Reading the Book of Nature

An Introduction to the Philosophy of Science

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This is an introductory survey of the philosophy of science suitable for beginners and nonspecialists. Its point of departure is the question, Why should we believe what science tells us about the world?

In this attempt to justify the claims of science the book treats such topics as observation data, confirmation of theories, and the explanation of phenomena. The writing is clear and concrete with detailed examples drawn from contemporary science: solar neutrinos, the gravitational bending of light, and the creation–evolution debate, for example. What emerges is a view of science in which observation relies on theory to give it meaning and credibility, whereas theory relies on observation for its motivation and validation. It is shown that this reciprocal support is not circular since the theory used to support a particular observation is independent of the theory for which the observation serves as evidence.

Attractive features of the book include a glossary of technical terms and concepts commonly used in the philosophy of science, and a helpful guide to further reading.

READING THE BOOK OF NATURE

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INTRODUCTION

SCIENCE enjoys a lot of respect these days, if not always for the social value of its results then at least for the rigor and precision of its methods. It is an honor to say of a study or an argument that it has been done scientifically. This must be because we think that, in general, science and scientific methods are effective for getting at the truth. If pressed to articulate these feelings we might start by saying that the careful, accountable, and methodical approach of science prevents, as much as possible, the influence of personal bias, superstition, sloppiness, whimsy, sloth, and other human weaknesses that obscure the truth. Thus, when we claim to have done something scientifically, we speak with the authority of a truth-generating enterprise.

There has to be more to it than just being careful (careful to do *what?*) and accountable (accountable by what standards?), and we can appropriately ask why science has its special status as a supplier of knowledge about the world. Thus the unifying question in the pages that follow is, Why should we believe what science says about the world?

This is a question of justification of scientific knowledge. It asks not so much about *what* science claims about the world but more about *how* science proves what it does claim and why it gives us reason to believe that these claims are true. To ask about the justification for knowledge is not an attack on its credibility. There is no implication of skepticism here, and the request for proof is not a veiled suggestion that there is none to give. Instead, the concern for justification represents a requirement of responsibility that is the burden of any purveyor of knowledge. Not just any belief or

statement counts as knowledge, only those that can be justified as likely to be true.

Perhaps, in the case of science, finding the justification is as easy as giving credit for success. Science gains credibility from its phenomenal success. Airplanes fly. Smallpox has been done away with. Humble uranium gets turned into electricity, which in turn keeps the Bud Light cold. This record of success may be enough to give us responsible warrant to believe that science, by and large, gets at the truth about the world, but there are three reasons why this appeal to success is just a suggestive beginning to the analysis of scientific justification.

For one thing, the most interesting science – that is, the sorts of claims whose justification we are most interested in – is about things that nonspecialists can never check for themselves. The currency of science is largely of unobservable entities such as electrons, black holes, DNA molecules, tectonic plates, and the like. We can *see* that airplanes fly, but how do we know that the electrons in an accelerator or in an atom do what the physicists say they do? What counts as success of a theory that is about things that can never be experienced? The criteria and measure of success in this domain are the business of experts, the scientists themselves, and in this sense science is a largely self-regulating business whose success in crucial areas is self-proclaimed.

Again, this is not intended as a threat to the integrity or credibility of science. It is, though, a warrant to investigate further just what it is about science and doing things scientifically that justifies belief in the results being true.

A second reason to be skeptical of the direct association of success as justification is the undeniable fact that the scientific description of the world changes over time. It was once respectable and successful science to describe the universe as being full of ether, and for a very long time the scientific account of the heavens placed the planets and stars in crystalline spheres centered at

and revolving around the earth. We no longer take these once-successful theories to be true. Such a dramatic turnaround should be sufficiently humbling to allow us to ask whether quarks and quasars aren't just today's flash in the pan, which may appear as object lessons in the introduction to a book written years from now on justifying scientific knowledge. An arrogance of the present (yes, but *now* we've got it right) can be avoided by focusing on a general method by which to tell when we've got it right.

The third motivation for looking beyond success is this: Even if these worries about the evaluation of success (it's left up to internal review; it's too ephemeral) could be put aside, there is a deeper question of interest here. What fuels the success? To say that something is done scientifically is not to say simply that it is done with success. Success may be the result, but it is not the methodological structure. What then is this structure, and what about it gives us reason to think it produces truths?

Putting the question in this way motivates the plan of presentation in the following chapters. The first step in the analysis will be an accurate description of the scientific enterprise, focused on the activity of justification of theories rather than their discovery. A clear account of the process of science will then be the evidence for deciding the issue of justification. Once the picture is clear as to how science works, the next step is to ask whether this way of working is conducive to producing the truth. The motivating goal is to be able to evaluate the justification of scientific claims, but first we need to know just what it is we are evaluating.

