Introductory Essay

Christopher Hitchcock

Welcome to the fiftieth-anniversary edition of Wesley C. Salmon's *The Foundations of Scientific Inference*. This is the book that taught a generation of students and researchers about the problem of induction, the interpretation of probability, and the logic of confirmation. It is remarkable in that it succeeds in being both an introductory textbook and a scholarly monograph at the same time. It presupposes no background knowledge yet succeeds in articulating and defending a coherent vision of the nature of scientific reasoning.

The Foundations of Scientific Inference (hereafter *Foundations*) has appealed, and will continue to appeal, to a broad variety of readers. For specialists in the philosophy of science, it shows us how one of the great thinkers of the previous century formulated and conceptualized the central questions about induction and confirmation. For historians, it provides a window into the work of some of the leading philosophers of the mid-twentieth century, including Max Black, Rudolf Carnap, Norwood Russell Hanson, Sir Karl Popper, and Hans Reichenbach. For students of philosophy, and specialists in other areas of philosophy, *Foundations* provides a clear, accessible, and rigorous introduction to these central topics in the philosophy of science. For scientists and science students, it provides a first look at the philosophical underpinnings of scientific investigation. And for broad-minded and curious readers of all stripes, it provides a clear taste of what it means to formulate and think one's way through a genuine philosophical problem.

Academic writing is always an optimization problem. There are many goals that a writer is trying to achieve, and these goals are often in conflict. Salmon deftly accomplishes these diverse goals without apparent sacrifice or compromise.

Despite its relatively short length (168 pages), *Foundations* is sweeping in its scope. The reader is introduced to many of the central movements in epistemology, including the programs championed by Bacon, Descartes, and Kant, in addition to the extended discussion of Hume's problem of induction. Indeed, Salmon's first three chapters, dedicated to the problem of induction, provide an excellent introduction to the topic of epistemology in general. *Foundations* also educates the reader about the basics of formal logic and lays out the basic elements of the mathematical theory of probability. Salmon is able to cover so much ground in so little space with prose that is spare and concise, yet it somehow never feels rushed or miserly.

Salmon's text presupposes no background in philosophy of science or indeed in any area of philosophy or science. His presentation is accessible to all. And yet he achieves this accessibility without sacrificing precision or argumentative rigor. Of course, some details and advanced topics have been omitted, but nothing has been fudged, dumbed down, or cheaply popularized for the reader. Indeed, it is Salmon's desire to make this work accessible to all that forced him to proceed from scratch in such a careful, methodical manner.

Finally, Salmon provides a balanced overview of his central topics without losing his own distinctive voice. *Foundations* functions like a textbook in providing the reader with a broad survey of prevailing opinion on the topics it treats, but Salmon does not shy away from expressing and defending his own preferred approaches. He does so transparently, never abusing the reader's trust in his role as expositor.

In this introduction, I will reintroduce *Foundations* to the contemporary reader. I will say a little bit about the state of philosophy of science in the 1960s and the major influences on Salmon. I will point to some of the most important contributions made in *Foundations* and discuss the evolution of Salmon's thinking on the major topics covered in the book. Finally, I will say something about its impact. I will not attempt to provide a more detailed overview of Salmon's life and work.

Major Themes and Influences

We may, somewhat arbitrarily, divide the contents of *Foundations* into three major topics. The first, occupying chapters I–III, is David Hume's problem of induction together with attempts to solve it. The second major topic, occupying chapters IV–VI, is the problem of how to interpret probability. Finally, chapter VII explores the logical structure of the confirmation of scientific hypotheses.

Among the many philosophers whose work Salmon discusses, three play a particularly prominent role: Rudolf Carnap, Sir Karl Popper, and Hans Reichenbach. The first two serve as Salmon's primary foils, while Reichenbach had the greatest direct influence on Salmon's own thinking. These three scholars are emblematic of the shift in the landscape of philosophy that was triggered by the rise of fascism in Europe. Throughout the 1930s, leading scholars fled the German-speaking countries of central Europe to resettle in English-speaking countries, primarily the United Kingdom and the United States.

