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History of the Scientific Method

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The history of the scientific method is a fascinating and long one, covering thousands of years of history.

The development of the scientific method involves some of the most enlightened cultures in history, as well as some great scientists, philosophers and theologians.

As well as looking at the changes in the philosophy underpinning scientific discovery, we cannot forget some of the tools that make science possible, including library indexing and peer reviewed scientific journals.

From the observations of the Ancient Greeks and Zoroastrians, to the Hubble Space Telescope, the history of the scientific method underlies the development of all science and technology, and we owe our modern technology to some great and innovative minds.

It is a cliché, but we really are standing on the shoulders of giants.

The Beginning of the History of the Scientific Method

At the time when the two great cultures of Ancient Greece and Ancient Persia were seeking dominance and fighting wars at Thermopylae and Platea, it is easy to forget that these two cultures also had a deep mutual respect, and traded ideas and knowledge.

Unsurprisingly, and fittingly, our history of the scientific method will start here, although we must point out that knowledge knows no boundaries. Whilst Babylonian, Indian and Egyptian astronomers, physicians and mathematicians developed some empirical ideas, the Greeks were the first to develop what we recognize as the scientific method.

Initially, the Ancient Greek philosophers did not believe in empiricism, and saw measurements [1], such as geometry, as the domain of craftsmen and artisans. Philosophers, such as Plato, believed that all knowledge could be obtained through pure reasoning [2], and that there was no need to actually go out and measure anything.

This does sound strange to us, but there were some good reasons for this; however, discussing Platonism would take an entire website in itself, so the Stanford Encyclopedia of Philosophy [3] is a great source for those interested in learning more.

Aristotle, regarded as the father of science, was the first to realize the importance of empirical measurement, believing that knowledge could only be gained by building upon what is already known.

Measurement [1] and observation [4], the foundations upon which science is built, were Aristotle's contribution. He proposed the idea of induction [5] as a tool for gaining knowledge, and understood that abstract thought and reasoning [2] must be supported by real world findings.

He applied his methods to almost everything, from poetry and politics to astronomy and natural history. His 'proto-scientific method' involved making meticulous observations about everything.

To study the natural world, he scrutinized over 500 species and, in a treatise about politics, he studied the constitutions of 158 Greek city-states, a mammoth undertaking and a direct contrast to Plato, whose idea of a perfect republic was based upon his idea of perfection rather than upon existing systems.

Aristotle's methods can be summed up as follows.

1. Study what others have written about the subject.
2. Look for the general consensus about the subject
3. Perform a systematic study of everything even partially related to the topic.

This is the first sign of a scientific method, with literature reviews [6], consensus and measurement [1]. The Greeks were the first to subdivide and name branches of science in a recognizable way, including physics, biology, politics, zoology and, of course, poetry!

In about 200 BC, the famous library at Alexandria saw the first introduction of library cataloguing, essential for any scholar conducting a peer review [7].

See also:
Aristotle's Zoology

[8]
Alchemy and the Philosopher's Stone [9]
Ancient Medicine [10]
Ancient Physics [11]
Aristotle's Psychology [12]

The Muslim Influence On the History of the Scientific Method

The early Islamic ages were a golden age for knowledge, and the history of the scientific method must pay a great deal of respect to some of the brilliant Muslim philosophers of Baghdad and Al-Andalus.

They preserved the knowledge of the Ancient Greeks, including Aristotle, but also added to it, and were the catalyst for the formation of a scientific method recognizable to modern scientists and philosophers.

The first, and possibly greatest Islamic scholar, was **Ibn al-Haytham**, best known for his wonderful work on light and vision, called 'The Book of Optics.' He developed a scientific method very similar to our own:

1. State an explicit problem [13], based upon observation and experimentation [14].
2. Test or criticize a hypothesis [15] through experimentation [14].
3. Interpret the data [16] and come to a conclusion [17], ideally using mathematics.
4. Publish the findings

Ibn al-Haytham, brilliantly, understood that controlled [18] and systematic experimentation [14] and measurement [1] were essential to discovering new knowledge, built upon existing knowledge.

His other additions were the idea that science is a quest for ultimate truth and that one of the only ways to reach that goal was through skepticism and questioning everything.

Other Muslim scholars further contributed to this scientific method [19], refining it and preserving it. **Al-Biruni** understood that measuring instruments and human observers [20] were prone to error [21] and bias [22], so proposed that experiments [23] needed replication [24], many times, before a 'common sense' average was possible.

Al-Rahwi (851 - 934) was the first scholar to use a recognizable peer review process [7].

In his book, Ethics of the Physician, he developed peer review process to ensure that physicians documented their procedures and lay them open for scrutiny. Other physicians would review the processes and make a decision in cases of suspected malpractice.

