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Introduction: Rationality 1

Rationality and realism are the two main topics of today's philosophers of science. That is, there are questions about reason, evidence and method, and there are questions about what the world is, what is in it, and what is true of it. This book is about reality, not reason. The introduction is about what this book is *not* about. For background it surveys some problems about reasons that arose from Thomas Kuhn's classic, *The Structure of Scientific Revolutions*.

PART A: REPRESENTING

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Realism about theories says they aim at the truth, and sometimes get close to it. Realism about entities says that the objects mentioned in theories should really exist. Anti-realism about theories says that our theories are not to be believed literally, and are at best useful, applicable, and good at predicting. Anti-realism about entities says that the entities postulated by theories are at best useful intellectual fictions.

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4 **Pragmatism** 58
C.S. Peirce said that something is real if a community of inquirers will end up agreeing that it exists. He thought that truth is what scientific method finally settles upon, if only investigation continues long enough. W. James and J. Dewey place less emphasis on the long run, and more on what it feels comfortable to believe and talk about now. Of recent philosophers, H. Putnam goes along with Peirce while R. Rorty favours James and Dewey. These are two different kinds of anti-realism.

5 **Incommensurability** 65
T.S. Kuhn and P. Feyerabend once said that competing theories cannot be well compared to see which fits the facts best. This idea strongly reinforces one kind of anti-realism. There are at least three ideas here. Topic-incommensurability: rival theories may only partially overlap, so one cannot well compare their successes overall. Dissociation: after sufficient time and theory change, one world view may be almost unintelligible to a later epoch. Meaning-incommensurability: some ideas about language imply that rival theories are always mutually incomprehensible and never inter-translatable, so that reasonable comparison of theories is in principle impossible.

6 **Reference** 75
H. Putnam has an account of the meaning of 'meaning' which avoids meaning-incommensurability. Successes and failures of this idea are illustrated by short histories of the reference of terms such as: glyptodon, electron, acid, caloric, muon, meson.

7 **Internal realism** 92
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8 A surrogate for truth 112

I. Lakatos had a methodology of scientific research programmes intended as an antidote to Kuhn. It looks like an account of rationality, but is rather an explanation of how scientific objectivity need not depend on a correspondence theory of truth.

BREAK: Reals and representations 130

This chapter is an anthropological fantasy about ideas of reality and representation from cave-dwellers to H. Hertz. It is a parable to show why the realism/anti-realism debates at the level of representation are always inconclusive. Hence we turn from truth and representation to experimentation and manipulation.

PART B: INTERVENING

9 Experiment 149

Theory and experiment have different relationships in different sciences at different stages of development. There is no right answer to the question: Which comes first, experiment, theory, invention, technology, . . .? Illustrations are drawn from optics, thermodynamics, solid state physics, and radioastronomy.

10 Observation 167

N.R. Hanson suggested that all observation statements are theory-loaded. In fact observation is not a matter of language, and it is a skill. Some observations are entirely pre-theoretical. Work by C. Herschel in astronomy and by W. Herschel in radiant heat is used to illustrate platitudes about observation. Far from being unaided vision, we often speak of observing when we do not literally 'see' but use information transmitted by theoretically postulated objects.

11 Microscopes 186

Do we see with a microscope? There are many kinds of light microscope, relying on different properties of light. We believe what we see largely because quite different physical systems provide the same picture. We even 'see' with an acoustic microscope that uses sound rather than light.

12 Speculation, calculation, models, approximations 210
There is not one activity, theorizing. There are many kinds and levels of theory, which bear different relationships to experiment. The history of experiment and theory of the magneto-optical effect illustrates this fact. N. Cartwright's ideas about models and approximations further illustrate the varieties of theory.

13 The creation of phenomena 220
Many experiments create phenomena that did not hitherto exist in a pure state in the universe. Talk of repeating experiments is misleading. Experiments are not repeated but improved until phenomena can be elicited regularly. Some electromagnetic effects illustrate this creation of phenomena.

14 Measurement 233
Measurement has many different roles in sciences. There are measurements to test theories, but there are also pure determinations of the constants of nature. T.S. Kuhn also has an important account of an unexpected functional role of measurement in the growth of knowledge.

