we mean when we say that someone literally passed a test, and to assert both is to assert something that is conceptually impossible.

Concepts change. The modern concept of space is different from that of Galileo and Urban. Combinations of beliefs that are conceptually inconsistent in one context might become consistent if we revise our concepts. But at any given time there is a prevailing way of understanding things, and there are some cases where concepts are unlikely to change very much. Things can't be red without having color, for example, and one and the same individual can't be both a dog and a tree. Where there are logical or conceptual matters at stake, we often say that we "can't imagine" a given state of affairs. I can't picture a four-dimensional physical object, however hard I try, and I can't imagine one and the same individual being both a dog and a tree. Such things are conceptually impossible, as distinct from the blatant Yes-No cases that we identify as logically impossible.

There is a third sort of possibility-impossibility question that figures in evaluating our beliefs. A situation that we might perfectly well be able to picture or imagine is judged to be theoretically impossible if it is inconsistent with a general explanatory theory that we accept, even though logical and conceptual issues don't arise. It would be theoretically impossible for a new planetary body to enter the solar system without its motion being affected by the existing planets and the sun. Such a thing would be inconsistent with Newton's laws of motion and gravitation, even as they have been hedged and modified by contemporary astrophysicists. Wherever there is a well-established body of theory, we can generally make a clear determination as to whether or not a given supposition is consistent with the theory—whether or not it is theoretically possible.
But if we are going to try to separate coherent sets of beliefs from incoherent ones, we can't simply settle for saying that what we believe isn't impossible—that it isn't inconsistent from a logical, conceptual, or theoretical point of view. If we are willing to assert that something is the case and seriously expect someone else to believe it, we must be willing to defend our assertions as plausible—minimally worthy of belief. Plausibility requires something more than possibility.

Consider this as a hypothesis:

There are diamonds on Mars.

At this moment, I don't believe that there are diamonds on Mars or, for that matter, that there aren't. The question is, Is the hypothesis plausible? Might I come to believe it? Is it worth considering further?

Let's tackle the question of possibility first. The hypothesis is possible in all three ways mentioned: There is no logical inconsistency, and there is nothing in my understanding of either diamonds or the planet Mars that would prevent its being true. So far as I know, there isn't any well-established theoretical reason to doubt that there are diamonds on Mars.

Beyond possibility, there are some other, less formal, grounds on which to assess the plausibility of a hypothesis. First is the matter of precedent or instances: Do we know of a similar situation where such a thing has actually occurred? So far as this hypothesis is concerned, of course we do. The Earth is similar in many geological respects to Mars, and there are diamonds on Earth. Even if we couldn't explain why there are diamonds on Earth, we know that there are, and that precedent makes it more than just possible that there are diamonds on Mars. It confers a degree of plausibility to the supposition that there are.

A second question that affects the plausibility of a hypothesis is how it might enter into explanations. Would the hypothesis serve to explain a range of events that we don't have a satisfactory explanation for? Alternatively, could we explain the hypothesis itself? The diamonds-on-Mars hypothesis doesn't explain anything much, but we could explain how there came to be diamonds on Mars. We know how diamonds are formed on Earth, and Mars is similar enough to our planet that the chemical and physical processes involved in forming diamonds could well have taken place. So we can see how it could have come to be.

Having a precedent or an explanation lends plausibility to a hypothesis, but failure to have one or the other doesn't necessarily constitute grounds for saying that the hypothesis is implausible. There are some things that we know occur but can't explain (for example, how aspirin works). And there are some things that we are able to explain before we are sure that they happen. This is exactly the situation that physicists are in when they say, on the basis of their theories, that a given sort of subatomic particle is liberated in the interaction of other particles before any experimental evidence is brought in. It has happened frequently in the past fifteen years or so that the characteristic "tracks" of particles in a bubble chamber have been predicted by an explanatory theory before the tracks were observed.

There is a third consideration in assessing the plausibility of a hypothesis: How does it mesh with what we already believe? If a hypothesis is inconsistent with some of our beliefs, whether or not we are willing to consider it—whether or not it is judged to be plausible—will depend in large measure on how important the challenged beliefs are to us and how central they are to our overall pattern of beliefs. The diamonds-on-Mars hypothesis is consistent with everything I believe, including beliefs about both central and peripheral matters. If further exploration should produce evidence of diamonds on Mars, it wouldn't cause me to change any of my beliefs.

Here is a second hypothesis that I have heard people assert recently:

A human being can levitate (that is, can rise from the ground simply by wanting to).

I don't believe this one either. But, again, the question is whether or not it is plausible. Let's run through the criteria. First, the questions about possibility. On the face of it, there is no logical or conceptual difficulty. Is it theoretically possible? This comes down to the question whether or not levitation is inconsistent with a generally accepted explanatory theory, and in these terms levitation is not theoretically impossible. It is not inconsistent with any well-established physical theory to suppose that some unspecified agency, linked with a particular sort of emotional state ("wanting to"), might act on the human body in a given way. What bothers, of course, is that we know of no such agency. But to claim that levitation is theoretically impossible simply because we would have
no theory to explain it is to suppose something about the present state of science that is simply false. There are a number of familiar events that cannot be explained by current physical theory, including events involving gravity. Partly for this reason, there is no theory about how gravity works that is agreed upon by the western scientific community. There are as many as eight competing explanations of gravity right now, but none of them is generally accepted.  

As a first step toward evaluating the plausibility of the levitation hypothesis, we have to say that it is possible logically, conceptually, and theoretically. There is no inconsistency. Now, on to the other three criteria for plausibility.

Is there a precedent for the levitation hypothesis? Do we know of any instance where it has happened, or do we know of similar events where the emotional state of a human being has produced such an extreme physical effect? Here the matter of precedent is less clear-cut than it was with the hypothesis about diamonds on Mars. The religious literature of both East and West contains accounts of incidents of levitation. How seriously do you take such accounts? Are they to be understood as literal eyewitness reports, or as metaphors of some sort to the effect that it was as if a given saint or other personage had risen from the ground? I don’t think there would be as easy a consensus on this matter as there was about the precedents for the diamonds-on-Mars hypothesis.

But there are other apparent precedents for levitation. Photographic evidence has been published recently of American students learning meditative techniques, who—as the photographs seem to indicate—literally rose several feet from the ground while meditating.  

In addition, there have been reports of related events involving “psychokinesis,” where witnesses claim that objects can be moved about by a “pure act of will.” Some of these reports are clearly fraudulent, but it isn’t clear that all of them are.

So the matter of precedents for the levitation hypothesis is a bit muddy. Incidents have been claimed, but there is no general consensus as to the reliability of the claims. There have been fraudulent claims made in the past about similar matters, and it just isn’t clear whether or not the recent claims are to be taken seriously.

As a public matter, the question of precedents is undecided. (If, on the other hand, you have witnessed or experienced levitation, the question of precedents is settled so far as your personal beliefs are concerned.)

Could we explain levitation? This is the second question related to the plausibility of the hypothesis. As I noted in considering the theoretical possibility of levitation, current physical theory could not explain it. Levitation is theoretically possible in the sense that it isn’t inconsistent with any of our physical theories, but it gains nothing in plausibility from the physical theories, because we could not explain it, even if we were confronted with indubitable evidence that it had taken place as described.

