

# Chapter 1

## Why Epistemology?

### 1.1 The Desire to Know

The opening line of Aristotle's *Metaphysics* states, "All men by nature desire to know." But what does it mean to know? While one might wish for a universal answer to this question, none as yet has been forthcoming. As we understand the question, what it means to have knowledge depends on one's standpoint. Moral knowledge is of a different kind than scientific knowledge. Even in science, the domain of scientific knowledge and what is accepted as authentic knowledge, meaning that it is accepted as "true," has changed dramatically over time.

The domain of scientific knowledge for Aristotle was much smaller than it is today. He could not make observations of the atom or of distant galaxies. He could not observe the genes and proteins in a cell, nor could he measure electrical impulses in the brain. His concept of truth was limited by his ability to observe and measure, but it was also limited by the mathematical systems he had available to represent the behavior he viewed. It is naïve to think that our concept of knowledge in today's world of quantum physics and microbiology would be the same as it was for Aristotle in 340 BC, what it was for Newton in 1687, or what it will be in 2500.

Scientific knowledge relates to the manner in which the mind formulates and operates on ideas concerning Nature. These must ultimately be related to our senses that provide the data from which the neural system formulates ideas. My idea of a rock is not outside my mind. Something is out there that results in sensations, that in turn results in the idea of a rock. Such ideas are the raw material of theories that describe the interaction of the ideas—and if a theory is valid it should produce consequences that can be checked against future sensations. The fundamental point is that theoretical operations in the mind correspond to physical operations in Nature that are not directly experienced, but whose activity is reflected in new sensations resulting in new ideas concordant with outcomes the original operations predicted. This very general description of scientific knowledge has been developed over many centuries and is not Aristotle's view.

The first aim of this book is to trace this development up to and including the turbulent effects of quantum mechanics in the Twentieth Century. The second aim, which cannot be accomplished absent an appreciation of the subtle relations

between reason, science, and metaphysics, including their historical evolution, is to scrutinize the new and rapidly accelerating crisis of scientific knowledge that has accompanied the desire to model extremely complex systems such as those arising in biology, environmental science, economics, and social science.

## 1.2 What is Epistemology?

Implicit in these aims is that it is possible to characterize a specific kind of knowledge to be called “scientific.” This characterization lies outside of science and must be constructed prior to the organization of experience within scientific categories. Such characterization amounts to having a theory of scientific knowledge. *Epistemology* is defined as the theory of knowledge, so a scientific epistemology is required. What would it entail?

Wilhelm Windelband (1848–1914) defines epistemology in the following way: “The problems, finally, which arise from the questions concerning the range and limit of man’s knowing faculty and its relation to the reality to be known form the subject-matter of epistemology or theory of knowledge.” [Windelband, 1958] Taking the word “range” to refer to the kind, or nature, of the knowledge under consideration, the nature of scientific knowledge is determined by its manner of representation and its criteria for truth; its limitations are determined by the limits of its form of representation and the degree to which its criteria of truth can be applied; and its relation to reality is determined by the manner in which its representation is connected to physical phenomena and the relation between scientific truth and physical phenomena.

Many researchers appear to believe that epistemological issues are too arcane and irrelevant to their everyday efforts. One just has to get on with gathering data, building models, and justifying the models. But how should one gather data, what kind of models should be constructed, and, most importantly, what constitutes genuine validation? These questions relate to Windelband’s definition of epistemology. Absent some understanding of their answers, one might spend years wandering about aimlessly, producing meaningless results, simply because a bona fide theory must conform to the epistemological requirements of science.

José Ortega y Gasset (1883–1944) phrases the matter this way: “Whoever wishes to have ideas must first prepare himself to desire truth and to accept the rules of the game imposed by it. It is no use speaking of ideas when there is no acceptance of a higher authority to regulate them, a series of standards to which it is possible to appeal in a discussion.” [Ortega y Gasset, 1994]

The foundations of a discipline are inseparable from the rules of its game, without which there is no discipline, just idle talk. The foundations of science reside in its epistemology, meaning that they lie in the mathematical formulation of knowledge, structured experimentation, and statistical characterization of validity. Rules impose limitations. These may be unpleasant, but they arise from the need to link ideas in the mind to natural phenomena. The mature scientist must overcome the desire for intuitive understanding and certainty, and must live with stringent limitations and radical uncertainty.

Inattention to epistemology results in research that appears scientific but fails to have depth, or even worse, is scientifically unsound. Albert Einstein (1879–1955) writes, “The reciprocal relationship of epistemology and science is of a noteworthy kind. They are dependent upon each other. Epistemology without contact with science becomes an empty scheme. Science without epistemology is—insofar as it is thinkable at all—primitive and muddled.” [Einstein, 1949]

Only through deep reflection on epistemology can one come to grasp what it means to possess scientific knowledge of Nature and therefore be in a position to effectively seek such knowledge. Significant effort must be spent escaping a naïve realism that would attempt to force one’s conceptualizations of Nature to conform to ordinary everyday understanding.

