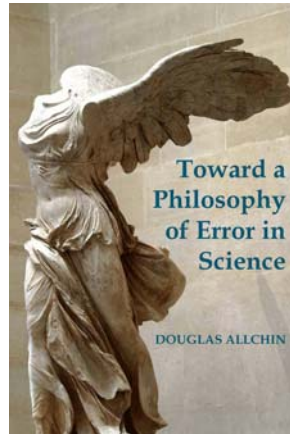


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### *Toward a Philosophy of Error in Science*

Overview [excerpted from the Preface]

For many philosophers, the central aim of science is to produce reliable knowledge. Yet ironically, the history of science is littered with errors. For many, perhaps, these are simply embarrassing failures, to ruefully acknowledge and cast into the shadows. In this book, by contrast, I *celebrate* these errors. They are integral to the process — and progress— of science. The cost of new knowledge is the risk of error.

Conventionally, philosophers have focused on science’s distinctive methodologies and disciplined protocols for establishing reliable knowledge. Error might seem an annoyance—a distraction along the way to true knowledge. Here, I detail how scientists respond to and identify errors. Based on historical analysis, I also suggest how, from a more pragmatic perspective (looking ahead), scientists may fruitfully manage the errors that inevitably occur.

While many philosophers (as well as historians and sociologists—and scientists themselves) have disparately commented on error, we need a comprehensive and systematic approach to organize our understanding and to guide scientists in practice: a *philosophy of error in science*.

This book thus engages in a thoughtful reflection about error in science. Indeed, a concerted study yields some unexpected conclusions. For example, “negative” knowledge has a “positive” role. Understanding particular errors contributes to deepening the precision and accuracy of knowledge—even when some earlier concepts are abandoned as “wrong.” Accordingly, we can conceptualize knowledge, not as “true” *versus* “false,” but as embracing both forms of knowledge. That is, we should contrast true-or-false (the known) to uncertainty (the unknown).

Errors lead to improving methodologies at multiple levels. Thus, standards of proof escalate. The quality of knowledge improves. Looking ahead, we can improve scientific practice through more systematic attention to error. We can nurture a habit of deepening knowledge by deliberately probing for possible unresolved sources of errors.

## Market & Unique Features

This volume will complement other recent books in OUP's catalog: Peter Vickers' *Identifying Future-Proof Science* (2022), Nancy Cartwright (et al)'s *The Tangle of Science*, and the edited volume on *Philosophy of Science: A Companion* (2018). It also echoes themes in earlier OUP books: Stuart Firestein's *Failure* (2016) and Walter Gratzer's *Undergrowth of Science* (2000).

The book is a timely contribution addressing several significant issues. First, it provides perspective on the “reproducibility crisis” and the failure to replicate many landmark experiments, leading to doomsday warnings that (according to one prominent critic) “most scientific findings are false.” The apparently embarrassing “failures” are a prominent topic in the journals *Nature* and *Science* and in informal conversation among practicing scientists, as well as philosophers. Equally important are concerns about the scandalous rise of misconduct and “questionable research practices” — cold fusion, organic semi-conductors, room-temperature superconductivity, and other such incredible claims. A fruitful response to the current moment of perceived crisis, in my view, is to adopt a more holistic approach: to examine all the types of error in science, how they occur, and how they are remedied.

Another enduring concern is the status of the “pessimistic induction.” Philosophers have mused on the history of science for decades. By observing that past theories seem to eventually fall by the wayside, some conclude that current theories must inevitably be wrong, as well. A dire prospect, if true. I take a more pragmatic view and articulate, in particular, the importance of negative knowledge and its role in the growth of knowledge. When, and in what concrete ways, are current theories vulnerable to error?

I also address the persistent ambiguity between viewing science as “tentative” and yet also reliable. Here, I provide a sequel to and reconciliation of the contrasting positivist traditions and radical Kuhnian perspectives. We may resolve this tension by articulating both how (and when) scientists have indeed erred and how (and when) they have found and remedied their errors. An empirically based science of science, perhaps?

Finally, many philosophers and science advocates of many stripes admit that science (at the margin) is not perfect and that individual scientists, at least, do sometimes make errors. But they tend to add hastily that science is *self-correcting*. No cause for alarm. In this book, I describe, instead, how errors are concretely found and fixed, allowing us to understand more clearly the various contingencies and conditions that shape the trustworthiness of science.