Finally, we come to the question whether or not the levitation hypothesis is consistent with what we already believe. Again, the matter is problematic. The relevant beliefs are precisely in an area where we lack a consensus. A belief that dominated western thought for hundreds of years is that “mind” and “matter” are to be sharply distinguished, that “mental events” and “physical events” influence each other only within the human body—where physical stimuli are linked to awareness, and where the decision to move a certain part of the body is linked to the actual movement. The levitation hypothesis would certainly challenge this belief. But the belief is already under challenge from other quarters. The sharp distinction between the mental and the physical that was until recently characteristic of western thought just doesn’t seem to work very well in the practice of medicine, for example. Psychosomatic medicine, cures of obvious bodily ailments effected by hypnotic suggestion, and other developments have made it clear that the distinction needs to be reconsidered.

To ask whether or not a hypothesis is plausible is to ask for a critical examination of the hypothesis in the light of established beliefs and in the light of available evidence. To say that a hypothesis is plausible is to say that it is worth pursuing further by looking for more evidence that will support it or refute it.

We evaluate hypotheses both privately and publicly. Not all of us are equally critical concerning our personal beliefs. But scientific beliefs are another matter. A scientific community is a critical community in which hypotheses are publicly evaluated in rather stringent ways. For good reason, the scientific community tends to be more conservative about accepting hypotheses than most individuals are. Personal beliefs and scientific beliefs are not identical,
then—not even when we are talking about the personal beliefs of a working scientist. Most working scientists have pet hypotheses that are not accepted by the scientific community at large; the public critical verdict isn’t in yet.

Now, where do we stand on the two hypotheses we have been considering? The first, that there are diamonds on Mars, is quite plausible. It is surely possible in all the senses described, and the three additional criteria—precedent, explanation, and consistency with established beliefs—are all in its favor. It is clearly worth pursuing further, and no doubt there will be evidence gathered by an exploratory spacecraft that will have some bearing on the hypothesis.

The second hypothesis, that human beings can levitate, remains problematic. It is possible, in all three senses, but we didn’t get a clear-cut answer as to whether or not it is something more than possible. There may be some instances, but it is hard to be sure. There isn’t an available scientific explanation for it, at least not in contemporary physical theory. The beliefs relevant to it are precisely in that area where there isn’t a good consensus at present.

But is the hypothesis plausible to you? That is a different question from whether or not it is scientifically plausible. Whether or not you or I take the claimed precedents seriously,Barley have not been established by controlled experiment, and that is what scientific plausibility demands. Whether or not you or I think that there might be some rather strong physical agencies that can be influenced by our thoughts, there is in western science no theory that has been subjected to critical scrutiny that would explain how such forces work.

I doubt that very many western physical scientists would grant the plausibility of the levitation hypothesis, at least not when “speaking professionally.” Most would say that it is implausible, on the explanation grounds alone. We simply cannot see how it could happen. This may be too conservative an attitude for individuals to take. Perhaps the relative conservatism of the scientific community is too extreme to apply to our personal beliefs. On the other hand, some people will believe anything, and we must avoid that extreme as well.

Identifying, Counting, and Classifying

In Chapter 1 I introduced the question “How many objects in this room?” as a means of making the point that there is not a uniquely correct answer to such a question. There are ways of modifying the question that don’t help at all. “How many red objects in this room?” doesn’t do the job, for example; there is still more than one reasonable way to decide whether you have a single red object or a connected group of red objects. “How many soluble objects?” doesn’t help either. “How many dogs?” on the other hand, admits of a straightforward answer. If you are counting dogs rather than things, there is one correct answer. Other terms, like “chairs,” “soldering irons,” “bricks,” or “linoleum tiles” would work as well. They are all terms that tell us what kind of thing is being asked about.

I’m going to use the words “identify” and “classify” here as a biologist uses them: We identify individual things as being things of a kind; we classify a group of individual things (or all things of a given kind) as being within a more inclusive grouping. Individuals are never classified in this sense; they are identified as being of a given kind or as being composed of a given substance. Thus, we identify Fido as a dog, or a mammal, or a vertebrate, but we classify dogs as mammals and mammals as vertebrates. The distinction can easily be extended to “stuff” or “matter” terms: We identify a given quantity of a substance as peanut butter, and we classify peanut butter as nourishing food.

There is not, of course, precisely one correct way of identifying objects; the activity can be carried out in a variety of ways, using a variety of different vocabularies. But the activity of identifying things is a very basic conceptual activity that has to do with the identity of individual things. To identify an object is to say what kind of thing it is, to delineate its boundaries in such a way that if it ceased to be that kind of thing it would also cease to be that thing.

Time for an example:

Fido was sick yesterday but is well today.

No problem. Being sick has no connection with Fido’s identity, and it is just the sort of thing that comes and goes in a given individual. But how about this:

Fido was a dog yesterday but is a squirrel today.

It just doesn’t work. If Fido stops being a dog, Fido ceases to be the individual he is.

There is nothing especially mysterious about basic identifications. They reflect not some arcane truths about the universe but, rather,
the way we sort things out in a given context. Identifying a thing as a thing of a kind gives a basis for individuating it as a particular thing, for saying that it is one chair rather than twelve pieces of wood, for example. To play on the terms a bit, when we identify something, we give it an identity that allows us to count it and to describe it further.

But despite the close connection between identification and identity, we can't claim to have a unique way of identifying objects. There is more than one way of identifying and counting individual objects, both in common sense contexts and in the more systematic contexts of the sciences. There are situations where we voluntarily change our identifications—our basic sorting out of objects—for one reason or another, as when we consider how a cabinetmaker might identify the objects in the room as distinct from the way a moving man might identify them for an inventory. I will suggest shortly that re-identification of individuals and re-description of events figures importantly in certain kinds of scientific explanation.

It's the activity of identifying and classifying that is basic, not any particular scheme of identification or classification. Both identification and classification have characteristic patterns in natural speech, and these patterns are reflected more formally in the way the various sciences identify and classify the objects they study. In the next chapter I will take a brief analytic look at the way these activities are carried out formally in biology and chemistry.

Describing and Explaining

Suppose you are walking along a beach and you come on the remains of an exploded aerosol can. Some of the paint is burned off, and all the jagged edges stick out from the can rather than into it. So far, we are just describing what you've found, from what seems to be a reasonable point of view. We've identified the thing, and from its appearance it looks as if it exploded. If you start asking why the aerosol can exploded, you're asking for an explanation and inviting hypotheses.

A hypothesis, as I have used the term, is a supposition. Typically, when looking for an explanation, we try out a few hypotheses and sort out which of them is the most likely. If one hypothesis comes to be accepted, we will call it a thesis.

A plausible enough hypothesis about the aerosol can is that it was simply left in the sun, overheated, and exploded. If you can still read the relevant parts of the label, you might see a cautionary notice telling you not to leave the can in the sun. Another hypothesis is that the can was thrown into a fire while it was still sealed. This second hypothesis seems more likely than the first because of the burned paint. The next step is to take a look around the area . . . sure enough, just over the dunes are the remains of a bonfire, giving even more reason to prefer the second hypothesis.

A straightforward causal explanation of this sort typically involves three items: a question that includes a description (why did the can explode?); one or more hypotheses; and a procedure for testing the hypothesis on its own, to see if it is plausible, independent of its connection with the event to be explained (the search for the site of the fire).