The specimen under observation here is going to be science at its best. We will not be concerned with fraud in science, episodes such as lying about experimental results, fudging the numbers, and other willful violations of the code of good scientific practice. The topic is the code itself and an assessment of its truth-conduciveness when properly followed. This abstract level of analysis is analogous to a political scientist's study of a social

policy to see if it facilitates a just distribution of social welfare. Of course, there will be cheaters, but before dealing with these problems, the analyst wants to know the worth of the policy when it is properly enforced. Can it deliver as it promises, whether it promises justice or truth, when it is working at its best?

All this talk of justification of scientific knowledge and the scientific method makes it sound as if we have license to generalize about all sciences following a single method at all times. But surely the methods differ from scientific discipline to discipline. From astronomy to zoology, the diverse varieties of sciences study very different kinds of objects and very likely require different ways of theorizing and testing. Even within each domain it is unlikely that there is a single road to the truth, appropriate for all circumstances.

Just as surely, though, all these endeavors have *some* aspect of method in common, and it is this shared methodological ground that is the object of study here. What is it that allows all of these disciplines to be described as being done scientifically and as presenting characteristically scientific evidence? It is at this level of generality that we operate here, and I intend to demonstrate that the common methodological factor in the sciences (when done at their best, don't forget) is important as a truth-indicative ingredient. In other words, working at the high level of generality does not force the discussion to rise above all that is interesting and into the realm of only trivial generalizations. Granted that many of the features common to all the sciences are unimportant to evaluation of justification, there are nonetheless some common features that are significant to justification. But there is no need for you to believe this now, because the demonstration of this point is exactly the burden of what is to follow.

To be blunt, then, I do plan to generalize across the sciences and to proceed as if there is, at some level, a unity of method. I plan to generalize this much and then some by suggesting that the methodological mark of good science is what we take to be

the character as well of good common sense. In other words, as in science so too in life on the street. A close look at science is as a view of our less glamorous reasoning processes under a microscope, in that science is a slowed-down, more open and accountable image of what we normally do in coming to know about the world around us. Good science is an image of good sense.

I do intend to pay attention to a distinction between natural and social sciences, and the discussion here will be limited (though not strictly) to the natural side of the divide. The book of nature is of things without minds or the ideas, intentions, and emotions that are characteristic of minds. The focus on the natural world is not meant to suggest, though, that studying different kinds of objects, nonmental versus mental, necessitates wholly different methods of theorizing and justification. In fact, there is good reason to believe that the methodological model of the natural sciences also fits rather neatly onto the social sciences. I hope to motivate this belief by applying the understanding of natural science to examples of archaeology, indicating that this bridge discipline, with clear affinities to both natural and social studies, is methodologically similar to the natural sciences.

Furthermore, the model that will be used throughout for understanding natural science is one that is most often used in describing social sciences. This is the model of reading a text. Just as science builds models of the world, describing gases as crowds of colliding point-particles, for example, this study of science builds a model of the process of science as being methodologically like reading and interpreting a book, the book of nature. The method by which science comes to understand the natural world is very similar to the method used to understand the meaning of a text written in an unfamiliar language. Understanding the mechanism of nature is like understanding the plot. It is important to realize that this analogy between science and reading is intended to apply only at a methodological level. Though the methods of understanding and justification may be similar between the two

activities, this does not imply that their subject matter is similar as well. In particular, the methodological analogy is not meant to suggest that nature has an author.

The translator of an unfamiliar text comes to understand its meaning through an attention to context. Recurring patterns in the symbols on the page prompt speculation about the meanings of passages, and most importantly, these speculations are testable and amenable to revision. Under the assumption that the text makes sense, that is, that the passages are consistent and they cohere, at least in small sections, into a cogent message, testing a speculated translation of a symbol is done by applying it to other occurrences in other contexts to see if it still makes sense. If the passage comes out as nonsense, the hypothesis must be revised. Through this back-and-forth of suggestion and revision, an understanding of the plot develops and is used to facilitate finding the meaning of passages by giving them a large context into which they fit. Thus the understanding of the whole text guides the interpretation of the parts, and the whole message is itself composed of the meaning of the parts.

This is what happens in reading the book of nature. Instead of marks on a page there are the experiments and observations done by scientists, but like the unfamiliar marks on a page, the observations are meaningless without some prior understanding, if only at the stage of revisable speculation, of what's going on in the story. In the context of science, the observations aren't evidence of anything without a theoretical description of their relevance. For example, the data of a particle detector are interesting only if we know already that a click means that an electron has passed through. Theories, such as the one that describes the link between clicking meters and passing electrons, represent an understanding of general aspects of how the world works and will influence the interpretation of individual pieces of observational evidence. Thus the big picture guides the interpretation of the parts. And of course the theoretical understanding of the big

picture is built from and tested against the individual, observational parts.

