An Introduction to the Philosophy of Science

This book guides readers by gradual steps through the central concepts and debates in the philosophy of science. Using concrete examples from the history of science, Kent W. Staley shows how seemingly abstract philosophical issues are relevant to important aspects of scientific practice. Structured in two parts, the book first tackles the central concepts of the philosophy of science, such as the problem of induction, falsificationism, and underdetermination, and important figures and movements, such as the logical empiricists, Thomas Kuhn, and Paul Feyerabend. The second part turns to contemporary debates in the philosophy of science, such as scientific realism, explanation, the role of values in science, the different views of scientific inference, and probability. This broad yet detailed overview will give readers a strong grounding whilst also providing opportunities for further exploration. It will be of particular interest to students of philosophy, the philosophy of science, and science.

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To Peter Achinstein and the late Paul C. L. Tang, who introduced me to philosophy of science.

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Preface: philosophy of science for philosophers, scientists, and everyone else

For better and for worse, in ways both obvious and subtle, the work of scientists has helped to shape the world around us. The obvious impacts of science on our lives include the technologies that depend on scientific research. Our approaches to communicating, eating, becoming or staying healthy, moving from one place to another, reproducing, entertaining ourselves – all of these have been changed by the findings of scientific research. Perhaps less obvious, but not less important, are changes in how we think about ourselves and our world. The concepts and ways of thinking that scientists employ as they engage in research and seek to explain the phenomena they uncover tend to migrate out of the specialist settings in which they originate. Though they tend to be transformed in the process, these concepts and methods turn up in the broader culture as themes we draw upon to describe and explain the world.

Clearly, science is a big deal. This book is not just about science, though, it is about the philosophy of science. Even if you agree that one should care about science, you might wonder whether you should care about the philosophy of science. The point of this preface is to begin to persuade you that you should care about it. I will divide my arguments based on different types of readers. My first argument will be directed at those who either are or will become working scientists. My second argument will be directed at those people *and* at those who are interested in philosophy, but unsure about philosophy of science. My last argument will be directed at anyone, whether or not a scientist, whether or not philosophically inclined, who lives in a world as strongly influenced by scientific work as ours.

First, a caveat: These arguments are not meant to be fully persuasive as such. Full arguments regarding important practical matters – such as whether to devote one's valuable time to reading a particular book – can rarely be stated succinctly (and I do not wish to linger over-long here in the

preface, but to get on to the subject at hand). What I present here should rather be understood as the articulation of promissory notes that make more or less explicit the value of philosophy of science for assorted concerns that I take to be rather widely shared. It is my hope that reading through the rest of the book will leave you fully persuaded that this is a worthwhile subject matter. I grant that some measure of trust is required to get started.

Let me now address my arguments to those who are or will become working scientists. The argument here is quite simple: whether performing experiments, analyzing data, developing theories, building instruments, or writing papers, scientists at some point in their work implicitly *rely on* philosophical assumptions about their discipline and their subject matter. This is perhaps most easily shown in the case of those scientists who would most vocally *oppose* the importance of philosophy in science, who espouse a 'shut up and calculate' approach. To endorse such a view is to take a certain position regarding the value of attempting to interpret the meaning of a scientific theory; it is, in short, a philosophical claim to the effect that the value of theory resides only in its usefulness for calculating outcomes in application, whether experimental or technological. This position is a form of what philosophers call *instrumentalism*, and the instrumentalists constitute a long-standing and important tradition within philosophy of science. My aim is not to criticize instrumentalism, but only to point out that for the scientist there is no escaping philosophy. The question for the scientist is not whether to engage in philosophy, but only whether to do it well or badly.