The next sort of question you might ask about the aerosol can is Why did it explode when it was thrown into the fire? The "why" questions can go on indefinitely. In this case, we have some well-established general theses about why such things happen. To explain why the can burst when it was thrown into the fire, you might talk about what happens when you increase the temperature of air (or any gas) while holding the volume constant: the pressure builds up until the container isn't strong enough to resist it, and the container ruptures.

Notice that there is a new step in this explanation that didn't occur in the first one. We have replaced the elements in the original description of the event as follows:

The closed container is re-identified as a system of constant volume.

Throwing the can into the fire is re-described as increasing the temperature of the system.

The explosion of the can is re-described as a symptom of an abrupt and extreme increase in the pressure of the system.

The first explanation of why the can exploded—because it was thrown into the fire—didn't require any re-description. Causal explanations typically do not. When we have to shift ground and re-describe an event in order to explain it, or to re-identify elements in the original description, the explanation becomes theoretical. By this I don't mean that there has to be an organized theory to back us up; I simply mean that there is a discernible shift in the language we use.
for the explanation that reflects a new context of presuppositions. It is exactly the re-identification of objects and processes that marks a shift between data (description and causal explanation) and theory.

The line between data and theory is not a fixed one, and it can be drawn only with respect to a given context. What signals that the line is being crossed in a given instance is the need to re-identify items and re-describe circumstances. But it isn’t as if the original description was in some sense neutral or independent of its own context of presuppositions. We could as well have identified what was found as a dragged, torn piece of metal and then re-identified it as an exploded aerosol can. The data-theory line isn’t fixed in either direction from what seems in a given instance to be a natural context of description. (This is what I take Karl Popper to mean when he says, “We are theorizing all the time.”)

The explanatory re-description introduced the terms “volume,” “temperature,” and “pressure.” But these same terms can serve to describe data for further theorizing. If you were to ask the more general question why the pressure of a system increases when the volume is held constant and the temperature is increased, you would most likely get an explanation in terms of the kinetic theory of gases. This involves a shift to yet another context of presuppositions, in which the following description can be given:

Temperature is re-identified as the mean kinetic energy of gas molecules.
Pressure is re-identified as the velocity with which gas molecules collide with the wall of the container.

The line between data and theory can be drawn on such contexts, but it cannot, in general, be drawn in any permanent way on a whole language, or even on the whole vocabulary of a given scientific discipline. In the first instance of theoretical explanation, the question was about an aerosol can thrown into a fire, and the answer was about temperature, pressure, and volume. In the second instance, the question was about temperature, pressure, and volume, and the answer was about the energy and velocity of gas molecules.

An explanation of an event (or kind of event) is causal when it invokes hypotheses about other events but does not necessitate re-describing the event to be explained. A hypothesis is typically a trial explanation. Suppose that the can had been thrown into the fire; that would have caused it to burst. Further checking (independent evidence) shows that there was indeed a fire nearby, and the explanation seems plausible.

An explanation of an event (or kind of event) is theoretical when the hypotheses or theses invoked necessitate re-describing the event to be explained. There is a location that is often used in such cases that harks back to the argument about the red shirt in Chapter 1. It’s this: “What really happened is that the mean kinetic energy of the gas molecules increased, so that they collided with the walls of the container with greater velocity than the metal could withstand.” The word “really” signals a preferred way of describing the event, but it also suggests a kind of unique correctness that just isn’t present.

**Truth, Falsity, and Accurate Description**

The position I have taken about asserting beliefs and describing situations provides a way of dealing with statements that occur within different contexts of presupposition without trapping us into the kind of vicious relativism that leads to dismissing questions of truth and falsity altogether. Too often we hear people suppose that what they say can be “true for me” whether or not it makes sense to anyone else. Such a supposition misses the most important feature of claims for truth and claims for knowledge: they are objective, not subjective, claims. The fact that there is not a uniquely correct way of describing a state of affairs should not mislead us into thinking that we can’t sort out correct descriptions from incorrect ones.

We can judge statements to be true or false only if we understand the context in which they are asserted. The objects we identify are objects of our experience, and the properties they have are natural properties by virtue of human nature; they are a function of the relationship between human beings and the objects they attend to. Beyond this, there are indefinitely many ways of identifying objects and describing their properties—determined by language, local idiom, the purpose of the identification or description, and the overall context of presuppositions in which any discourse takes place.

But this is a rather confusing claim, because to challenge it you must start asking whether or not objects “really” are the kind of objects we take them to be and whether or not they “really” have the properties that we ascribe to them. Such a question involves a fundamental confusion about what is involved in making an objec-
tive claim that a given description is accurate or that a given statement is true. I hope to convince you of this before the end of this chapter.

Now, before I lay out a way of looking at judgments of truth and falsity, let me soften you up with an example. Figure 3-1 shows three different maps. The top map shows how land is used in the area near an electric power line. The middle map represents points in a given geographical area that are the same height above sea level. The bottom map is a street map of part of a city, as you might guess.

In a fairly obvious sense, each of the three maps may be said to be an accurate map or an inaccurate map of the area it represents, once we know how to interpret the symbols in each map. As a matter of fact, they are all accurate maps, within reasonable standards. Now, to be able to tell that they are accurate, you would have to know what each different sort of line and symbol on each map represents—what it corresponds to in the physical area that the map covers. In addition, you would need to understand how to determine whether or not the relevant features of the geographical area depicted in each map are indeed as they are represented. Without understanding these things, which are not part of the maps themselves, you would have no way of evaluating the maps.

Before I connect the example with assertions, there is one more thing about the three maps that should be noted now, so I can refer back to it later. The top and middle maps are recognizable as maps of the same territory. Without even knowing what city the maps represent, you can probably tell that these two are maps of the same area. But chances are that you can't tell from the maps themselves whether or not all three represent the same area, and, if you were to compare the bottom map with either of the others alone, you would not be able to tell whether or not these pairs represent the same area. As you've probably guessed by now, all three maps do represent precisely the same area (part of San Francisco). But this is clear from the maps themselves only in the case of the first two.

There are several points to be noted about the maps:

Each map stands in its own relation to the geographical area it represents. There is no "basic map" that must stand between each of the other maps and the geographical area. Each map can be understood and assessed for accuracy only if its legend—the idiom of its symbols—is understood.
The elements of each map either do or do not correspond to discernible elements in the geographical area represented. The question is a purely objective one, which is to say that anyone who understands the idiom of a given map and has access to the area it represents can determine the extent to which the correspondence exists.

The relationship between each map and its geographical area is independent of any particular individual's beliefs about it. No one of the maps is in any sense uniquely correct. All of them are accurate, and a preference for one over the others must have as its basis something other than the question of accuracy.

Truth and falsity are properties of statements in the view I have taken here. We assert our beliefs within well-understood contexts, and our assertions can be assessed as true or false statements only within their own contexts.

If I describe the facts of a given situation, you can determine whether or not my description is accurate, provided we are on common ground—provided, that is, that you understand the context in which I am offering the description. An accurate description does not carry with it the guarantee that it is the only accurate description. Someone else might describe the same situation accurately from another point of view.

The point of view that is characterized by a given set of presuppositions does not decide the facts; it merely provides a way of describing them in a set of statements. Whether or not the statements are true is a matter for empirical investigation. The whole descriptive package of presuppositions and statements is then subject to further judgment concerning the adequacy of the account it gives, relative to the reasons why the description was undertaken in the first place. What I am considering here are, of course, ways of evaluating descriptions of particular situations. I will discuss beliefs of a more general nature in the next two chapters.

