Philosophy of Science History

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For centuries, the history of the philosophy of science has been important for plotting the course of human endeavor.

Until the 18th and 19th centuries, there was no real distinction between scientist and philosopher, and many of the great scientist-philosophers of antiquity were also theologians.

Science gave philosophy a way of empirically testing theories and concepts, whilst philosophy has helped to develop the scientific method used today.

Philosophy also dictates what areas science can and cannot test, delineating the boundary between physical and metaphysical questions. These boundaries and the rules governing research have developed over the centuries, and philosophy and science are intertwined.

The history of the philosophy of science shows the development of the underlying methodology and foundations of the scientific process, and shaped science, as we know it today.

Science could not exist without philosophy, and even the experiments underway in the Large Hadron Collider owe homage to Aristotle, Bacon and Kuhn.

Beginnings - Aristotle's Empiricism vs Plato's Forms

The history of the philosophy of science, certainly in the Western world, begins with the philosophers of Ancient Greece.

Whilst many other philosophers contributed to the very beginning of the scientific process, the genesis of science began with the contrast between Platonism and Aristotleism.

Plato (428/427 BC[a [1]] - 348/347 BC) had the archetypal Greek belief, that humanity was born with an innate knowledge of everything, and that learning was a process of unlocking the memories.

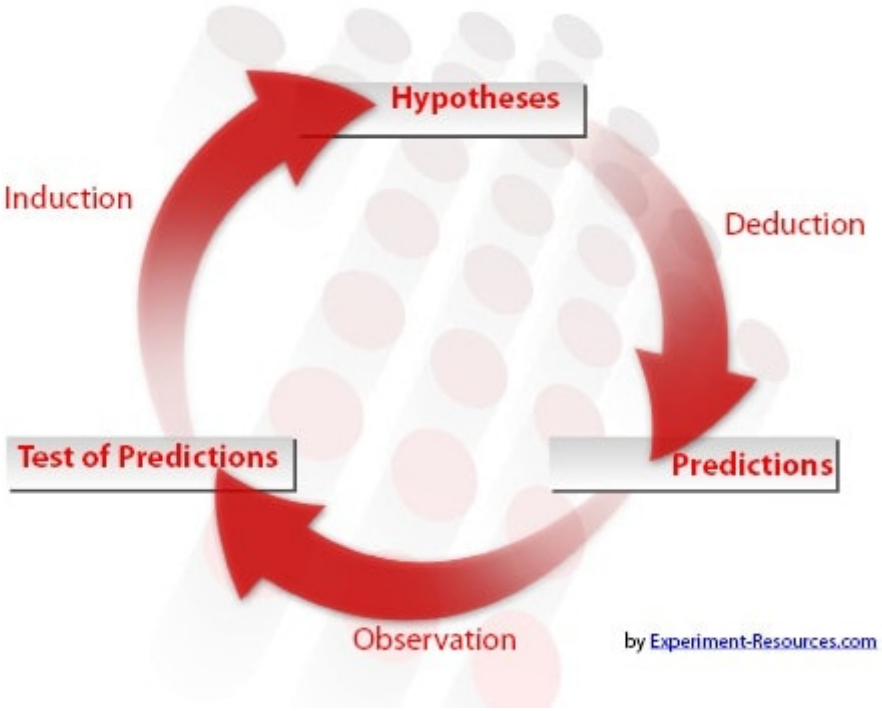
His argument was that everything had a perfect potential abstract form, and that any knowledge gained through observation and experiment was filtered by the senses. Empirical knowledge [2], according to Plato, was mere opinion. Therefore, he reasoned, that pure knowledge could be advanced by deduction [3] alone.

Aristotle (384 - 322 BCE), by contrast, believed that Plato had everything the wrong way around, and that knowledge could only be gained by comparing it with what was already known and perceived.

For example, Plato's famous idealized Republic required a perfect Philosopher King to rule it, with wisdom and benevolence. He argued that because such a perfect human being could exist, therefore such a king would be possible to find.