I look forward to seeking endorsements from: Hanne Anderson, Hasok Chang, Lindley Darden, Deborah Mayo and Hans-Jorg Rheinberger, each familiar with my work.

## Readership

This book will be valuable to anyone concerned with how science works (and also how, on occasions, it doesn't work). While of primary interest to philosophers of science, it will also be relevant to many historians, sociologists, ethnographers, and others in Science Studies. It will be of concern to many scientists — those who reflect on the nature of their practice. Thus, it may inform science graduate students and other aspiring scientists, science teachers, and science administrators. Perhaps science journalists? Indeed, it should engage anyone who thinks carefully about the epistemic foundations of science and how science informs public policy or personal decision making. It offers an informative perspective for anyone tasked with assessing the reliability of scientific claims.

Table of Contents and Chapter Summaries  
Attached.

#### Publication Metrics

The text is 103,000 words (not including front matter, references, or index).  
There are 14 figures: 5 tables, 4 line-drawings, and 5 half-tone diagrams.

The manuscript is complete (pending comments by reviewers).  
The full manuscript (or selected chapters) is available for review.

#### Author

Douglas Allchin has been writing about error in science for over three decades. He brings together a distinctive convergence of expertise in history and philosophy of science (PhD, University of Chicago, 1991) and science education (History of Science Society Hazen Prize, 2021), as well as research experience at several ecological field stations.

His early paper on “James Hutton and Phlogiston” (on one of the most notorious errors in the history of science) won the Fishbein Essay Prize at the University of Chicago in 1988. That was followed by in-depth analysis of a contemporary case, “A Twentieth-Century Phlogiston” (1997), about hypothesized chemical intermediates in oxidative phosphorylation. A 1999 invited contribution focused on “Negative Results as Positive Knowledge, and Zeroing In on Significant Problems.” The seed for this book appeared in Allchin’s landmark 2001 paper, “Error Types,” and the theme has been echoed in numerous case studies since (e.g., “To Err and Win a Nobel Prize” (2002), “Naturalizing as an Error-Type in Biology” (2008), and a forthcoming chapter on “Error Repertoires” in a collected volume on *Failure, Error, Malfunction* in science). The topic was also the occasion for a short-term invited residency at Aarhus University in 2012.

These philosophical publications have been complemented by historical research appearing largely in educational contexts — for example, “Celebrating Darwin’s Errors” (2009), “Nobel Ideals and Noble Errors” (2008), and “Teaching the Nature of Science through Scientific Error” (2012). Many cases have appeared in “Sacred Bovines,” Allchin’s column for *American Biology Teacher* (and collected in a 2013 book—published by Oxford University Press).

Finally, Allchin’s approach is richly informed by deep familiarity with actual scientific practice. He participated in research projects at several field stations — on tree gap succession in the forests by the Chesapeake Bay, on sexual selection of flowers in the Rocky Mountains, on species turnover in a tropical rainforest in Panama. His modeling of the dynamics of “information-center” foraging among honeybees and other animals appeared in the journal *Behaviour* (1992). He reads *Science* magazine regularly, not just philosophy and history journals. Perhaps more importantly, the conclusions in this book have been shaped by many, many informal conversations with working scientists, who encounter error as a normal part of their everyday practice.

A full CV is available.

# *Toward a Philosophy of Error in Science*

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# Toward a Philosophy of Error in Science

## CHAPTER SUMMARIES

### Preface

Given the philosophical heritage of characterizing science in terms of its reliable knowledge, focusing on its errors may seem counterproductive, or even perverse. But scientists regularly discover errors. And learn from them. While many philosophers (as well as historians, sociologists and scientists themselves) have disparately commented on error, we need a comprehensive and systematic approach—a philosophy of error—to organize our understanding and guide scientists in practice.

### 1 Error Itself

Errors permeate the history of science, even among the most famous scientific heroes and Nobel Prize winners. What can these cases tell us about science as a process? First, what precisely do we mean by *error*? Defining error proves to be surprisingly difficult, because the identification of an error straddles different times, contexts, and bodies of evidence. I focus on the change in justification—from a claim once considered justified to its later status as unjustified. This cryptic shift will guide our analysis, and invite us to think more fully about what is meant by *scientific justification*. Some errors seem trivial—good for a chuckle, perhaps. So, does the scale of the error matter—whether it is a blunder, a big whopper, or just a small blooper? An important dimension of interpreting error is not the content of the claim itself, but the epistemic posture towards or commitment to the justification of the claim in question. Error is definite, even if a negative claim perhaps. Error thus differs from *uncertainty* or vague disclaimers of “tentativeness.”