We already have an example before us that provides several descriptions of the same event: the explosion of the aerosol can on the beach.

In the first description we simply assert that at a given time, \( t \), and at a given place, \( p \), an aerosol can was thrown into a fire and that it exploded.

In the second description, also about what happened at time \( t \) and place \( p \), we assert that a container of gas at constant volume was subjected to an increase in temperature, so the pressure increased sufficiently to rupture the container.

In the third description we assert that at \( t \) and \( p \) the mean kinetic energy of a system of gas molecules was increased, so the velocity with which the molecules struck the walls of the container exceeded the breaking strength of the walls.

Given the example, all three of these alternative descriptions are accurate. Each of them corresponds to the facts under a given interpretation, which is just to say that the incident can be accurately described in any of the three ways. Assessing the accuracy of each description entails understanding the context in which it is asserted. Alternative descriptions need not have any more in common than that they all are connected with the world in a recognizable way by their own semantic relationships. It need not be the case (as it is in the example) that every verbal element in one set of statements can be matched up with a verbal element in the others.

Now, some observations concerning the alternative descriptions which parallel the earlier observations about the alternative maps:

Each description stands in its own relation to the facts. There is no "basic description" that must stand between each of the other descriptions and the facts.

Each description can be assessed for accuracy or inaccuracy only if the context of presuppositions in which it occurs is understood.

The statements in each description either do or do not correspond to discernible elements of the incident described. The question is purely objective, which is to say that anyone who understands the idiom of a given description and knows what it is about can determine whether or not it is accurate. The relationship between the description and the incident is independent of any particular individual's beliefs about it.

No one of the descriptions is uniquely correct. All of them are accurate, and a preference for one over the others must have as its basis something other than the question of accuracy or inaccuracy.

The objectivity of claims for the accuracy or inaccuracy of descriptions is a matter of intersubjective agreement: a set of descriptive statements asserted within a given context of presuppositions has the objective property of truth or falsity if anyone who
understands the context of presuppositions and knows what the statements are about can determine whether or not the statements are true. Objectivity, then, does not entail unique correctness. The statements in each of the three contexts are true. Each of the three descriptions is accurate. Which of them tells what really happened on the beach? They all do.

FURTHER READINGS

This chapter reflects a good deal of recent critical dialogue among philosophers. For general discussion of the relevant issues, see Stephen Toulmin, *Knowing and Acting* (1976), and Jay Rosenberg, *Linguistic Representation* (1974).

On presupposition, the seminal work in this field is in P. F. Strawson, *Introduction to Logical Theory* (1952). The present account differs from Strawson's in treating presuppositions as both statements and semantic rules.

On possibility and plausibility, for a more technical development of the concepts, see D. Paul Snyder, *Modal Logic and its Applications* (1971), Chap. 6. For a formal treatment of existence presuppositions, see Chaps. 5 and 8.

On truth and objectivity, see Karl Popper, "A Realist View of Logic, Physics, and History," reprinted as Chap. 8 of his *Objective Knowledge* (1972). The view presented here is very close to Popper's.

Readings on the theory-data distinction and on explanation are listed at the end of Chapter 4.

Science as we recognize it in western civilization today is a highly organized group activity. There is an identifiable scientific community that now crosses national and linguistic lines and that performs its specialized behavior on behalf of the entire community. Scientists did not evolve separately from the rest of humanity, of course, any more than teachers, dancers, cooks, farmers, whores, or handymen did. All parents, for example, teach their own children, but some people specialize in teaching children and do it on behalf of the whole community.

Similarly, everyone wonders about why things happen and develops hypotheses to explain why things are as they are. Everyone develops and acts on generalizations about what it is reasonable to expect in given situations. Scientists specialize in these activities and carry them out in systematic ways. Such division of specialized labor is important to the organization of human communities, and there are, of course, analogues to be found in the communities of other "social animals."

My emphasis on the verbal character of the activities of identifying objects and describing and explaining events may seem excessive on the face of it. But it is precisely the communication of scientific ideas in a systematic way that makes it possible for science to function as a public activity and that provides the scientific community itself with the critical devices that sort out acceptable scientific judgments from unacceptable ones. Such judgments are
always subject to critical evaluation within a given scientific discipline and within the context of presuppositions that characterizes the idiom of a given discipline at a given time.

The objectivity that science requires depends in large measure upon the public examination of specific assertions in the light of evidence and in the light of already accepted theoretical judgments. If there is a "scientific attitude" that can be encapsulated in a slogan, it is this: Assert only what you can defend.

The awe with which we tend to treat scientific assertions leads some people to suppose that the slogan should read: "Assert only what you can prove." This is misleading, because there are at least two distinct uses of the term "prove" that can cause confusion about just what it is a scientist does. On the one hand, there is the sense of proof within a mathematical, geometric, or logical system wherein a given result is derived from a set of axioms and definitions by means of specific inferential rules. Given the logical rules, the axioms, and the definitions, the result follows by necessity. Scientific proof, on the other hand, reflects another long-established use of the term that is closer to the German word Prüfung—"testing."¹ This use is reflected in the notion of proving a weapon (as a sword, or the more modern weapons that are tested at military "proving grounds") or the proofs that are struck from a page of type. It is also reflected in the expression, "The exception proves the rule," which is absurd on the mathematical proof understanding. The apparent exception to a rule tests the rule and its ability to account for its subject matter. It doesn't, of course, demonstrate the rule. And, finally, how do you prove a pudding? If we want to rephrase the slogan, it might read: Assert only what can be publicly tested.

I have already described this book as containing a theory about science. It is, in that sense, a description of what happens when people do science; it is not a prescription about what should happen, except in the sense that it might underscore certain methodologies which have proved successful. I believe that a philosopher of science should study scientific methodology and theory in much the same way that a linguist studies the grammar and content of natural language—as an empirical study of a living system. Any pronouncements about what it is to do science should be approached with the same critical attitude—the same demand for public testing in the light of evidence—that pronouncements in the physical sciences receive.

Data, Theory, and Nomenclature

Many of the key terms that are used to describe scientific activity have suffered from overuse and have taken on a variety of different meanings. "Theory," for example, might be used to refer to Einstein's theory of special relativity—a well-articulated physical theory—or your maiden aunt's theory that her bathtub is haunted—an unconfirmed belief, at best—or any of the many theories about the assassination of President Kennedy—conjectures that are consistent with the known data. I think it best to set out here just which of the various uses of key terms I am adopting and to be as scrupulous as possible hereafter in using them always in the same way.

Data

The word "datum," of which "data" is the Latin plural, means simply "fact" or "what is given." It is customary to use this plural term in singular constructions. The data, collectively, is what happens—what we experience, in general. But, because there is no singular way of describing our experience, there is no clear-cut segment of language that we can set apart as the vocabulary for describing data.² Recall the example of the aerosol can in the last chapter. In the first instance, the data consisted of a description of a container that had burst when it was thrown into a fire, and what was introduced to explain the data was a theoretical re-description of the situation in terms of temperature, pressure, and volume. In the second instance, temperature, pressure, and volume entered into the description of the data, and the theoretical re-description was in terms of molecules of a gas and their properties.