Aristotle countered this concept by stating that because he had never seen or heard of such a human in recorded history, then it was an impossible concept. He believed that inductive reasoning [4] was required to establish some basic premises before scientific demonstrations.

Between the two schools of thought, the idea of deductive reasoning [3] emerged, which has remained a cornerstone of the scientific method. This idea remained a common theme throughout the history of the philosophy of science [5].



Aristotle used the term 'first principles' to illustrate his belief that gathering knowledge was a process of gaining experience, building upon what is already known to be true.

Even in the modern world, each scientific field has its own unique first principles upon which research is built, postulates that cannot be deduced and act as a foundation. Aristotle still used deduction for building up his view of the universe, believing that every phenomenon could be explained through reason, as long as the first principles were sound.

The split is why Aristotle is referred to as the Father of Science and Plato as the Father of Philosophy, with Aristotle credited as the initiator of the scientific method [6].

Throughout the history of the philosophy of science has, science has built slowly knowledge upon what is already known, measuring phenomena and trying to uncover the rules governing them. In this way, humanity undergoes a gradual accumulation of knowledge.

Aristotle believed in observational science [7], and performed many measurements [8] and observations, including describing the hydrological cycle and undertaking taxonomic work, separating many animals into families according to shared characteristics.

This is not to say that Plato has no place in science; for example, physicists generating beautiful and elegant mathematical theories to explain the cosmos are far closer to Plato than Aristotle. They generate theories and empirical scientists [9] follow behind, attempting to prove or disprove them.

Beyond the Greeks

The Romans were the next to take the burgeoning science, developing the scientific method [10] of the Greeks.

The Romans, as their architecture and engineering shows, were far more interested in the empirical applied side of science, using mathematics and practical knowledge to create some great technological advances. They did not, however, have too much of a contribution to the philosophical side, simply building upon the methods used by Aristotle and Ptolemy.

Their contribution to practical science was immense, but they had a minimal effect upon the history of the philosophy of science, leaving the field largely devoid of momentum for hundreds of years.

The Islamic Contribution to the History of the Philosophy of Science

The Islamic world took up the baton and preserved the philosophical knowledge of the Ancient Greek philosophers, adding to it techniques and philosophies learned from the Vedics in India.

Whilst there were many Islamic scholars generating and developing ideas, there were a few whose names became enshrined within the history of the philosophy of science.

The great scientist and polymath, Ibn-Sina (980 - 1037), also known as Avicenna, built upon the scientific processes postulated by Aristotle, but was one of the first philosophers to bring

the metaphysical issue of God into the picture. He believed that general and universal questions were the first stage, and experiments [11] uncovered the truth [12].

Ibn al-Haytham is commonly regarded as the first scholar to define the modern scientific method, laying down the steps of the scientific process [13] and attempting to unite the induction [4] of predictions and generalizations [14] with the deduction [3] of experiments.

He also pointed out that scientists should not regard themselves as infallible [15], and that they should be open to criticism.

The other great contributor to the history of the philosophy of science during the Islamic Golden Age was Al-Biruni, who was the first philosopher to understand the importance of errors [16] within scientific experimentation. He understood that any experiment would contain small and random fluctuations, and that repeated experimentation was the only way to neutralize these inaccuracies.

The Renaissance

As the Islamic 'Houses of Learning' became less influential, and the Muslim stronghold of Al-Andalus, in Spain, declined, much of this knowledge was taken to Europe, where it formed the basis of the first Renaissance.

Here, during a time of great philosophical and theological discovery, the collaboration of science and religion continued, in an attempt to understand the nature of reality.

Roger Grosseteste and Roger Bacon, in the 13th century, further refined the scientific method, but the history of the philosophy of science began to take shape with the meticulous and innovative work of Francis Bacon.

Francis Bacon

In 1620, the great philosopher Francis Bacon (1561 - 1626) made great leaps in determining the course of modern science by making a great leap in the process of scientific reasoning [17] and method [18].