Rudolf Carnap was at the University of Vienna from 1926 to 1931 and was a prominent member of the Vienna Circle, an informal group of philosophers and philosophically minded scientists led by Moritz Schlick. They came to be called the Logical Positivists in the English-speaking world, although this is not a name they adopted themselves. Carnap taught at the University of Prague from 1931 to 1935, when he fled to the United States. He taught first at the University of Chicago and then at UCLA. Interestingly, Salmon pursued his master's degree at the University of Chicago while Carnap was there; but at the time, Salmon was interested in the philosophy of Alfred North Whitehead and did not interact with Carnap. Carnap did important work on the foundations of probability and in inductive logic (Carnap 1950, 1952), developing a logical interpretation of probability and a probabilistic account of the confirmation of theories by evidence.

Sir Karl Popper was raised in Vienna, where he interacted with Carnap and other members of the Vienna Circle. He rejected their views, however, and was never considered a member of the circle. He published *Logik der Forschung* in 1934 (Popper 1959a) while teaching at a secondary school. In 1937, he moved to New Zealand to take a faculty position at the University of Canterbury. After the war, in 1946, he moved to the London School of Economics, where he spent the rest of his career. In 1959, he translated *Logik der Forschung* into English and published it as *The Logic of Scientific Discovery* (Popper 1959a). In 1963, he published *Conjectures and Refutations: The Growth of Scientific Knowledge* (Popper 1963), a wide-ranging collection of essays that presented a number of his ideas in a more accessible form. These works were profoundly influential and made Popper the best-known philosopher of science at the time Salmon was writing *Foundations.* Popper's eminence was recognized by Queen Elizabeth II in 1965, when he was knighted.

Hans Reichenbach had attended Einstein's early lectures on general relativity at the University of Berlin and took a position there in 1926. He left in 1933 and spent five years at the University of Istanbul in Turkey. During this period he published two important books: In 1935, he published *The Theory of Probability* in German, which he later expanded and translated into English in 1949 (Reichenbach 1949). In this work he developed his frequency interpretation of probability. In 1938, he published *Experience and Prediction* in English (Reichenbach 1938). This wide-ranging work presented his alternative to Logical Positivism and argued for the central role of probability in understanding the relationship between theory and evidence in science. In 1938, Reichenbach moved to UCLA. He supervised Salmon's dissertation on John Venn's theory of induction, which was completed in 1950. Reichenbach was the strongest influence on Salmon's own views, and Reichenbach's ideas echo throughout *Foundations.*

The Problem of Induction

A reader coming from a background in science might expect a book titled *The Foundations of Scientific Inference* to discuss topics like experimental design, the use of scientific instruments, statistical hypothesis testing, and so on. Instead, Salmon focuses on a more elementary presupposition of almost all scientific reasoning. Most scientific inferences have two closely related features: they are *ampliative,* and they are *not necessarily truth-preserving.* An inference is ampliative if its conclusion has content that goes beyond what is contained in the premises. Philosophical discussions of induction tend to focus on inferences that extrapolate from past cases to future ones or from observed cases to unobserved ones. From the fact that all emeralds that have been observed so far have been green, we infer that the next emerald to be observed will be green. But Salmon takes pains to point out that such simple extrapolations are not the only inferences that are ampliative. We also make ampliative inferences when we infer a shared evolutionary lineage from similarities in the morphology of animals, when we infer the structure of a crystal from a pattern of X-ray diffraction, or when we infer the collision of black holes over a billion years ago from the miniscule wobblings of detectors in Washington and Louisiana. The ampliative character of these inferences implies that they are not necessarily truth-preserving. That is, it is *logically* possible for the premises to be true and the conclusions to be false. It is logically possible for all emeralds observed until now to be green and for the next observed emerald to be blue;

it is logically possible for the detectors to wobble without having been caused to do so by gravity waves emitted by colliding black holes.

Scientific inferences are thus different from inferences in logic and mathematics, which are non-ampliative and necessarily truth-preserving. It may not be apparent that the Pythagorean theorem is "contained in" the axioms of Euclidean geometry: a perusal of the axioms won't reveal any statement that has the form of the Pythagorean theorem. But the Pythagorean theorem is nonetheless implicitly contained in the axioms: there is no logically consistent set of propositions that includes the Euclidean axioms and denies the Pythagorean theorem. Inferences in logic and mathematics confer certainty, but it is only a hypothetical certainty. The Pythagorean theorem is certain to be true, *if* the axioms of Euclidean geometry are true. The price to be paid for this certainty is non-ampliative inference: inferences can only serve to unpack the contents of a given set of axioms.