Whether a given term enters into a description of the data or into a theoretical explanation of the data will vary with context. The line between theory and data often gets lost in practice and emerges as a clean line of distinction only when a difficulty arises with a given theory or when an analysis of the theory is carried out.

The data level for an emerging theory is the level at which no one concerned would disagree about the accuracy of descriptions. In such a situation, the data must be described at a "ground level" of general agreement, so that even rival theorists will be able to agree on it.

The data level of a well-established theory will be different from that of a theory that is still in the hypothetical stages and will be
more influenced by the theory itself. Statements expressed in the data vocabulary describe what the theory explains, and the vocabulary is often constrained by what the theory can explain. An orthodox style of description develops relevant to a given well-accepted theory (as in contemporary chemistry and biology), and it is likely to be abandoned in favor of a more basic style of description only when the theory comes under attack. So the question whether or not a given term is part of the data vocabulary is not a logical or even a linguistic one. It is an empirical question, which is to be answered in a given instance by an empirical study of scientists at work.

We can, in a given context, talk about data statements and vocabulary as distinct from other portions of the context; the distinction is made according to how terms function in that context. Specifically, in general chemistry, the data vocabulary is used to describe what is measured and observed in chemical reactions—the colors, textures, weights, and volumes of substances; the temperatures at which they undergo physical change, such as boiling, freezing, or melting; what visible changes happen when we drop pellets of zinc into hydrochloric acid or pour sulfuric acid over sugar, and so on. In zoology, the data is described in what is called the phonetic vocabulary—the general appearance of organisms, their skeletal structure, internal organs, coloration, nourishment, breeding patterns, and so on.

Hypotheses and Theories

A hypothesis is offered in an attempt to explain data. Hypotheses that require a re-identification of the items to be explained I will call theoretical hypotheses. The ancient supposition that the lights in the sky are holes in concentric spheres which surround the earth is just such a hypothesis. Explanatory hypotheses that do not require such re-identification will be called data-level hypotheses. Where context makes it clear which is meant, I will use the term “hypothesis” alone.

Data-level hypotheses typically figure in causal explanations. When you explain a broken cup on the kitchen floor by supposing that the dog knocked it off the table, there is no need to re-describe the situation you are explaining. The hypothesis is at the “same level” of discourse as the description of the data to be explained, which is to say that the description and the hypothesis occur within the same context of presuppositions.

An explanatory hypothesis which is theoretical in the sense just described is not necessarily part of a well-articulated theory. Some theoretical hypotheses never get beyond the stage of supposition or the suggestion that we “look at it this way.” They are eventually discarded without ever being taken seriously enough to enter into an organized theory. Other theoretical hypotheses survive, either by standing up to critical examination better than competing hypotheses or by receiving confirmation from further independent data. These may become theses of a nascent theory. A group of related theses may finally be linked together in a fully developed theory. I will reserve the term theory for such organized groups of theses.

Each of these terms has to do with the role that a statement plays in a given context and at a given time. A statement which begins as a theoretical hypothesis may become so well established that we are willing to call it a thesis; it may then be integrated with other statements into a theory. Over a period of time the theory may become so well absorbed into familiar discourse that it becomes commonplace—part of the everyday vocabulary used to describe experience directly. Theses about the temperature, pressure, and volume of gases have certainly been thus absorbed. In such cases, a statement which begins as a theoretical hypothesis ultimately becomes part of a straightforward description of data and is itself subject to further theoretical explanation.

Moreover, the line between what we experience and what we do not is blurred in several ways. How sophisticated our concepts are and how we connect them in immediate, non-inferential ways to sensory stimulation varies from one person to another. An experienced mechanic listening to an automobile engine literally hears sticking valves and loose tappets, whereas the owner of the car hears knocking and ping noises. Our technology also blurs the line. We are able, in some cases, to translate stimuli that are outside the range of the senses into stimuli that are well within sensory range. We see—in the direct sensory process—differences in color. We do not see differences in infrared (heat) radiation or in the reflected radiation from other parts of the electromagnetic spectrum. But we can translate reflected heat or other invisible radiation into color images through a highly developed technology for doing so. Other sorts of property can be brought within the sensory range by means of gauges or other measures or by electronic visual display. In well-

*In some circles the vocabulary of a given psychological theory is often used, inappropriately I suggest, to describe directly the way people behave.
languages that individuality is of things. This crystal of salt, or this chunk of copper sulfate, ceases to be this individual thing when it is dissolved in a liquid or recombined in a chemical reaction. A given sample of matter may be identified as a non-metal, or as a halogen, or as iodine. The last identification is of course the most satisfactory of the three, because it is the most specific. It identifies the sample at the least general of the three levels, and thereby connects the identification with a set of properties associated with iodine, and a set of theoretically based judgments and expectations concerning the sample in question.

In biology, nomenclature consists of the names of taxa, and these are arranged in a highly structured way. A taxon is a group of organisms recognized as a formal unit in systematic taxonomy, and taxa are ranked from the basic level species through the more inclusive levels genus, family, order, cohort, class, phylum, and kingdom, with intermediate levels sometimes distinguished (such as superorder and suborder) between the ones mentioned. A given species of dolphin will be further classified in phylogenetic taxonomy as of the genus *phocaena*, family *delphinidae*, order *cetacea*, cohort *ungulata*, class *mammal*, subphylum *vertebrata*, kingdom *animal*. Classification of a given population must take place at all the major levels mentioned to be systematically complete.3

An individual may be grossly identified as an animal, a vertebrate, or a mammal, but as was the case with chemical identification, the biological identification of an individual is more satisfactory as it gets to the least general level. An individual specimen is completely identified from a biologist's point of view when its species is given.

Again, it isn't just a matter of neatness or compulsive thoroughness that makes complete identification preferable. The more specific the identification, the more we know what to expect of the item in question and the more we know how it is connected with other items.

**General Patterns of Activity**

The three activities of describing, explaining, and identifying are interrelated. In the informal cases discussed in the preceding chapter, the relationships are blurred, but in the formal extensions of those activities that comprise the organized sciences we can see the lines of connection more sharply. Typical patterns emerge in
chemistry and zoology, and they can be found in the other organized sciences as well. The general pattern of relationships among the three activities can be laid out as follows:

Figure 4-1 • The General Pattern

Criteria and Explication

Nomenclature in the sciences is a systematic activity. The names of items under study are used in both description and explanation: In general, data statements about things of kind \( K \) will tell what characteristics \( K \)s have; theory statements about \( K \)s will tell why they have the characteristics that they have. But it is the theory, not the data, that provides the systematic scheme for classification.

We cannot classify on the basis of all possible combinations of descriptive characters. The classification becomes impractical, for one thing; there will be many classes which are describable, but empty. There is nothing in the mere listing of characters that gives a clue as to whether or not there might be some undiscovered kind of object that meets the description. Systematic classification is done on the basis of the best available theory which explains why things have the characteristics they do. This means that classificatory schemes will change from time to time, as the best available theory in a given field is modified or replaced.