This reasoning may sound circular, both in the case of translating a text and in that of acquiring knowledge of the natural world, but it is not necessarily a harmful circularity. In both situations, translating and knowing about the world, the project is to describe what is going on behind the scenes. The achievement of science or of translation is to make expansive inferences about things other than but significantly related to what is apparent. It's not interesting simply to describe the appearances, to reproduce or analyze the marks on the page. We want to know the story. We want to know what the marks mean. In science we will never get a look at the answer key, in the form of an authoritative translation of the book or even a dictionary, so we must learn to do the best we can with the available information. The developing theories and theoretically influenced evidence are all we have to go on to draw an accurate description of the world. Of course, somehow this cozy relationship must be regulated to insure a factual reading of the book of nature. What then constrains this process in the direction of truth? That is exactly the right question to ask, and it is time to get on with answering it.

A bit of advice to the reader: The form of this book is true to the message of its content. Individual chapters will make sense and attain their full meaning within the context of the whole work. This is just a friendly warning that the contents are not piecemeal, and parts taken in isolation will convey less information than those parts taken as they participate in the whole. But reading this book will be easier than reading the book of nature, at least in that this one has a lexicon, a glossary of key terms at the end. Terms that are included in this glossary, when first mentioned in the text, will be printed in bold type.

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THEORIES

> "When *I* use a word," Humpty Dumpty said in a rather scornful tone, "it means just what I choose it to mean – neither more nor less."
>
> – Lewis Carroll, *Through the Looking-Glass*

HUMPTY Dumpty knew what he was talking about. We are in control of the meanings of the words we use, if not as individuals then at least as a group, but sometimes words acquire an authority and a persuasion that exceed our understanding of them. Through our profligate use, a word may become influential even when its meaning is unclear and poorly understood. When the link between meaning and emotive influence is strained like this, the authority of language has gotten away from us.

The word "natural" is a clear example of this. It means roughly that something is not human-made, not artificial, but influence has grown through advertising to suggest that anything natural must be good, wholesome, and healthy. The link between what we mean by "natural" and the authority it has over our behavior is poorly understood, at best. Why are things that are not human fabrications better, across the board, than those that are? More to the point of meaning and understanding, what does it mean to describe a product like shampoo, breakfast cereal, or even rat poison as "all-natural"? And why is it better for me, and the rat too, presumably, if I use all-natural rat poison? The word "chemical" is another case where authority is wielded in the

absence of understanding. Sinister in suggestion though unclear in meaning, it becomes a club of conviction, as we opt for chemical-free products.

A third example of a term whose use and influence are much more common and secure than is its understanding is "scientific." Treatment of this case will last the rest of the book. It is a persuasive word, and though poorly understood it surely indicates something good in what it describes. Responsible use of the concept and responsible citizenship in a society under the influence of science require clarity in both the meaning of the term and the link between the meaning and its authoritative use.

WHAT THEORIES AREN'T

Still heeding the advice of Humpty Dumpty, we begin our pursuit of clarity in the concept of science with a discussion of the use of a key scientific term, "theory."

Though unsure of just what it takes to be a **theory** or what it means to be theoretical, people inside and out of science often use the concepts in a vaguely pejorative way, as in "But that's just a theory!" This suggests a distancing from reality and a lack of proof, an absence of good reason to believe a claim that is *just* a theory. The implicit contrast is between facts, which are true of the world, and theories, which are, well, who knows? It may even be that there is good reason to disbelieve a claim that is merely theoretical. Presentations of the debate between supporters of the theory of evolution and advocates of creation science can exemplify this attitude. (Note the use of the appellation "science" by the latter camp, indicating that this is for them and, they assume, for their audience a thumbs-up word, indicative of good, solid work.) Many representatives of creation science open the attack by describing evolution as just a theory. Good science, the stuff we should be teaching in schools, must be factual science.

The irony is that the major accomplishments of science, the things that come to mind when we reflect on what good, successful, responsible science is, are all what we describe as theories. Think about it. What has science accomplished? It figured out, for one thing, the phenomenon of universal gravitation, that all massive objects, whether on the earth or in the distant heavens, are forcefully attracted to one another. This describes a variety of happenings in the universe, from the falling of unsupported things around us to the motions of planets and stars, to the expansion of the whole universe. In sum, we, as modern and informed commentators on science, must be referring to the general theory of relativity.

Science also has a practical impact in its application to the difficulties in coping with the world. It has explained the unseen mechanisms responsible for transmission of diseases. Who doesn't believe in the germ theory? And it describes the constituents and events in the microworld with sufficient detail and clarity to support the fairly reliable development of solid-state electronics and, of course, nuclear bombs. We must be talking now of the quantum theory. If you want to know about earthquakes, where, when, and why they occur, and you want a scientific answer, you consult the theory of plate tectonics. And so on.

When you stop talking about theories, you stop talking about science. So, if being scientific is a good thing as far as methodical approach to the truth about the world is concerned, and theories are the primary product of the scientific enterprise, it cannot be that theories are, because they are theories, unlikely to be true or in want of whatever it is that science provides as proof. Being theoretical is nothing to be ashamed about.

Is it something to be proud of? If "theory" is not a term of censure, is it a term of praise, indicative of a credible and comprehensive description of some feature of the world? No, at least not if we pay attention to how the concept is used in science. Consider