One particularly important context in which philosophical considerations are of considerable importance to the practice of science concerns the use of statistics. Many experimental results are couched in terms that result from the use of statistical tools. Moreover, theoretical explanations of phenomena involving, for example, quantum mechanics, population biology, or meteorology invoke statistical concepts. These statistical notions are developed within frameworks that make certain assumptions about the meaning of such concepts as probability, randomness, and so on that are a matter of significant philosophical dispute. The use of statistics without an awareness of these philosophical issues is likely to result in confused or misleading statements about the meaning of one's research results or the character of natural phenomena. This book devotes significant attention to philosophical issues regarding the use of statistics.

Finally, and perhaps most fundamentally, I would like to advance the idea that the pursuit of scientific knowledge is already, at least in part, a kind of philosophical inquiry in the broad sense. This might look like a trick of definition-mongering, in which I have simply chosen to give 'philosophy' such a broad meaning that this claim becomes trivially true. But there is a good historical reason for taking empirical science to be continuous with philosophy in this way: much of what we would today call 'science' was once called 'natural philosophy.' It makes sense, too: among the aims of scientific theorizing are (arguably) the understanding of the processes of the natural world, the kinds of things or structures that might be found there, and how these would appear to us under various circumstances, react to our intervention in them, and develop over time. It does not seem to be a stretch to call what does these things a 'philosophy of nature.'

Perhaps, however, you are not now and are not planning to become a scientist. Let us suppose that you are instead someone with an interest in philosophy more generally. Any well-developed philosophical view of the world will include a philosophy of science at least implicitly. Suppose, for example, your philosophical interests center on whether human actions are truly chosen freely. Any position regarding this issue of free will must respond *somehow* to the results of scientific research in such domains as neurophysiology and cognitive science. To be sure, one possible response would be simply to ignore these scientific results and develop one's position on purely a priori grounds derived from introspection. The point is that whether one does this, or tries to be sensitive to the scientific findings in some more or less substantive manner, one must have *reasons* for treating the scientific results in the way one does, and these reasons must involve some views about the relationship between empirical science and philosophical theorizing – a philosophy of science, in short.

This brings us to "everyone else." Perhaps you have no particular scientific training and do not plan on receiving any. Perhaps you do not plan on engaging in extended philosophical reflection or argumentation as a significant part of your life's undertakings. For you, philosophy of science will remain important at least for practical reasons – as a kind of instrument of self-defense if nothing else. Politicians, marketers, even scientists themselves, will attempt to persuade you to act in certain ways based on what they present as 'sound science.' Without expertise in the relevant scientific field, you might find yourself wondering about the soundness of their claims. Although we

often have to rely on the testimony of experts to form our own opinions, and it is sometimes right to do so, the very question of when to thus defer to authorities and when to doubt them relies on the ability to critically evaluate such testimony. What is the nature of the authority of empirical science? What are the limits of that authority? What questions in general are important for scrutinizing a claimed scientific result? Training in philosophy of science should equip you with some basis for thinking soundly about these issues as they arise in the public discourse of and around science.

At its best, the scientific enterprise exemplifies the bold, yet responsible pursuit of knowledge. Appropriately weighted and clearly understood, the best of our scientific heritage should stand as a check on our too-often indulged propensity to let demagoguery and obfuscation lead us into unreasoned, even dangerous ways of thinking. An understanding of what makes for good scientific thinking may help us to hold ourselves to a higher standard in how we understand our world and our place in it.

Finally, studying science from a philosophical perspective should highlight and explicate a fact about scientific inquiry that, though in some sense obvious, might be easily forgotten when confronted with the difficulty of understanding the technical language in which unfamiliar scientific claims are presented: science is a human undertaking, an extension of our common search for understanding. Scientists extend our ordinary ways of knowing into realms that are remote in terms of distance, or size, or degree of abstraction, or complexity. Knowing just how they do so is important to evaluating the results of their inquiry. Moreover, perhaps understanding how inquiry is conducted in these remote realms will shed light back onto our common knowledge-seeking practices. In any case, to understand science philosophically is to understand something about what it is to be human.