He believed that Aristotle's work, whilst broadly true, needed to be adapted to fit the reality of science, and he set out a new philosophy and scientific method to address the issues.

His main criticism of Aristotle was that deduction [3] from first principles was impossible in reality - the Greeks had a belief in the perfection of the cosmos, and so deduction could find answers to fit their view of the universe.

In the many centuries since, the view of the world had changed, and Bacon believed that the universe was much too complicated to explain by deduction alone. He redesigned the scientific method to utilize a largely induction based philosophy, where a series of observations could be applied to the universe as a whole.

Bacon was the first philosopher in the history of the philosophy of science to realize that pure Aristotelian methods taught scientists nothing about the universe, finding answers for observed phenomena, but lacking the great leaps made by Platonist thought.

He realized that whilst deduction allowed the application of a general rule to a particular and specific circumstance, induction was needed to allow observations of small or specific circumstances to a larger population, or the wider universe.

Cleverly, he also stated that induction did need to be used with caution, and that to try to explain the universe by inductive reasoning [4] alone was inherently dangerous.

Francis Bacon believed that pure empiricists gathered important information, but had little idea how to use their knowledge or advance science. There was no goal or ultimate aim to the patient gathering of data.

Rationalists, on the other hand, made great leaps and generated ideas but, without careful measurement, there was no method for determining which were correct, or how accurate any theory was. This process is still apparent in modern science.

Theoretical physicists like Einstein, Hawking and Feynman generate beautiful mathematical formulas and models to explain the unknown areas of quantum physics and cosmology. However, they understand that actual experimental and empirical evidence [2] always takes precedence, potentially leading to the adjustment or abandonment of one of these theories, if proved incorrect.

The other major addition to the scientific method made by Bacon, possibly his biggest contribution to the history of the philosophy of science, was the idea of experimental science [19], the basis of induction. He believed research could be used to test the validity [20] of real world observations, with inductive postulations made to generalize [14] the findings to the population as a whole.

He also developed the practice that he called the Instance of the Fingerpost,' where he proposed that an experiment should be designed around two discrete hypotheses [21]; the researcher should aim to find in favor of one and refute the other.

Whilst there was no split between science and philosophy during this Early Modern period, Bacon laid the foundation stone for the divergence of the two disciplines. As a side effect, his work also planted the seed of the first divisions between science and theology, a shift in the focus of the history of the philosophy of science.

Previously, science was very much seen as attempting to explain the perfection of creation, with God as the initial first principle, but science began to shift towards different principles.

Descartes (1596 - 1650) famously attempted to explain the cosmos and epistemology by deduction from Aristotelian first principles, based around the divine, but, at the end of his life, even he realized that the cosmos was simply too complex to be derived from first principles alone.

The Galilean Contribution to the History of the Philosophy of Science

Galileo [22] (1564 - 1642), whilst most famous as a scientist, was also a highly respected philosopher. He took the Baconian views of science to another level, further emphasizing the need for both empiricism and rationalist thinking.

Whilst he was a great proponent of carefully designed experiments, he believed that, in physics especially, mathematics and geometry were essential to idealize concepts. This was the first example of using modeling as a foundation of the scientific method.

Deduction, as shown by Bacon and later admitted by Descartes, could not explain the complexities of the universe, and so a simplified and idealized model would give the scientist another tool of discovery.

Empiricists argued that his idealized concepts could not be adapted to the real universe, but the idea of mixing mathematical theory with empirical 'proof' [2] was set.

The Definition of Science

The 18th century history of the philosophy of science began to see the first real development in a specific scientific method that would distinguish it from non-sciences.

It is difficult, even now, to give a definition of science [23], and it is perhaps more fruitful to define what it is not, a process started by the philosopher Christian Huygens (1629 - 1695). He argued that science and mathematics were actually different fields, and could not be treated the same way.

The distinction he made between the two was the idea of proof. He stated that mathematics and geometry could prove something beyond doubt, whereas science can never prove something emphatically; merely give a probability that a certain finding is true.

