Philosophy of Science and the Scientific Method

Emerging during the sixteenth seventeenth centuries, the Scientific Revolution eventually transformed the landscape of European intellectual and cultural life. Although what we might today call "scientific inquiry" dated to the ancient philosophers and was systemized in the writings of Aristotle, the Scientific Revolution ushered in new philosophies of how knowledge should or could be acquired, and how the natural world should be approached. This codification, or systematization, of knowledge acquisition and testing, under formation in this period, came to be called the "scientific method." The notion of a single scientific method is somewhat misleading, however, as debates were engaged (and continue to this day) over how knowledge could or should be acquired and tested.

Features of the Scientific Method Derived during the Period

Although the particular features of the scientific method were far from agreed upon by all natural philosophers, several methodological operations can be regarded as common. These features were rarely, if ever, used in this particular order. Thus, the following should be viewed as a theoretical sequence produced *a posteriori*, or after the fact.

1. *Identification of a problem*. The first step in the modern scientific method may be the identification of a problem to be addressed. Problems may consist of pre-existing data that requires explanation (for example the problems posed by planetary positions for Copernicus's circular rotations), or a question that requires an answer (for example, "Why is the sky blue?").

2. *Creating a hypothesis*. A hypothesis is a conditional statement that helps to frame the research methods and the approach for gaining knowledge with reference to a problem. An example of a hypothesis might be: "The orbits of the planets around the sun, including the Earth, are elliptical in nature." It is not clear that Kepler actually operated in this manner to develop his theory of the solar system, and it should also be remarked that not all natural philosophers accepted the centrality of hypotheses to the scientific method.

3. *Testing the hypothesis*. Upon creating a hypothesis, the next step might be to test it through observations or experimentation. Testing of the above hypothesis would involve predicting the positions of the planets based on an elliptical model and then checking these predictions against observations of the actual planetary positions.

4. *Reporting the results*. The next phase of scientific methodology generally involves the reporting of results. This is usually done in both natural and mathematical language.

5. *Analysis of the results and the framing of a theory*. The findings may then be analyzed and compared with the hypothesis to determine whether or not the latter can be (conditionally) accepted. An important method of analysis developed in the period was the use of mathematics for the ultimate expression and "proof" of phenomena.

Mathematics became the official language of scientific statements in this period, and has continued in this central role to this day.

Although leading figures of the Scientific Revolution contributed to the debates on the codification of the scientific method, what we now call the “philosophy of science” was most clearly represented by two major figures—Francis Bacon of England and Rene Descartes of France. A lawyer and statesman, Bacon proposed a rigorous theory of scientific inquiry that we now call “empiricism.” A philosopher and mathematician, Descartes formulated the theory that we now call “rationalism.” Empiricism and rationalism were two significant and effectively opposing epistemologies, or philosophies of knowledge, developed during the period.

Empiricists highlighted the importance of experience, broadly speaking, which included observation and experimentation, all with the aim of collecting data to support or negate knowledge claims. The method of empiricism is *induction*, or the gathering of particular elements of data in order to make more general statements. On the other hand, rationalists, while not excluding induction from their methodology, nevertheless held that true knowledge was only to be finally justified using a *deductive* method, or reasoning from given premises to necessary conclusions.

To this day, within the philosophy of science and ranging beyond it into other studies of science, debates over epistemology continue. These debates include various forms of empiricism and rationalism but also many other epistemological positions. In contemporary scientific communities, both inductive and deductive methods are used for the acquisition and testing of knowledge statements, and mathematics is employed to both express and test hypotheses and theories.

Empiricism and the Baconian Method

Empiricism, as it developed over the course of the seventeenth century, stressed the central role of experience—both observation and experimentation—for the acquisition, testing, and conditional confirmation of data, and thus, of theoretical statements. Induction, or moving from particular instances to general statements, is the method of empiricism. While Francis Bacon (1561–1626) argued that induction was necessary for science, hypothetical statements could never be proven by the inductive method as Bacon formulated it (in what has been called the Baconian Method). Rather, anticipating the twentieth-century philosopher of science Karl Popper by three and a half centuries, Bacon suggested that induction could only serve to falsify and could never absolutely prove a knowledge claim. One piece of negating data was sufficient to overturn a hypothesis or theory.

Empiricism as propounded by Bacon was not adopted by natural philosophers in the form that he had suggested in his major works, *The Advancement of Learning* (1605) and *Preparative toward a Natural and Experimental History* (1620). Rather, most natural philosophers employed a combination of inductive methods, deductive reasoning, and mathematical proofs. It is not clear that they used these in any particular order, but they surely did not follow the somewhat elaborate cyclical processes of the Baconian Method. Nevertheless, while Bacon’s codification of method was not wholly accepted, it served as a major expression of the Scientific Revolution and came to epitomize the inductive aspect of the movement.