The first problem Salmon addresses, then, is how to justify ampliative inferences. The inference rules of logic and mathematics wear their justification on their sleeves: they are designed to safely convey truth from premises to conclusions. But the rules of ampliative inference, whatever they may be, offer no guarantee that they will yield true conclusions, given true premises. So why should we rely on them at all? This is David Hume's famous problem of induction (Hume 1999, §§ IV–V).

Salmon carefully reconstructs Hume's argument for the conclusion that no rational justification of ampliative reasoning is possible. In a nutshell, induction can't be justified using deductive, non-ampliative reasoning, because the failure of induction is not *logically* impossible. Nor can ampliative reasoning be justified by ampliative reasoning, on pain of circularity. Salmon is careful to explain that an argument can be circular without being an instance of *petition principii*—the logically valid but unhelpful rule:

$$\begin{array}{c} A \\ \therefore A. \end{array}$$

(From proposition A, infer that A is true.) A justification of ampliative reasoning can be circular if it *employs* ampliative reasoning, even if it does not assume the reliability of ampliative reasoning as an explicit premise. But these two alternatives—non-ampliative and ampliative reasoning—seem to be exhaustive. Hence, no justification of any kind is possible. Salmon is careful to show that Hume's reasoning does not just apply to extrapolation from past experience—what is often called "induction"—but to *any* ampliative inference.

At the time Salmon was writing *Foundations*, it was trendy to dismiss philosophical problems as "pseudoproblems" to be "dissolved" rather than solved.

This was due, in part, to the influence of Ludwig Wittgenstein, the Logical Positivists, and also to the Oxford "ordinary language" school of philosophy. Salmon rejects this maneuver, defending the problem of induction as a genuine problem to be tackled head on. He is careful to state that empirical science need not be put on hold, but that anyone who maintains that empirical science enjoys a privileged epistemic status should be concerned with the problem of induction as a matter of "intellectual integrity" (55).[1]

One of the highlights of Salmon's discussion of the problem of induction is his critique of Popper. Popper's work remains influential today and has probably had a greater impact upon practicing scientists than the work of any other philosopher. Popper is best known for proposing *falsifiability* as a criterion of *demarcation* for empirical science. The distinction between science and other endeavors, according to Popper, is that scientists formulate hypotheses that are capable of empirical falsification. From scientific hypotheses, it is possible to derive precise predictions. For example, Einstein's general theory of relativity entails that light from a distant star, passing close to our sun, would be deflected by an angle of 1.75 arc seconds.[2] This could be tested by observing distant stars that were aligned with the sun during a solar eclipse. Such observations were carried out by Sir Arthur Eddington in 1919, and the results were in accord with the theory's predictions. If the predictions of a theory are not in accord with observation, then the hypothesis in question is falsified.

It is less well known outside of philosophical circles that Popper's demarcation criterion formed part of his attempt to solve the problem of induction. According to Popper, Hume's problem should be taken at face value: Hume correctly showed that induction is irrational. Empirical science does not require induction; it requires only deductive logic. Specifically, hypotheses are falsified according to the rule *modus tollens.* Where H is a hypothesis, and O some observation statement that is implied by the hypothesis, we can write the rule of *modus tollens* as follows:

$$\begin{array}{l} H \supset O \\ \neg O \\ \therefore \neg H \end{array}$$[3]

However, if the prediction is borne out (O is true), we cannot infer that the hypothesis H is true, or that it is probably true, or even that H is supported by the evidence O. All that we can say is that the hypothesis was not falsified. Eddington's observations gave us no more reason to believe in the truth of Einstein's theory than we had without them. Popper says that a theory that has survived serious attempts at falsification is well *corroborated*, but he insists that corroboration does not constitute any kind of inductive support; corroboration is simply a track record of failed attempts at falsification.