Huygens was the first proponent of the hypothetico-deductive method [24], where a scientist proposes a hypothesis [21] and then tries to deduce the probability that it is correct, through observational and empirical observation.

This built upon the work of Bacon, but also developed the idea that scientists could approach the truth by constantly refining experiments and increasing the probability of their hypothesis being correct. This period saw the first divergence of the history of the philosophy of science from metaphysical philosophy.

At this time, Newton also entered the fray, initially possessing a divergent view from Huygens, possibly because of his differing viewpoint as a mathematician. He did not advocate hypotheses, believing that any research using a hypothesis could not be scientific [18].

Newton argued that any scientific undertaking should begin with analysis, where a scholar performed observations and experiments and then made conclusions [25] depending upon he results [26].

His viewpoint was christened synthesis, where these inductive conclusions should be applied to the universe as a whole, to build up a model of the universe.

Newton was also an example of a scientist/philosopher who believed that the almighty was behind every process in the universe, and that it was too complex to be explained by physics alone. He saw his works as uncovering the laws of the universe behind creation.

Huygens and Newton did both agree that science could not give definite answers, only a probability that something was correct, because humanity could not possibly understand or comprehend the complexities lying behind the universe.

The other main contributor of this period, to the history of the philosophy of science, was David Hume (1711-1776), who first highlighted the problem of induction, in that any inductively derived 'proof' could be undone by a single contrary observation.

This idea was elaborated upon by the Twentieth century philosopher Hempel, in his Raven Paradox [27].

The History of the Philosophy of Science in the Nineteenth Century

During the nineteenth century, the history of the philosophy of science took on a form recognizable to modern science, and the debate took a new turn.

Philosophers were now satisfied that science needed to be largely empirical, albeit with a deductive aspect for generating new ideas and theories.

The debate now addressed the link between science and theology [28], with the growing schism [29] started during the Galileo debate beginning to widen.

The Catholic Church felt that science was undermining the teachings of religious scripture, and philosophers began to address this issue.

John Herschel (1792 - 1871) published a groundbreaking book, A Preliminary Discourse on the Study of Natural Philosophy, in 1830, which addressed this very issue, and attempted to breach the growing divide, possibly realizing the damage that this widening rift could cause.

Herschel argued that science was not questioning religious beliefs, such as the existence of God or the immortality of the soul. He stated that rather than attempting to doubt the existence of God, science should be used as a tool to undermine the burgeoning trend of atheism.

Herschel's other contribution to the history of the philosophy of science was his refinement of the structure of the scientific process, building upon the earlier work of Bacon and Huygens. Herschel believed that science should use inductive processes to arrive at laws, in tandem with forming a hypothesis and attempting to test it through rigorous and repeated experimentation.

Comparing the results with known facts strengthened the foundations of the hypothetico deductive method [24]. He also made the first attempt to address the fact that it was becoming increasingly difficult to speak of science as a united body, with science starting to separate

into many different fields and disciplines.

For some areas, such as physics, it was possible to combine induction and the hypothetico-deductive methods, but for many types of experimentation, this was not always possible.

The next great contributor of this period to the history of the philosophy of science is Whewell (1794 - 1866), a philosopher who attempted to update the philosophy of Bacon.

Importantly, he believed that scientific philosophers needed to not only try to develop philosophical ideas, but that they should look back at how science had developed.

He postulated that philosophers needed to take a historical view, looking at the processes that scientists already used rather than merely attempting to tell them what they should do. With the increasing preponderance of scientists who were not necessarily philosophers, this became an increasingly important development in modern science.

Whewell believed that the inductive processes could lead to absolute proof and that science could generate unbreakable truth. Whilst this view is not used by modern scientists, who understand that scientists can only work with probabilities, it is important to remember that most of these philosophers and scientists believed firmly in God. The history of the philosophy of science shows that most philosophers also believed in God, and that the laws of the universe had some perfection that empiricism and rationalism could uncover.