Abu J?bir, known as Geber (721 - 815), an Islamic scientist often referred to as the father of chemistry, was the first scholar to introduce controlled experiments [14], and dragged alchemy away from the world of superstition into one of empirical measurement.

Ibn Sina (Avicenna), one of the titans in the history of science, proposed that there were two ways of arriving at the first principles of science, through induction [5] and experimentation [14].

Only through these methods could the first principles needed for deduction [25] be discovered

Other Islamic scholars contributed the idea of consensus in science as a means of filtering out fringe science and allowing open reviews. These contributions to the scientific method, and to the tools required to follow them, made this into an Islamic Golden Age of science.

However, with the decline in the Islamic Houses of Knowledge, the history of the scientific method passed into Europe and the Renaissance.

See also:
Islamic Scholars and Biology [26]
Islamic Ophthalmology [27]
Islamic Alchemy [28]
Islamic Medicine [29]
Islamic Psychology [30]

The Renaissance and the History of the Scientific Method

The renaissance was another turning point for the scientific method, where European scholars took the knowledge of the Greeks and the Muslims, and added to it.

Again, it is impossible to list every single scholar, but there are some names that stand out in any narration of the history of the scientific method.

Roger Bacon (1214 - 1294) was one of the earliest European scholars to refine the scientific methods.

He developed the idea of making observations, hypothesizing [31] and then experimenting [23] to test the hypothesis [15]. In addition, he documented his experiments meticulously so that other scientists could repeat [24] his experiments and verify his results.

Francis Bacon (1561 - 1626), was one of the greatest movers behind the development of the scientific method.

He reiterated the importance of induction [5] as part of the scientific method, believing that all scientific discovery should proceed through a process of observation, experimentation, analysis and inductive reasoning [5], to apply the findings to the universe as a whole.

He also believed that experimental evidence could be used to eliminate conflicting theories and move closer to the truth [32].

The great philosopher and mathematician Descartes (1596 - 1650), by contrast, firmly believed that the universe was like a huge machine. Therefore, if you understood the basic laws of the universe, you could deduce [25] how anything will act.

Galileo (1564 - 1642) is generally remembered for his famous gravity experiment, but he also contributed greatly to the scientific method. In fact, physicists such as Einstein and Hawking proclaimed him as the father of modern science.

Certainly, his methodology shaped physics and other fields relying upon mathematical theorems. His methods, which were the origins of the split between science and religion [33], included a standardization of measurements allowing experimental results [34] to be checked anywhere.

Galileo [35] used a heavily inductive scientific method because he understood that no empirical evidence could perfectly match theoretical predictions.

He believed that it would be impossible for an experimenter to take into account every single variable [36]. In the world of physics, for example, Galileo theorized that mass had no effect upon gravitational acceleration.

No experiment could ever hope to measure this perfectly, because of air resistance, friction and inaccuracies with timing devices and methods.

However, repetition by independent researchers could build up a body of evidence that allowed an extrapolation [37] to the general theory to be made.

This period, covering the sixteenth and seventeenth centuries, is often referred to as the Scientific Revolution, and threw out some more elements required for the scientific method.

The Royal Society was set up, in 1660, providing a panel of experts to advise and guide, as well as oversee the spreading of information, establishing a journal to aid this process.

This body ruled that experimental evidence always supersedes theoretical evidence, one of the foundations of modern science.

Naturally, the installing of a panel of experts and the founding of journals also led to genuine peer review [7], a process adapted from the Muslim practices.

The Scientific Revolution reached its zenith with Isaac Newton, who made perhaps the greatest contribution to the history of the scientific method.

He was the first to really understand that the scientific method needed both deduction [25] and induction [5].

The History of the Scientific Method and the Twentieth Century

The scientific method, as developed by Bacon and Newton, continued to be the main driver of scientific discovery for three centuries.

However, their ideas were based at a time where most scientists were polymaths, working in many scientific fields and also understanding philosophy and theology.

Science gradually began to move away from those areas and developed into a separate area of study. In addition, the increasing complexity of science and the increase in both breadth and depth made it impossible for a scholar to work across disciplines.

As science began to split into chemistry, physics, biology and the proto-scientific psychology, the history of the scientific method [38] became much more complex.

Physicists could remain true to the Baconian inductive methods, but psychologists began to find this increasingly difficult when dealing with the extreme variability of the human mind and man-made constructs.

As a result, the Twentieth Century saw a huge change in the scientific method as philosophers of science [39] attempted to address this. Probably the most famous of these was Karl Popper, who understood the limitations of the old scientific ways.

Popper's Contribution to the History of the Scientific Method

Documenting Karl Popper's contribution to the history of the scientific method took up an entire book, so it is only possible to cover the main points.

Popper's main point of attack was establishing that science was not infallible [40]. Well-established scientific disciplines often followed the wrong path and generated incorrect theories.