In a letter, Einstein wrote the following:

I fully agree with you about the significance and educational value of methodology as well as history and philosophy of science. So many people today—and even professional scientists—seem to me like somebody who has seen thousands of trees but has never seen a forest. A knowledge of the historic and philosophical background gives that kind of independence from prejudices of his generation from which most scientists are suffering. This independence created by philosophical insight is—in my opinion—the mark of distinction between a mere artisan or specialist and a real seeker after truth. [Einstein, 1944a]

“Independence from the prejudices of his generation!” Only in this way can one break free of the run-of-the-mill grind that never gets to the heart of the matter.

### 1.3 Modern Science

Starting in the early part of the Seventeenth Century, a radical new understanding of natural science took shape. On the one hand, Francis Bacon proposed ordered observations in the context of experimental design; on the other, Galileo contended that scientific knowledge must be constituted within mathematics and not be bound by the need to explain matters in ordinary language. Isaac Newton manifested Galileo’s conception with his laws of motion, which he proclaimed free of non-empirical, metaphysical notions such as substance and causality. This was indeed a “new science.” What is gravity? Who knows? All that matters is that science provides mathematical descriptions of behavior. It would no longer be required to satisfy the human desire for explanations in a deeper reality.

Mathematics was not new to science; Archimedes, the greatest scientist of antiquity, was a great mathematician and this was reflected in his scientific thinking. Now, however, instead of supporting a theory whose status as authentic knowledge was rooted in causality, mathematics was the theory. Knowledge was constituted within it, and its validity depended solely on its ability to make predictions confirmed by observation. The birth of modern science was the greatest revolution in human history. It radically changed the human condition because it altered man’s perspective on himself and Nature.

The full extent of the change did not become apparent until the arrival of quantum mechanics in the Twentieth Century. Only then did the unintelligibility of Nature become forcefully apparent with the uncertainty principle and strange notions like wave-particle duality. The theory was mathematically sound and agreed with predictions, but defied human understanding.

Hannah Arendt (1906–1975) frames the dilemma brought about by science in the early Twentieth Century: “To understand physical reality seems to demand not only the renunciation of an anthropocentric or geocentric world view, but also a radical elimination of all anthropomorphic elements and principles, as they arise either from the world given to the five senses or from the categories inherent in the human mind.” [Arendt, 1977a]

It is not just that the senses cannot be trusted; neither can the categories of our understanding, which form the womb in which modern science was conceived. Indeed, Nature is not even thinkable. Arendt writes, “The trouble, in other words, is not that the modern physical universe cannot be visualized, for this is a matter of course under the assumption that Nature does not reveal itself to the human senses; the uneasiness begins when Nature turns out to be inconceivable, that is, unthinkable in terms of pure reasoning as well.” [Arendt, 1977b]

A vast number of scientists have not even taken Newton to heart, let alone come to terms with the strangeness of Nature to which Arendt is referring. Many appear to hope that a light will go on, Nature will become transparent, and simple explanations will emerge. Engaging the subtleties of epistemology will quickly rid one of such a puerile outlook. Indeed, as technology provides more detailed observation, Nature is becoming more unfathomable.

## 1.4 The Crisis of Complexity

With the advent of the Twenty-first Century, it has become apparent that the epistemology that began with Galileo, took shape with Isaac Newton, and came to fruition in the first half of the Twentieth Century with Niels Bohr, Hans Reichenbach, and others cannot support the desire to model complex systems. Across disciplines, scientists and engineers want to gain knowledge of large-scale systems composed of thousands of variables interacting nonlinearly and stochastically, often over long time periods. This massive complexity makes the standard modes of discovery and validation impossible.

The unverifiable character of many proposed systems is most troubling because the proliferation of such systems compromises the notion of scientific truth and threatens to erode the credibility of science. Consider medicine, which confronts huge complexity in physiological systems. In 2011, Janet Woodcock, Director of the Center for Drug Evaluation and Research at the FDA, estimated that as much as 75% of published biomarker associations are not replicable. She went on to comment, “This poses a huge challenge for industry in biomarker identification and diagnostics development.” [Ray, 2011] This dismal record could only have been produced by a widespread lack of attention to legitimate scientific method. A large number of studies involving immense complexity or

dimensionality have been undertaken in which there is no possibility of obtaining scientifically meaningful conclusions.

If, as Aristotle says, all men desire to know, and in the Twenty-first Century the desire is for knowledge of complex systems, then, in Windelband's words, scientists must address "the questions concerning the range and limit of man's knowing faculty," as these pertain to systems involving high dimensionality, complexity, and uncertainty.