The advantage of classifying on the basis of theory rather than data is considerable. Either way there are going to be some classificatory slots which have no known members. But although a classifi-
have received more publicity), or that a laboratory element is discovered in small quantities in nature.\textsuperscript{4}

In biology, the relevant theory is of course the theory of natural selection that was discussed in Chapter 2. The theory is of a different sort than chemical theory, and classifying on the basis of it requires a "reconstruction" of the phylogeny—the genetic relationships among organisms—from physiological data. Although the method of the reconstruction needn't concern us here, it involves sorting out characters; those which result from phylogeny must be sorted out from those which result from adaptation. A whale's general shape, for example, would place him closer to fish than to mammals, but the shape is taken to be part of the whale's adaptation to an aquatic habitat, and his mammalian characteristics are taken to be part of his phylogenetic heritage.\textsuperscript{5}

Knowledge of the story of evolution is inferential and incomplete, and the classification of organisms is not nearly as neat and compact as the classification of chemical elements. But despite frequent revisions necessitated by the discovery of unexpected fossil remains, the theory has been able to provide a basis for classification which, like chemical classification, allows for the "prediction" of species that must have existed between known species. From time to time, we hear of the discovery of another missing link in the phylogenetic chain that has just the characteristics that the theory leads one to expect.

We can't leave this topic without noting the difference between the two sorts of explanatory theory just described and noting some recent developments relevant to each. Biological theory has a time dimension; chemical theory does not. There are \textit{historical} gaps in the biological theory that may never be filled in. Interestingly enough, astrophysicists have recently developed hypotheses about the \textit{evolution} of chemical elements, a process which takes place within certain kinds of stars, in which simple particles are combined into simple atoms and these in turn, through a process of fusion at certain times in the life-cycle of a star, are brought together to form the heavier elements. This new theoretical development will probably have no effect on the chemical classification of elements, although it does explain how the natural chemical elements came to be.

On the other side of the coin, there has been great excitement among biologists in recent years about molecular biology—the study of the genetic chemicals DNA and RNA—which promises to explain the mechanism by which a living cell replicates and \textit{how} mutations occur in the structure of the DNA and RNA molecules. (Evolutionary theory needs only to claim \textit{that} mutations occur.) It is not too farfetched to suppose that within the next fifty years or so molecular biology will have progressed to the stage where a full analytic "map" of a given DNA molecule can be drawn, and connections can be established between a particular DNA structure and the conspicuous characteristics of the organism whose cells have that structure.

Once both of these things have been accomplished, a new basis for biological classification will be at hand: organisms will be classified on the basis of the \textit{new} best available theory which explains why they have the characters they do, and at the same time explains how the evolutionary process took place.\textsuperscript{6} One would expect a DNA-based taxonomy to mesh rather well with existing evolutionary taxonomy, perhaps correcting some of the inferences that have been made about particular lines of ancestry but supporting the overall taxonomic structure.

Although theory typically provides the schematic basis for classifying things into kinds, the data—the descriptive statements—provide the \textit{criteria} for deciding whether or not a given individual is of a given kind. Zoologists use a "key" in the field for identifying individual specimens by their conspicuous bodily characteristics.\textsuperscript{7} In chemistry, the criteria for deciding what a given substance is consist of a series of laboratory procedures or tests, typically using known chemicals in reactions with the unknown one to make the identification.

There is a term that is conspicuous by its absence here: \textit{definition}. There are a number of different ideas as to just what it is to define a term, but what they come down to is this: To define a term is to set the limits for its correct use, and this can be done in a number of different ways. Providing a precise synonym is probably the least common way, because it is seldom possible to provide a second term that will be synonymous with the first in all contexts.\textsuperscript{8}

*There are field guides to birds, animals, and plants which are just such keys. Keys are typically hierarchical, like systematic theoretical classifications, but the hierarchy is one of more or less conspicuous characteristics by which a specimen can be recognized, and the names given are of course taken from the theoretical hierarchy and arranged along different lines. A key is a systematic listing of known species, used for identification only.
We can say that the term "halogen" is properly applied to all and only the chemical elements fluorine, chlorine, bromine, iodine, and astatine, and we have defined the term in one way. We can say that the halogens are chemical elements which have seven electrons in the outer shell, have a chemical valence of minus one, and occur just before the inert gases in the periodic table, and we have defined it in another way. Or we can say that the halogens have relatively low melting and boiling points, react vigorously with metals to form binary salts by direct combination, have such-and-such colors, odors, and standard states, and so on, perhaps even outlining a series of laboratory tests to determine whether or not a given bit of gaseous, liquid, or solid matter is a halogen or a compound of halogens, thus defining the term in yet a third way. Any of these three methods, and perhaps others, is a legitimate way of defining the term that must be kept distinct for our purposes here, so none of them will be singled out as the "correct" way of defining a term in the nomenclature.

For convenience, I will use the term *explication* for the theoretical scheme of classification, including of course the theoretical statements that tell what it is to be a thing of a given kind. The data statements, which describe things of a given kind, provide the *criteria* for deciding whether or not a given specimen is of that kind.

What we have now are a set of functional distinctions among the terms used in the sciences: theory, data, and nomenclature are sorted out according to how the terms and statements of each are used. As with any set of distinctions that are made on a living system, there will be places where the lines are difficult to draw—particularly the line between theory and data. But in a given context, some terms will clearly be data terms, functioning solely to describe, others will clearly be theoretical terms, functioning solely to explain, and others will be terms of the nomenclature, used to identify and classify and occurring in statements of both data and theory.

Theory explicates the nomenclature; data gives criteria for applying the nomenclature. What remains to be considered are the lines which connect theory and data. Their character is of course implicit in the way I have made the distinction between theory and data. The theory explains the data, and, to the extent that the explanation is successful, the data provides evidence and support for the theory.

Before we move on to the character of theoretical explanation and the question of how theories are supported by data, here are the patterns of Figure 4-1 as they apply to chemistry and biology:

**Figure 4-2 • The Pattern in Chemistry**

<table>
<thead>
<tr>
<th>Names of Elements and Compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen, chlorine, zinc, oxygen, sulfur, sulfuric acid, calcium carbonate, . . .</td>
</tr>
</tbody>
</table>

**Figure 4-3 • The Pattern in Biology**

<table>
<thead>
<tr>
<th>Names of Taxa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cetacea, mutica, ungulata, mammal, hominid, canis, . . .</td>
</tr>
</tbody>
</table>

**Theoretical Explanation and Prediction**

Now we get down to a good thorny philosophical question: What is it to explain something? The sort of explanation described in the preceding chapter, which entailed re-describing the data in order to explain it, is what I take to be a typical theoretical explanation. Perhaps the best way to analyze the pattern further is with a simple example.
One of the first laboratory demonstrations in an introductory chemistry course is the hydrogen generator. Scraps of zinc are placed in a laboratory bottle and dilute sulfuric acid is poured into the bottle. The gas is collected in another bottle, which is inverted in water (to seal it from the air) and connected to the first with glass tubing. The result is a flammable gas in the collection bottle, and the zinc disappears in the acid solution in the generator bottle. The presence of hydrogen gas in the collection bottle is usually demonstrated by simply igniting the gas as it meets the air when the collection bottle is removed from the water. The laboratory setup is shown in Figure 4-4.

In practice, there is, of course, no problem in identifying the zinc and the sulfuric acid that are used in the chemistry lab. They come neatly labeled from the supply house, and we assume, safely, that the appropriate identifying tests have been made. If there should be a doubt, there are reasonably straightforward criteria and tests that can be used to assure that what we have are indeed zinc and sulfuric acid. Zinc is a bluish-white metal, malleable at 100–150°C Centigrade and brittle above and below that range. The acid is tested by its reaction with other known chemicals.