On the other hand, pseudoscience [41], as psychology and social sciences were at the start of the Twentieth Century, often found the right answer, even if they could not follow the scientific method perfectly.

This led him to question the very definition of science [42] itself, and so he tried to develop a scientific method that addressed the limitations. Previously, the definition between science and non-science revolved around empirical techniques and the inductive method [5].

This definition did not address the development of new disciplines, and did not properly unite the increasing complexity of theoretical science with practical science.

For example, why were Einstein's theories regarded as scientific, whilst a psychologist's theories were regarded as pseudoscientific [41]?

Popper postulated that science advances through a process of "conjecture and refutations;" that a theoretical scientist would develop a theory and an empirical scientist would attempt to test it to destruction. For this to happen, the theory had to be 'falsifiable [40]'.

If the theory could not be properly tested by science, then it could not be scientific.

For example, physics theory was open to empirical testing, and many scientists developed ways to empirically test relativity; therefore, it could be falsified [40] and the scientific method applied.

Until the time of Pavlov [43] and Skinner [44], psychological theories were extremely difficult to falsify because there were few quantitative methods [45] available.

Because of this, the discipline was regarded as more pseudoscientific [41]. Even now, staunch Popperians cast doubt upon the falsifiability and therefore usefulness of psychology and the social sciences, although this is driven by a little scientific snobbery!

Kuhn's Contribution to the History of the Scientific Method

Thomas Kuhn was the next of the Twentieth Century to add to the history of the scientific method, by introducing the idea of paradigms [46].

This particular idea was built around the idea that science developed conflicting theories about how everything worked. Experimentation would lead to one of these theories becoming dominant and accepted by the scientific community. Kuhn christened this a 'scientific paradigm.'

He believed that a group of scientists would hold to a particular paradigm, often very stubbornly, until the body of evidence became so great that a 'paradigm shift [47]' became unavoidable.

Scientists would then adopt the new paradigm and begin working within its constraints, although two paradigms were not necessarily mutually exclusive.

For example, some physicists believed that electrons were particles; others believed that electrons were waves. Eventually, physicists found that they acted as both and so the paradigms overlapped.

Now, of course, quantum physics is opening up new definitions and the paradigm is shifting again.

Psychology provides another perfect example of paradigm shift, in the form of the nature vs. nurture debate. Some psychologists argued that all behavior was inbuilt and dictated at birth, whilst others believed in the Tabula Rasa, a clean slate mind, where all programming was the result of upbringing, environmental stimuli and education.

Currently, the current paradigm is that both have an important influence, and psychology and physiology seem to support this paradigm.

Feyerabend's Contribution to the History of the Scientific Method

The last of the three great philosophers behind the history of the scientific method is Paul Feyerabend, the scientific anarchist.

As Popper had realized that science had split into many differing disciplines, Feyerabend realized that these disciplines had become too complex to define by one overarching method.

In fact, Feyerabend believed that trying to force all scientific disciplines to follow a set of rules actually hampered science, creating false restrictions and barriers to progress.

His famous philosophy of 'Anything Goes' was an attempt to address this, by arguing that scientists should not be influenced by 'arcane' philosophies.

He pointed to physics as an example of this, lamenting the abundance of physicists who had no grasp of philosophy, arguing that if they did not understand it, how could they be constrained by it?

His strongest argument against the scientific method [19] was that, historically, many great discoveries would not have been made if constrained by the strict limitations of the scientific method, pointing to the work of Galileo and Copernicus. He believed that scientists often had to make up rules as they went along, adapting their methods to tackle new discoveries that could not be examined without breaking the established rules.

He pointed out that scientific discovery progressed unevenly and that the greatest scientific leaps ignored the scientific method.

If Copernicus, Darwin, Einstein or Wegener had stuck with the strict scientific method, they would never have published their theories and instead they would have become stuck in an endless loop of observation and experiment.

They would have been consigned to making small scientific leaps without ever gaining enough momentum and evidence to propose a grand and sweeping theory.

The History of the Scientific Method - Moving Into the Future

After the long history of the scientific method, passing from the Greeks, the Muslims and the Renaissance, where does the modern scientific method stand?

Certainly, the ideal scientific method does not work for all disciplines and they have to adapt and modify it.

Perhaps the best way to look at the scientific method is on a disciplinary basis, as every scientific field seems to have developed its own philosophy.

Physicists can follow Popperian ideas of method and falsification [40], whereas social scientists and behavioral biologists tend to line up behind Feyerabendian philosophy.

Whatever method is accepted, the scientific method is built upon a long and ancient history and some of the greatest minds in the history of humanity have contributed to it.

A single article cannot possibly do justice to this development and you will need to dig much more deeply if you wish to really understand the complexities.

For now, if you understand the basic principles affecting your discipline, your research will be perfectly acceptable and valid [48].

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