The British philosopher, John Stuart Mill (1806 - 1873), vehemently disagreed with Whewell, believing that science could not use induction [4] to arrive at absolute truth [12]. He stipulated that however many times a hypothesis was found to be proved by the empirical evidence, this could not guarantee that this would always be the case and so science could only ever be possibility, as believed by Herschel and Newton.

The other great contribution to the history of the philosophy of science made by Mill is the Laws of Agreement, also known as Mill's Methods, used to determine a causal effect in any relationship, by a process of elimination.

The Victorian Age and the Twentieth Century

This period of the history of the philosophy of science is where the subject became almost completely disentangled from theology.

Napoleon's secular ideals caused a separation and, instead of trying to reconcile science with religion [28], philosophers concentrated upon refining the basic underlying tenets of science.

Victorian philosophers attempted to discern what constitutes science, and set down the protocols of the scientific method [13].

Science, inspired by Darwin [30] and J.J. Thomson [31] began to unveil new discoveries at a breakneck pace, burgeoned by the second industrial revolution. This period also saw the first real division between the philosophies governing the various fields of science.

For example, physicists required a completely different approach to naturalists.

Pierre Duhem, 1861-1916, was the first philosopher to divide physics from the other fields,

arguing that it was a very different beast from the other sciences. Physics, more than any other field, relies heavily upon theory and maths, and so needs different structures than the previously accepted Baconian and Newtonian view of things.

He advocated holism, believing that the universe cannot be divided into discrete and individual hypotheses, because it is interlinked and intertwined, needing this united view. His contribution to the history of the philosophy of science was mainly in the field of physics, but his ideas had some wider appeal.

Duhem was a devout Catholic, and attempted to make a distinction between science and religion [29], arguing that the two fields could not answer the same questions. He strongly believed that physics was only able to systematically uncover structures and processes, without questioning the very nature of reality.

Metaphysical questions were only answerable by metaphysics and theology. He did stipulate, however, that a good theologian should understand the physical aspects to be able to enquire into the metaphysical structure of the universe.

This statement was a clear attempt to show the church that science was essential and did not harm Christianity. He also produced histories documenting his firm belief that the Church had been the driving force behind science.

The great scientist, philosopher and mathematician, Poincare (1854-1912), began the twentieth century history of the philosophy of science. He questioned the very nature of scientific hypotheses [21], arguing that there were many different types.

Poincare also brought the idea of 'convention' to the history of the philosophy of science, believing that scientists often used the most convenient methods to describe the universe. He used the example of geometry, where Euclidian geometry was used to describe space, even though it was not the only correct method.

Poincare also argued that there were many types of hypothesis, some fulfilling the scientific ideal of empiricism, testing [32] and generalization [14], whereas others were incorporated into the building blocks of scientific theory and were always the last to be abandoned. His famous 'indifferent hypotheses' possessed an auxiliary role in building theories, but were not vastly important. He used the example of the hypothesis that unseen atoms exist.

Whilst each discipline had its own burgeoning underlying philosophy, there was still a consensus upon the basic structures and forms defining the entire nature of science, whilst laying out protocols for the scientific method.

Karl Popper

One of the biggest names in the history of the philosophy of science, Karl Popper (1902 - 1994) tried to delineate the boundary between science and non-science [33], arguing that metaphysics was non-observational, and therefore could not be science.

He championed the idea of falsification [15], where a hypothesis must be potentially disprovable for it to be regarded as scientific. He believed that theological, epistemological and metaphysical questions were not falsifiable, and therefore not scientific. Popper firmly believed that such concepts should not be given credence by science.

One of the major problems with Popper's analysis is that he tries to impose a strict boundary upon a grey and fuzzy delineation.

Many fields, such as social science, anthropology and even psychology are not sciences according to his strict definition. These fields rely upon case studies, which, by definition, are non-falsifiable.

Popper believed that how the hypothesis was derived was an unimportant part of the scientific method [18]. He believed that the only important issue was that the hypothesis was testable [34] and falsifiable [15]. He felt that instead of attempting to prove theories, scientists should instead try to falsify them, a belief still held by many scientists and fields.