Salmon offers a concise and penetrating critique of Popper's anti-inductivism (21–27). Specifically, Salmon charges that Popper's account of science renders it *empty*. While science includes many bold theoretical conjectures, these are not to be believed as true, probably true, or approximately true. Since Popper admits only non-ampliative inference from observations, the only propositions that we are entitled to believe are ones describing the observations themselves. Science tells us nothing about the world other than what we directly observe. In fact, the situation is even worse than this, since Popper does not accord observation statements any kind of privileged epistemic status: they too are hypotheses that are capable of falsification. What remains of science, then, is a collection of propositions lacking any empirical justification.

Salmon later sharpened his critique in response to criticism from Popper's colleague John Watkins. The resulting paper, "Rational Prediction," was published in 1981 (Salmon 1981). There, Salmon distinguishes three different reasons for making predictions based on scientific theories: (i) satisfying curiosity; (ii) testing the theory in question; (iii) guiding practical decision making. Popper's focus is on (ii). When we derive predictions in order to test a theory, we don't have to believe that the theory is true or even approximately true. Perhaps here we can safely dispense with ampliative inferences. However, we also rely upon theories when we make practical decisions. Salmon illustrates the point with an anecdote about a physicist friend who won a bet when he predicted that a child's helium balloon would move forward as the airplane they were in took off. For a less homey example, NASA's Jet Propulsion Laboratory (JPL) successfully landed the *Curiosity* rover on Mars. It was launched in November 2011, and landed in August 2012. This would not be possible without the ability to predict the location of Mars nine months in advance. Since *Curiosity* was much larger than any rover that had previously been sent to Mars, JPL engineers had to develop a new landing protocol. The elaborate protocol they developed could not be tested on Earth, since the Earth's atmosphere is much denser, and its gravity stronger than Mars'. Salmon asks why it is rational to rely on well-tested scientific theories when making such predictions: Why not consult a horoscope or examine the entrails of an animal sacrificed for the purpose? Popper claims that we should rely on well-corroborated theories to make such predictions. But Salmon argues that Popper gives no adequate reason for why we should do this. After all, the corroboration of a theory is not supposed to confer any kind of confidence in the correctness of the theory. Salmon's paper remains one of the clearest, most incisive critiques of Popper's falsificationist methodology.

Among the other attempts to address the problem of induction, the one Salmon finds to be the most promising is Reichenbach's pragmatic justification of induction (Reichenbach 1938). Even if we cannot provide a reason for *believing* that induction is reliable, we might nonetheless have a reason for *relying* on it. Reichenbach tried to provide such a reason by arguing for the following conditional: if any ampliative inference rule is reliable, then induction is. For suppose that rule *R* has a good track record of generating ampliative inferences with true conclusions; then the world will contain a regularity of the form: "when rule *R* produces conclusion *C*, *C* is true." This regularity is the sort of thing that can be successfully tracked by ordinary induction. Putting Reichenbach's conditional in the contrapositive: if the world is so chaotic that induction will fail, then no ampliative inference can succeed. So we have nothing to lose by relying on induction. Salmon rejects this argument as too vague, but he returns to this general strategy in chapters V and VI.

There is one omission from Salmon's discussion that may seem surprising: There is no mention of Nelson Goodman's "new riddle of induction," which appeared in part III of his *Fact, Fiction, and Forecast*, first published in 1954 (Goodman 1983). Goodman offers a response to Hume's original problem of induction, and poses a new puzzle about inductive inference. The rules of deductive logic are purely *syntactic*. Consider for example, the rule of *modus ponens:*

$$\begin{array}{l} A \\ A \supset B \\ \therefore B. \end{array}$$

This rule is valid simply in virtue of its logical form. It does not matter what the contents of A and B are. By contrast, consider the following candidate inductive rule:

All observed As have been Bs
∴ The next observed A will be a B.

Goodman showed that this rule leads to inconsistency if it is applied to all A and B. Before we can attempt to justify induction, we need to specify the appropriate scope of inductive inference.[4] Goodman's discussion was certainly well known when Salmon was writing *Foundations*; indeed, Salmon proposed a solution to Goodman's new riddle in his 1963 paper "On Vindicating Induction" (Salmon 1963a). In that paper, Salmon indicated that a response to Goodman's riddle was a necessary component of his own attempt to vindicate (a specific form of) induction. Salmon also briefly engaged with Goodman's new riddle in Salmon (1973) and Salmon (1975).