Figure 4-4 • A Simple Hydrogen Generator

Now, to explain what happened in the lab, the chemist first introduces a formula containing abbreviations of the names of chemicals:

\[
\text{H}_2\text{SO}_4 + \text{Zn} \rightarrow \text{ZnSO}_4 + \text{H}_2
\]

Sulfuric acid, combined with zinc, yields zinc sulfate and hydrogen gas. Why? Here the theory begins. The experiment is re-described in the context of the presuppositions of chemical theory without contradicting the earlier description of what happened in the lab.

The atoms of the elements are understood on the Bohr model as consisting of nuclei with “shells” of electrons surrounding them. The number of electrons in the outer shell of each atom determines its valence—its combining capacity with other atoms—expressed as a positive or negative number. In a given compound, the valences must, in general, “balance out” to zero.

Zinc is understood to be an active metal with two electrons in the outer (fourth) shell of its atom. Its chemical valence is +2. Sulfuric acid is a compound of two hydrogen atoms and the sulfate radical (which is in turn compounded of a sulfur atom and four oxygen atoms). Hydrogen has a valence of +1. The sulfate radical has a valence of −2 and is thus combined with two atoms of hydrogen to form the acid.

Because of the electronic structure of its atom, zinc is higher in electromotive force than hydrogen, which is to say that it easily displaces hydrogen from acids. When zinc is combined with sulfuric acid, each atom of zinc (+2) bonds with the sulfate radical (−2), forming zinc sulfate, which is an extremely soluble salt. (Thus the “disappearance” of the zinc in the demonstration: the zinc sulfate was dissolved in the water which diluted the acid.) Two atoms of hydrogen (+1) are displaced by each atom of zinc (+2). Hydrogen is only slightly soluble, so it is liberated as a gas.

Note the steps involved in this explanation:

1. The chemicals are identified by data criteria.
2. The reaction is described at the data level.
3. The chemicals are re-described in theoretical (Bohr atom) terms.
4. The reaction is re-described in theoretical terms.
THEORY (3) Zn + H₂SO₄ (plus interpretation) → (4) ZnSO₄ + H₂ (plus interpretation)
re-description

DATA (1) Zinc (blue-white metal, etc.) plus dilute sulfuric acid → (2) Zinc dissolves; flammable gas bubbles off

Now, what does the theory provide that the data description did not provide? The re-description of the chemicals and the reaction allow the theorist to account for this particular chemical reaction in terms that relate it to every chemical reaction and to a set of general statements about the atomic structure of substances, their chemical valences, and how they can and do combine. The reaction in the hydrogen generator has been explained in terms of the atomic structure of the chemicals involved.

Moreover, the reaction can be “calculated” (literally, in the case of chemistry) when it has been re-described theoretically. The concepts of the theory are interlinked by a set of rules and principles: the relations of valences—the relative electromotive force of the elements. These rules and principles allow us to draw conclusions about the reactions of any substances that have been identified chemically. This is something that data can never do, no matter how much of it we gather and summarize.

The theory in this case is a well-established one, with virtually no current competitors. The re-description of the data does not need to be independently justified; the theory “has its credentials.” (In the next chapter, I will pay some attention to how a given theory gets its credentials.)

The same four steps, in different order, would have allowed an experienced chemist to predict the outcome of the demonstration even if it were not so familiar an example. If the question “What would happen if I combined zinc with dilute sulfuric acid?” were asked, the steps would be as follows:

1. The chemicals are identified by data criteria.
2. The chemicals are re-described in theoretical terms.
3. The reaction is calculated in theoretical terms.
4. The reaction is re-described at the data level.

Theoretical prediction involves crossing the data-theory line twice. The initial situation is re-described in terms of the relevant theory, a determination is made of the theoretical consequences of the initial situation thus described, and there must be a second re-description back to the level of data.

The fourth step is, in general, the difficult one. It is one thing to re-describe the whole demonstration in theoretical terms and account for the known outcome, as in the explanation pattern; it is quite another thing to say with certainty just how a given theoretically described state is going to manifest itself in a particular case. Predictions of this sort typically include a ceteris paribus disclaimer (all other things being equal) to allow for the possible things that can go wrong and alter the expected result. In this case, assuming a controlled laboratory situation, an experienced chemist would be likely to state his prediction with sufficient care to cover intervening contingencies.

The control in a laboratory situation is important and at the same time elusive. The aim of experiment is to isolate just the items we are interested in and eliminate all other items (variables or variable conditions) that might influence the outcome. Chemists assume “standard temperature and (atmospheric) pressure” in a laboratory experiment. If they deviate from this, they specify as accurately as possible the temperature and pressure under which a given experiment is carried out. Any chemist distinguishes between a well-run lab and a sloppily run one, and this is precisely the question of how well conditions in the laboratory are controlled: Is the ventilation...
sufficient to assure that gases given off in one reaction won’t contaminate another reaction? Control comes right down to good housekeeping in a chemistry lab: How thoroughly is the laboratory equipment cleaned after each use? Minute residues from past experiments can distort the results of new experiments.

Let me return one last time to the aerosol can that was tossed into the fire to get that last predictive step emphasized in an uncontrolled situation. We have already considered two theoretical explanations of what happens when a closed container is heated indefinitely. Suppose, now, that someone is about to throw the can into the fire and is wondering what might happen if he did. A straightforward appeal to temperature-pressure-volume relationships would give the following pattern. In this case, the prediction at the theoretical level

\[
\begin{align*}
\text{THEROY} & \quad (2) \quad \text{Volume held constant;} \\
& \quad \text{temperature increases} \quad \rightarrow \\
& \quad \text{Pressure increases indefinitely}
\end{align*}
\]

\[
\begin{align*}
\text{THEROY} & \quad (3) \quad \text{Pressure increases indefinitely} \\
& \quad \text{re-description}
\end{align*}
\]

\[
\begin{align*}
\text{THEROY} & \quad (4) \quad \text{Symptoms of pressure increase} \\
& \quad \text{re-description}
\end{align*}
\]

\[
\begin{align*}
\text{DATA} & \quad (1) \quad \text{Closed aerosol can;} \\
& \quad \text{heat applied indefinitely} \\
& \quad \text{Pressure increase}
\end{align*}
\]

is that the pressure of the system will increase so long as the temperature is increased. What isn’t clear is just what to expect in terms of the aerosol can. Trouble, to be sure. “Symptoms” of an indefinitely large increase in pressure. It might explode.

But there are any number of ways in which such an increase in pressure might manifest itself, depending upon the other circumstances of the case. This is not a controlled situation—and, even in the laboratory example, we had to make an allowance for circumstances other than those immediately relevant to the theory. Here we are dealing with “found” objects. The can might explode, or it might have a weak spot that will open and let the gas out gradually, or the plastic cap might blow out, or, if the situation is just right, the cap might melt and release the gas at the last possible instant before the can explodes.

Now, you might object that the inability to predict precisely what is going to happen is due simply to a lack of information, such as the bursting strength of the container, the melting point of the plastic cap, the precise heat of the fire, and so on. But this is no objection. It simply is a characteristic of uncontrolled situations that there are many such relevant but unknown variables. But we still have to predict with some degree of accuracy what will happen in such situations.