15 Baconian topics 246
F. Bacon wrote the first taxonomy of kinds of experiments. He predicted that science would be the collaboration of two different skills – rational and experimental. He thereby answered P. Feyerabend's question, 'What's so great about science?' Bacon has a good account of crucial experiments, in which it is plain that they are not decisive. An example from chemistry shows that in practice we cannot in general go on introducing auxiliary hypotheses to save theories refuted by crucial experiments. I. Lakatos's misreports of the Michelson–Morley experiment are used to illustrate the way theory can warp the philosophy of experiment.

16 Experimentation and scientific realism 262
Experimentation has a life of its own, interacting with speculation, calculation, model building, invention and technology in numerous ways. But whereas the speculator, the calculator, and the model-builder can be anti-realist, the experimenter must be a realist. This

thesis is illustrated by a detailed account of a device that produces concentrated beams of polarized electrons, used to demonstrate violations of parity in weak neutral current interactions. Electrons become tools whose reality is taken for granted. It is not thinking about the world but changing it that in the end must make us scientific realists.

Preface

This book is in two parts. You might like to start with the second half, *Intervening*. It is about experiments. They have been neglected for too long by philosophers of science, so writing about them has to be novel. Philosophers usually think about theories. *Representing* is about theories, and hence it is a partial account of work already in the field. The later chapters of Part A may mostly interest philosophers while some of Part B will be more to a scientific taste. Pick and choose: the analytical table of contents tells what is in each chapter. The arrangement of the chapters is deliberate, but you need not begin by reading them in my order.

I call them introductory topics. They are, for me, literally that. They were the topics of my annual introductory course in the philosophy of science at Stanford University. By 'introductory' I do not mean simplified. Introductory topics should be clear enough and serious enough to engage a mind to whom they are new, and also abrasive enough to strike sparks off those who have been thinking about these things for years.

Introduction: rationality

You ask me, which of the philosophers' traits are idiosyncrasies?
For example: their lack of historical sense, their hatred of becoming, their Egypticism.
They think that they show their *respect* for a subject when they dehistoricize it – when they turn it into a mummy.

(F. Nietzsche, *The Twilight of the Idols*, 'Reason in Philosophy', Chapter 1)

Philosophers long made a mummy of science. When they finally unwrapped the cadaver and saw the remnants of an historical process of becoming and discovering, they created for themselves a crisis of rationality. That happened around 1960.

It was a crisis because it upset our old tradition of thinking that scientific knowledge is the crowning achievement of human reason. Sceptics have always challenged the complacent panorama of cumulative and accumulating human knowledge, but now they took ammunition from the details of history. After looking at many of the sordid incidents in past scientific research, some philosophers began to worry whether reason has much of a role in intellectual confrontation. Is it reason that settles which theory is getting at the truth, or what research to pursue? It became less than clear that reason *ought* to determine such decisions. A few people, perhaps those who already held that morality is culture-bound and relative, suggested that 'scientific truth' is a social product with no claim to absolute validity or even relevance.

Ever since this crisis of confidence, rationality has been one of the two issues to obsess philosophers of science. We ask: What do we really know? What should we believe? What is evidence? What are good reasons? Is science as rational as people used to think? Is all this talk of reason only a smokescreen for technocrats? Such questions about ratiocination and belief are traditionally called logic and epistemology. They are *not* what this book is about.

Scientific realism is the other major issue. We ask: What is the world? What kinds of things are in it? What is true of them? What is truth? Are the entities postulated by theoretical physics real, or only constructs of the human mind for organizing our experiments? These are questions about reality. They are metaphysical. In this book I choose them to organize my introductory topics in the philosophy of science.

Disputes about both reason and reality have long polarized philosophers of science. The arguments are up-to-the-minute, for most philosophical debate about natural science now swirls around one or the other or both. But neither is novel. You will find them in Ancient Greece where philosophizing about science began. I've chosen realism, but rationality would have done as well. The two are intertwined. To fix on one is not to exclude the other.

Is either kind of question important? I doubt it. We do want to know what is really real and what is truly rational. Yet you will find that I dismiss most questions about rationality and am a realist on only the most pragmatic of grounds. This attitude does not diminish my respect for the depths of our need for reason and reality, nor the value of either idea as a place from which to start.

I shall be talking about what's real, but before going on, we should try to see how a 'crisis of rationality' arose in recent philosophy of science. This could be 'the history of an error'. It is the story of how slightly off-key inferences were drawn from work of the first rank.