The idea of falsifiability earned Popper a place amongst the great philosophers apparent throughout the history of the philosophy of science.

The main criticism of Popper's idea was that he did not actually look at the reality of how scientists worked, and that the actual scientific processes did concentrate upon obtaining proof rather than rejection.

Scientists rarely abandon their theory if it is falsified, usually clinging to it and modifying it. One of Popper's students, Lakatos, attempted to resurrect the idea by stratifying the idea. He postulated that there was a 'hardcore' scientific theory that was taken as given, and needed no falsification.

A hierarchy of strata provided a layer of protection to the central theory - these hypotheses could fail and be rejected, but not the hardcore itself.

Only when the entire research program shuddered to a halt and it failed to corroborate predictions would the hardcore be abandoned, in a similar way to Kuhn's idea of paradigms [35] and paradigm shifts [36].

Hempel

Hempel (1905 - 1997) was one of the most influential philosophers of the twentieth century history of the philosophy of science, known especially for his criticism of the inductive method [4], known as the Raven Paradox [27].

He built upon the work of Hume, and realized that any scientific finding relying upon induction could only give a probability of an answer being correct, not a black or white yes or no. He reaffirmed the belief that science required a strong hypothesis predicting certain results, derived at through observation, and testing measured results against the predictions.

Thomas Kuhn

The 1960's saw a complete change in view, with the publication of Thomas Kuhn's work, The

Structure of Scientific Revolutions, in 1962. This work is commonly regarded as the most influential text in the history of the philosophy of science.

This blew away the logical positivism and concerns about the scientific method, with Kuhn feeling that the philosophy of science had become bogged down in the minutiae.

Once again, he brought up the idea that the philosophy of science had to look at the history and evolution of science. He did not subscribe to the Aristotelian notion of science as cumulative; instead, Kuhn's greatest contribution to the philosophy of science was the idea of paradigms and paradigm shifts.

Feyerabend

Feyerabend (1924 - 1994) believed that the scientific method was an artificial construct, and restricted the free thought of ideas.

He suggested that very few scientists actually followed any such method, and took a very open view of science, implying that there can never be a strict definition of what constitutes science.

This definition may have some credibility, because it is not always apparent what disciplines constitute science. For example, fields such as social science, economics, archaeology and even psychology fall somewhere in-between science and non - science.

Feyerabend was a student of Popper, but believed in 'Scientific anarchy,' a principle of anything goes, and that scientists would develop a good method that would work for their particular research field.

His landmark book, Against Method, in 1978, coined the phrase epistemological anarchy. Despite sharing completely different philosophies, Feyerabend and Lakatos were great friends, and both had an effect upon the history of the philosophy of science.

Lakatos' idea is often regarded as an ideal, whereas Feyerabend's theory is possibly closer to how scientists actually work, in a type of organized chaos.

The Future of the History of the Philosophy of Science

The modern scientific method is built upon the work of all of these great philosophers. Whilst a scientist may believe that they are following the methods of Kuhn or Popper, there is also a tribute to Aristotle, Avicenna or Bacon in their work.

Ironically, many scientists have not heard of any of these philosophers and blindly use the scientific method, without realizing how it grew and developed.

In terms of the direction of the philosophy of science, the most recent philosophers concentrate upon trying to define the very nature of science, as boundaries between the various fields blur and the amount of poorly constructed pseudoscience [33] and junk science [37] grows exponentially.

The history of the philosophy of science is added to daily, and the next revolution in scientific thought may be just around the corner.

Links
[1] http://en.wikipedia.org/wiki/Plato#endnote_Anone
[2] https://explorable.com/empirical-evidence
[3] https://explorable.com/deductive-reasoning
[4] https://explorable.com/inductive-reasoning
[5] http://www.angelfire.com/mn2/tisthammerw/science
[6] https://explorable.com/who-invented-the-scientific-method
[7] https://explorable.com/observational-study
[8] https://explorable.com/scientific-measurements
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