Further, it is a mistake to suppose that in even the most controlled of laboratory situations such variables can be eliminated entirely. They can only be reduced. This is underscored by the scientific community’s well-known demand that any given experimental outcome be repeated in a number of instances before a new result is accepted, no matter how carefully the circumstances of the first experiment were controlled.

The difference between theoretically described states and the same states described at the data level is further underscored by the “proving” procedures that are necessary when we design a device along theoretical lines. No matter how much theoretical care we exercise in designing an electronic circuit, a rocket launcher for spacecraft, or even a lever-and-pulley gadget for a farming chore, there is the familiar business of “getting the bugs out” of the completed device. The “bugs” may be the result of mistakes or sloppy craftsmanship in some cases, and these are, of course, irrelevant to the present point. But there are “bugs” that cannot be foreseen, and they are the result of an unavoidable slippage that happens when we put our theories into practice.

It is precisely in crossing the line from theory back to data that the slippage occurs. When a known situation is re-described in theoretical terms, the connection is clear: To put the can into the heat of the fire just is to increase its temperature; to keep the can sealed just is to maintain constant volume in the system. But any number of other situations might also have been identified as increasing the temperature of a system or holding the volume constant. The data-level descriptions and the theoretical descriptions don’t match up in a one-to-one way. The relationship between the two is not one of straightforward translation from one vocabulary to another. The connection between theory and data is not a linguistic one, then. It is mediated through the (real or hypothetical) situation being described in much the same way that the relationships among the maps of the same territory were in the preceding chapter: each description stands in its own semantic relationship to the (non-linguistic)
facts of the case, whether or not a direct linguistic tie can be established between the two descriptions. What the theory explains is not the descriptions couched in the data vocabulary, but the situation that has been thus described. The theoretical statements are not in any sense a “translation” of the data statements. The theory explains the situation by re-describing it in such a way as to connect it with other situations that are similar to it in relevant ways; and it is the theory itself that determines what counts as relevance.

The pattern of theoretical explanation just described involves a contextual shift in the following technical sense: The explanandum (data-level description) and the explanans (theoretical re-description) are both related semantically to the same objective situation—the same event or range of events. They make reference to that event from within different contexts of presuppositions.

The two descriptions may or may not have terms in common. If they do, the common terms will be from the relevant nomenclature ("zinc" and "sulfuric acid" in the chemical explanation). But the two descriptions are asserted about the same subject matter. They are, in linguistic terms, co-referential. Each, considered as a set of statements, is subject to judgments of truth or falsity within its own context of presuppositions relative to that subject matter.

We explain something, on this understanding of explanation, by re-describing it in a new context. Analogy and modeling also involve contextual shifts, but they are different from theoretical explanation, and we should get the distinction clear immediately. To draw an analogy is to shift from one context of description to another, but without a literal claim for the truth of the new description. To say that sound waves are like waves in water is not to say that sound waves just are waves in water; it is to invoke a similar and more familiar system (water waves) in order to clarify a less familiar one (sound waves). Analogy is what figures in the use of certain kinds of model in the sciences, as when we say that the molecules of a gas are like perfectly elastic billiard balls in order to make the properties of gas molecules more comprehensible.

There seem to be no prior logical or conceptual limitations that must be placed on the forms that theories can take in order to explain by theoretical re-description. The relationships among items in the theory must be clear and straightforward in order for it to function as an explanation, and there must be at least the possibility of connecting the particular situation or kind of situation to be explained with other situations. Clearly, those elements are present in the two explanations just considered.

In the case of biological explanations, it is sometimes suggested that the theory is not susceptible to generalization because it makes reference to this planet and the history of organisms on this planet. But surely any biologist would claim that the principles of evolutionary explanation can be generalized to cover other sorts of environment. The principle of natural selection would not come under challenge; the contingent facts about this planet would simply have to be replaced with the appropriate facts about a different environment.

Any given system—a set of related items and their properties—can be re-identified as a mechanical system, as a teleological (end-directed) system, as a fluid system, and perhaps as other sorts of system as well. In the next chapter I will cite some examples of areas where such shifts have taken place; but it is worth mentioning here that electricity, for example, has been variously identified as teleological (as in "Lightning strikes because Jib-Jub is angry"), as a fluid (as in eighteenth and nineteenth-century electrical theory), as mechanical (as the movement of physical particles), and finally as a particular kind of "field." What places limits on a theory is a series of critical decisions that must be made at any given time. In the examples cited—chemistry and gases—the critical decision has been made and still stands; we are dealing with well-established theories. In the next chapter, I will discuss how such critical decisions are made and how they are altered over a period of time.

What may seem to be an even more difficult problem for this account of theoretical explanation is finding a way to decide whether or not two descriptions are descriptions of the same situation or the same kind of situation. The answer is essentially the same as that to the question about the forms that theories can take. Theoretical explanations are accepted or rejected after critical examination and testing. There must first be a claim that two descriptions are of the same subject matter, and the claim must be defensible in the face of careful criticism. Again, this is a matter that we must return to in more detail in the next chapter.

FURTHER READINGS

The account of explanation and of the distinction between theory and data arises from a long critical dialogue in philosophy of science, beginning with
the movement called logical positivism in the 1930s and extending right up to the present. An excellent collection of articles by contemporary philosophers of science, which puts the contemporary views into perspective with the positivist movement, is to be found in Achinstein and Barker (eds.), *The Legacy of Logical Positivism* (1969). The literature on scientific explanation is almost entirely centered around early work by Carl G. Hempel and Paul Oppenheim, reprinted along with other relevant articles in Hempel's *Aspects of Scientific Explanation* (1965). The material which has most strongly influenced the account of explanation offered here is Richard Zaffron's "Identity, Subsumption, and Scientific Explanation" (1971).

The theory-data distinction is most strongly represented and argued along the lines presented here by Marshall Spector in "Theory and Observation" (1966). See also Karl Popper's essay "Evolution and the Tree of Knowledge," reprinted in his *Objective Knowledge* (1972); and the early chapters of his *Logic of Scientific Discovery* (1959).

The most readable and systematic source on evolutionary taxonomy is George C. Simpson's *Principles of Animal Taxonomy* (1962). See also Cain's *Animal Species and Their Evolution* (1960).

On chemistry, the material here is to be found in almost any introductory text. I have used Linus Pauling's *College Chemistry* (1957) in laying out the explanation of the hydrogen generator. On the history of chemistry, see J. R. Partington, *A Short History of Chemistry* (1965).

Like other species, human beings leave tracks: artifacts, ruined cities, works of art, and, unique to our species so far as we know, linguistic artifacts that record the oral traditions that preceded written language, as well as written chronicles that begin as early as 3500 B.C. and exist in increasing detail up to the present. The particular line of tracks that interest us here are the tracks human beings have left in doing science.

**The Critical Process at Work:**

*Electrical Theory in 1851*

I have placed a strong emphasis on the scientific community in the past two chapters. There is more to say, of course, about just which individuals constitute such a community and how they operate on new hypotheses in such a way as to accept certain ones rather than others.

In looking at the history of science, we tend to pay attention to the dramatic developments which are the direct antecedents of contemporary theories. What I propose to do here is look at the activity of the critical community of scientists as it operates on two competing hypotheses in physical theory, neither of which is accepted at present.

For the next few pages, I want to examine part of a highly respected textbook in natural philosophy (now known as physics) written in the first half of the nineteenth century by Denison