Rationalism and the Philosophical Method

One of the most important figures of the Scientific Revolution was the philosopher, natural philosopher, and mathematician René Descartes (1596–1650). Descartes's major works include *Discourse on Method* (1637), *Meditations on First Philosophy* (1641), and *Principles of Philosophy* (1644). Descartes established a method for scientific investigation that came to be known as *rationalism*. While accepting induction as a necessary part of knowledge acquisition, Descartes propounded that knowledge could only be validated vis-à-vis deductive reasoning, or the derivation of necessary conclusions from given premises. Further, the expression of said conclusions were best formulated in mathematical terms.

The scientific method of Descartes might involve induction in sciences that necessarily relied on observation, such as astronomy and physics. But finally, the results of a science must come from deductive reasoning applied to data provided by induction. Further, these findings would be best described and proofed in mathematical terms for precision.

Gottfried Wilhelm Leibniz (1646–1716), along with Descartes, was another important rationalist during the seventeenth century. Leibniz also made advancements in the fields of physics and technology. He was a prodigious writer, and produced publications in several areas of study, including politics, theology, history, law, and philosophy. His writings on rationalism anticipated modern logic and analytic philosophy. Leibniz argued that scientific or philosophical conclusions could not be reached through empirical observation alone, but had to be based on the application of reason to sense data, prior scientific theories, or definitions.

Cartesian Dualism

In his metaphysical writings, Descartes began with the starting point of profound doubt about existence, including his own. He then posited that the doubting self demonstrates the existence of the thinking self. This is the famous *cogito ergo sum* ("I think, therefore, I am") of Cartesian metaphysics. This doubt remained in effect with reference to the body, given a body that does not think and therefore cannot confirm its own existence, as had the mind. Descartes then considered the body as a material extension, like other objects in the world, and thus, of a different substance from the mind. He thus posited that the mind and body are two distinct substances, inaugurating a perennial problem for modern philosophy, known as the mind-body problem.

After Descartes distinguished the mind and the body, he remained puzzled about the relationship between the two entities. If the body was extension and the mind was non-extension, how did they interact? The question vexed not only Descartes himself, but his philosophical followers as well, who developed numerous theories for the interaction, including the idea (put forth by some) that God mediated the relationship.

Descartes and Mechanical Philosophy

If it followed from Descartes's metaphysics that the physical world was of a different substance than the mind, then the former might be described in strictly mechanical terms. The substances other than mind were machines that operated independently. Descartes introduced the analogy of the watch and the watchmaker to describe the universe itself. The universe acts as an automatic machine, like a watch. If the universe is like a watch, then someone like a watchmaker (God) must have created it and set it into motion. Said motion was sufficient for the continual operation of the universe from the origin onward. Descartes and his followers thus posited the conservation of motion, the idea that God had supplied a specific amount of motion to the universe that has been consistently conserved throughout the universe ever since.

Descartes did not believe in space as an empty container filled by objects, but rather, he believed that space itself was dependent on material extension. That is, there was no empty space, only the space created by objects themselves. Thus, there existed no void or vacuum.

Descartes's mechanical philosophy, while deplored by some, has been important to modern science, which has sought to break down complex material phenomena to their constituent parts. This method is sometimes referred to as "scientific reductionism."

Summary:

- During the sixteenth and seventeenth centuries, the Scientific Revolution gradually transformed the landscape of European intellectual and cultural life, and changed the approach taken to the natural world by natural philosophers and what we now call "philosophers of science."
- New methods were developed to study nature, and combined, these methods have come to be called the "scientific method." The scientific method involves the statement of a problem, the development of hypotheses, the testing of hypotheses, the reporting and analysis of results, and the proposal of theories.
- Two major approaches to natural philosophy, known as empiricism and rationalism, emerged during the period. Empiricism involved the method of inductive reasoning, which was applied on experience, including observation and experimentation. Rationalism, while not discounting induction entirely, maintained that deductive reasoning was the means to establish true knowledge. *Deduction* is reasoning from given premises to necessary conclusions.
- Francis Bacon was a major proponent of empiricism and precipitated its widespread use in England. Rene Descartes was one of the foremost advocates of rationalism.
- Descartes also introduced the mind-body problem in philosophy, as well as a mechanistic view of the universe, which has been applied more or less by natural philosophers and scientists ever since.