Qualms about reason affect many currents in contemporary life, but so far as concerns the philosophy of science, they began in earnest with a famous sentence published twenty years ago:

> History, if viewed as a repository for more than anecdote or chronology, could produce a decisive transformation in the image of science by which we are now possessed.

Decisive transformation – anecdote or chronology – image of science – possessed – those are the opening words of the famous book by Thomas Kuhn, *The Structure of Scientific Revolutions*. The book itself produced a decisive transformation and unintentionally inspired a crisis of rationality.

A divided image

How could history produce a crisis? In part because of the previous image of mummified science. At first it looks as if there was not exactly one image. Let us take a couple of leading philosophers for illustration. Rudolf Carnap and Karl Popper both began their careers in Vienna and fled in the 1930s. Carnap, in Chicago and Los Angeles, and Popper, in London, set the stage for many later debates.

They disagreed about much, but only because they agreed on basics. They thought that the natural sciences are terrific and that physics is the best. It exemplifies human rationality. It would be nice to have a criterion to distinguish such good science from bad nonsense or ill-formed speculation.

Here comes the first disagreement: Carnap thought it is important to make the distinction in terms of language, while Popper thought that the study of meanings is irrelevant to the understanding of science. Carnap said scientific discourse is meaningful; metaphysical talk is not. Meaningful propositions must be *verifiable* in principle, or else they tell nothing about the world. Popper thought that verification was wrong-headed, because powerful scientific theories can never be verified. Their scope is too broad for that. They can, however, be tested, and possibly shown to be false. A proposition is scientific if it is *falsifiable*. In Popper's opinion it is not all that bad to be pre-scientifically metaphysical, for unfalsifiable metaphysics is often the speculative parent of falsifiable science.

The difference here betrays a deeper one. Carnap's verification is from the bottom up: make observations and see how they add up to confirm or verify a more general statement. Popper's falsification is from the top down. First form a theoretical conjecture, and then deduce consequences and test to see if they are true.

Carnap writes in a tradition that has been common since the seventeenth century, a tradition that speaks of the 'inductive sciences'. Originally that meant that the investigator should make precise observations, conduct experiments with care, and honestly record results; then make generalizations and draw analogies and gradually work up to hypotheses and theories, all the time developing new concepts to make sense of and organize the facts. If the theories stand up to subsequent testing, then we know something about the world. We may even be led to the underlying laws of nature. Carnap's philosophy is a twentieth-century version of this attitude. He thought of our observations as the foundations for our knowledge, and he spent his later years trying to invent an inductive logic that would explain how observational evidence could support hypotheses of wide application.

There is an earlier tradition. The old rationalist Plato admired geometry and thought less well of the high quality metallurgy, medicine or astronomy of his day. This respect for deduction became enshrined in Aristotle's teaching that real knowledge – science – is a matter of deriving consequences from first principles by means of demonstrations. Popper properly abhors the idea of first principles but he is often called a deductivist. This is because he thinks there is only one logic – deductive logic. Popper agreed with David Hume, who, in 1739, urged that we have at most a psychological propensity to generalize from experience. That gives no reason or basis for our inductive generalizations, no more than a young man's propensity to disbelieve his father is a reason for trusting the youngster rather than the old man. According to Popper, the rationality of science has nothing to do with how well our evidence 'supports' our hypotheses. Rationality is a matter of method; that method is conjecture and refutation. Form far-reaching guesses about the world, deduce some observable consequences from them. Test to see if these are true. If so, conduct other tests. If not, revise the conjecture or better, invent a new one.

According to Popper, we may say that an hypothesis that has passed many tests is 'corroborated'. But this does not mean that it is well supported by the evidence we have acquired. It means only that this hypothesis has stayed afloat in the choppy seas of critical testing. Carnap, on the other hand, tried to produce a theory of confirmation, analysing the way in which evidence makes hypotheses more probable. Popperians jeer at Carnapians because they have provided no viable theory of confirmation. Carnapians in revenge say that Popper's talk of corroboration is either empty or is a concealed way of discussing confirmation.

Battlefields

Carnap thought that *meanings* and a theory of *language* matter to the philosophy of science. Popper despised them as scholastic. Carnap favoured *verification* to distinguish science from non-science. Popper urged *falsification*. Carnap tried to explicate good reason in terms of a theory of *confirmation*; Popper held that rationality