### 2 Observational Errors.

Experimentalists frequently refer to *sources of error*, the factors ranging from dirty glassware and contaminated samples to confounding variables and mistaken assumptions that can produce misleading results or faulty conclusions. Here, I generalize this concept to the whole process of science, applied at three levels: observational, conceptual and social (discursive). At each level, a survey of historical cases yields general *error types*—the many potential pitfalls that might ultimately guide more reliable scientific practice. They support assembling an *error inventory* as a reference guide.

Observational errors arise in laboratory experiments, field studies, or other forms of measurement or collection of data. They include material errors, instrument errors, human perceptual deficits, observer bias, observer effects (including artifacts), and various forms of misframing—sampling bias, sample size, incomplete sampling, proxy variables and heuristic gaps, and confounders.

### 3 Conceptual Errors

Conceptual errors arise in reasoning at many levels, from processing data and analyzing them statistically to conventional logic (and its fallacies) and interpretive practices (some shaped by heuristics and inherent cognitive biases). They include overgeneralizations, faulty assumptions, theory-laden judgment and confirmation bias, heuristic gaps, cognitive

lapses, unaddressed alternatives, cryptic alternatives, and various forms of cultural bias—such as those based on religion, gender, race, class, or politics.

#### 4 Social-Level Errors

Errors also occur at the social level, in the customary discourse among scientists. That is, there are institutional (even if informal) mechanisms of “quality control” in the scientific community. They are designed to regulate accurate and full reporting, expertise, theoretical bias, and deception. Error types include communal confirmation bias, communal cultural bias, lapses in peer review/publication, credibility bias and fraud and conflict of interest. Consensus arising from reciprocal criticism is thus an important benchmark.

#### 5 From Incongruence to Error

How, indeed, are errors remedied? Errors are errors in part because the flaws in their justification are hidden. Exposing them, and ascertaining their status as errors requires *work*—epistemic work, not the mere passage of time. The first step is an awareness that something is awry. Researchers may encounter *incongruences*: (1) in their conflicting observations (*discordances*), (2) in the mismatch between theory and observations (*anomalies*), or (3) in alternative theoretical interpretations (*ambiguities, or disagreement*). The next step is to *isolate the error* by tracing it to any of the error types. Prospective errors are confirmed through testing, especially through controlled experiments. The growth of knowledge poses an epistemic puzzle: how can new information upend a verdict once deemed to be justified by more limited evidence? How are learning and *unlearning* related?

#### 6 Deeper Evidence

But how does the relevant additional evidence arise? Deeper evidence may emerge through (at least) modified replications, increased sample size, more diverse sampling, wider scope, the increased resolving power of instruments or methods, new technology, filling of heuristic gaps, new conceptual perspectives, or happenstance. These strategies complement the inventory of error types and underscore the pervasive work of troubleshooting and error correction in science.

#### 7 The Conundrum of “Bias”

Can errors ever be eliminated from science? Individual perspectives (or “biases”) may generate blind spots and error. But they also seem to underlie important insights and discoveries. Bias can be fruitful, as well as misleading. The cost of innovation is the risk of failure. Science can harness diverse standpoints through a social system of checks and balances. Reciprocal criticism helps expose adverse bias and filter out various forms of individual error, while allowing new and marginal ideas opportunity.

#### 8 Managing Error

A deeper awareness of error in science may underscore that the practices of science are focused as much on regulating sources of error as on “seeking the truth.” We benefit from *negative knowledge*. Indeed, most of the familiar abstract methodological norms of science have concrete historical roots, based on encounters with particular error types. Errors may seem to threaten the notion of scientific progress, but by focusing on the escalating standards of proof, we may acknowledge growth in the quality of knowledge, even if errors lead us to abandon some concepts or theories. We may articulate field-specific *error*

*repertoires* and identify corresponding *error signatures* which may assist in mitigating future errors and in diagnosing problems in research. The familiar concept of checklists may be adapted in envisioning a series of *checkpoints*, occasions where reviewing sources of error seems especially appropriate. A deeper awareness of error types may also lead us to a view that confirming evidence alone is insufficient. To deepen reliability, we need *error probes* to actively search for possible loose ends and qualifications. “Nothing’s concluded until error is excluded.” All these projects may foster further study in the *Philosophy of Error* and in developing *Error Analytics*, a set of philosophically informed practices for managing errors in everyday scientific practice.