Plan of the book

This book divides roughly into two parts. The first seven chapters ("Background and basic concepts") introduce both some important concepts that will be used throughout the discussion and some important figures and movements in twentieth-century philosophy of science who have helped shape the discipline and whose ideas remain relevant to current debates. We will consider the arguments of writers such as Pierre Duhem, Karl Popper, Rudolf Carnap, Thomas Kuhn, Imre Lakatos, and Paul Feyerabend. This will allow us

to gain some familiarity with the *falsificationist* (Popper) and *logical positivist* or *logical empiricist* (Carnap) schools of thought that loomed large in the first half of the twentieth century, while also considering later developments involving *post-positivist* thinkers (Kuhn, Lakatos, Feyerabend) that offered alternatives to the falsificationist and logical empiricist points of view. We will explore some of the issues and arguments that they pursued with the help of some examples from the history of science.

Chapters 8 through 12 ("Ongoing investigations") will survey some of the areas in which lively debates are ongoing in current philosophy of science. These surveys will seek to connect these current areas of debate with the historical precedents that are the focus of the first section of the book, but will emphasize foundational concepts and more or less recent developments. Chapters 8 and 9 will concern competing approaches to the use of probability ideas in science. Probability is crucial to the analysis of data and to the understanding of scientific reasoning. These chapters will, as you might expect, have the most mathematical content, but are meant to be self-contained. Chapters 10 and 11 will survey current debates concerning scientific realism vs. anti-realism, and explanation, respectively. Chapter 12 concerns the role of values and value judgments in science, a matter of long-standing concern that has recently seen a resurgence of interest.

Acknowledgments

I am very fortunate to have had the opportunity to write this book. I thought that I was simply creating a potentially useful teaching resource for myself and (hopefully) for others. The project turned into an opportunity to revisit long-standing interests and discover some new literature as well. I am grateful to Hilary Gaskin at Cambridge University Press for her sage guidance and immense patience. Her assistants Anna Lowe, and subsequently Rosemary Crawley, provided wonderful support. The final text benefited from the skillful copy-editing of Jon Billam.

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Dianne Brain has as ever advised, sustained, and encouraged me. I rely daily on her good judgment and patience. Our daughter Nora has provided many delightful distractions from my work on this text.

Abbreviations

Abbreviation	Meaning	Chapters
ACh	Acetylcholine	11
CDC	Centers for Disease Control	12
CERN	Conseil Européen pour la Recherche Nucléaire	9, 12
CL	Covering Law	11
CM	Causal-Mechanical	11
D-N	Deductive-Nomological	11
DHHS	Department of Health and Human Services	9
DNE1	Empirical requirement of Deductive-Nomological Account	11
DNL1-3	Logical requirements of Deductive-Nomological Account	11
DR	Differential Refrangibility	2
DR_{NH}	Differential Refrangibility restricted to the northern hemisphere	2
EPA	Environmental Protection Agency	9
GTR	General Theory of Relativity	9
HH	Hodgkin–Huxley	11
I-S	Inductive-Statistical	11
IBE	Inference to the Best Explanation	10
IID	Independent and Identically Distributed	9
LDD	Law of Doughnut Delectability	1, 2
LDD′	Alternate formulation of Law of Doughnut Delectability	2, 4
$LDD'_{a, b, c, d}$	The same, applied to individuals named a, b, c, d	2
LHC	Large Hadron Collider	9
MDC	Machamer, Darden, and Craver	11
MSRP	Methodology of Scientific Research Programs	6
NCM	Newtonian Classical Mechanics	6

NIH	National Institutes of Health	12
NMF	Naïve Methodological Falsificationism	6
NOA	Natural Ontological Attitude	10
NP	Neyman–Pearson	9
OD	Origin and Development derivation	11
PUDP	Principle of Uniformity of Doughnut Properties	1
PUN	Principle of Uniformity of Nature	1
RF	Resonant Frequency derivation	11
SCC	Squamous Cell Carcinoma	9
SMF	Sophisticated Methodological Falsificationism	6
SSR	*The Structure of Scientific Revolutions*	5
UD	Underdetermination	3