Adrian Brockless
*Philosophy of Science 1*
05/10/2016

***History of Scientific Thought***

The history of scientific thought is tied up with the history of human thought more generally – religious thought, spiritualism, mysticism, witchcraft, magic and so on. Part of human evolution from their animal ancestry has been the development of thought and understanding in relation to what we see around us. It is sometimes easy to forget that the advances in technology we have seen since the 1960s (for example) exist on the same timeline as the development of artistic thought in Stone Age man. Since the Stone Age however, our thought has radically diversified both at individual and collective levels; individuals from Anglo-American and European backgrounds can be understood as cultured or philistines but, nevertheless, as exemplifying Western thought. Similarly, we can talk about Eastern thought and differences between individuals within it. And, of course, there are a myriad of different degrees of subtlety existing in between such general and individual cultural descriptions – few of which would have been available to Stone Age man.

Since the dawn of civilisation there have been practices that can be understood as proto-scientific or, at least, as exhibiting some of the traits that now characterise scientific methodology. By the same token however, many more cultures traded on ideas pertaining to the religious, spiritual or mystical than do today.[1]

So what is the difference between mysticism, spirituality, religion and science? – What is the scientific method? Is the scientific method a cultural phenomenon or is it something that exists independently of human culture? What are the presuppositions of science and its methods? What counts as progress? How do we judge the reliability of the scientific method? Are there forms of understanding that science is unable to address? Are there questions that it is impossible for science to answer?

The philosophy of science is, in essence, the examination of these questions. For the next two or three classes we will be looking at this area of philosophy, how scientific thought has developed and how it involves many other areas of philosophy – perhaps most notably, epistemology (theory of knowledge).

To begin, I want to look at some of the obvious differences between mysticism, spirituality, religion and science and how they have developed through time. To do this, we need to understand some basics – beginning with some basic definitions.

The classical definition of the scientific method runs approximately as follows: the development of a hypothesis that is submitted to a test (or tests). In other words, based on what is already known, the scientist will develop an hypothesis which will either be accepted or rejected depending on the results. Obviously, things are a good deal more complex than this – new forms of testing might become available which show those originally conducted to be flawed in some way; as such, they might case doubt on the initial findings and so on. Another facet of the scientific method is that it attempts to do away with dogma and "truth by authority" – dogmatic beliefs might be related to "old wives tales" about the benefits of certain homeopathic remedies, for example; "truth by authority" tends towards the unquestioning acceptance of religious edicts. This is rather similar to a fallacious form of argument known as 'appeal to authority'. In essence, the fallacy amounts to making a claim on the grounds that you know someone who you believe knows about whatever it is – you cannot support the claim with evidence of your own. However, it should be noted that there is a distinction between 'appeal to authority' and the acceptance of recognised expertise – were that not so then no one would learn anything.

Like philosophy, science relies a good deal on induction and deduction. Induction, you will remember, involves numerous observations of a phenomenon from which a general principle is formulated – for example, the boiling point of water in relation to atmospheric pressure was established by making numerous observations of the boiling point at different altitudes. From this a successful theory was formulated that explained these observations and, crucially, explained all future observations as well. From this theory, further knowledge could then be deduced. Naturally, such a methodology is vulnerable to the problem of induction (which we covered last year). To refresh your memory, the problem is that it only takes one counter example to scupper a principle that has been formulated on the basis of numerous observations.

[1] Cf. Frazer, J. *The Golden Bough*.

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Over the next couple of weeks, we will cover the development of scientific methodology in some detail – covering figures such as Aristotle, Ptolemy, Galileo, Newton, Kepler, Einstein, Gödel, Popper, Kuhn and Feyerabend. However, before we do that in any detail, I need to provide a sketch of the ways in which human thought has developed.

To our cave dwelling forefathers, the Sun dominated the day and the Moon the night. As our intelligence developed we (as human beings) began to act in ways that were not just instinctively related to changes in the seasons; we came to recognise the seasons in ways that expressed an awareness of longer-term changes. Part of this expressed awareness was the making of observations – many of which were oriented in terms of daylight and the growing of crops, hunting and the breeding of livestock. A further aspect of our evolved cognitive development however, was the search for explanations of those observations allied to a sense of wonder. The wonder was (and still is) made manifest in our attribution of unexplained phenomena to a god or gods (among other things); polytheistic religions developed on the back of the seasons – specific gods were believed to be responsible for (or exemplify) particular aspects of life. They were worshipped in order to bring the benefits of their particular domain; the pagan Sun god (who went by a variety of names – Horus (Egyptian), Lugh (Celtic), Sunna (Norse), Apollo, Ra among them) could bring famine but was also understood to be fundamental for life.

What this shows is a pre-historic concern with explanation and cause and effect in relation to observations made; in this sense at least, the rituals of worship designed to please such gods were based, not only on self-interest, but the desire for understanding. Thus, we have an embryonic version of scientific thought. But, of course, the worship of gods – and religious belief more generally – is grounded in much more than a desire to explain the universe in relation to the observations that we make and ever increased benefit in relation to cost. – That however, is something I will skip for the moment.

From this, human thought developed in both scientific and religious directions that have gradually become more and more distinct. In the ancient world, for instance, although the two were still obviously tied together, there were definite and distinct practices related to each; religious sacrifices were still common but there were also practices that could be understood as specifically scientific such as the ways in which the ancient Greeks proved the earth to be spherical. They did this in two ways; the first for different observers to make simultaneous observations from different areas in the known world. The results of these observations showed the sun to be at different heights in the sky at the same time in different locations, and being in different places according to sundials relative to those in Greece. As a result, the ancient Greeks realised the earth was spherical as opposed to flat and were also able to make a reasonable estimate of the circumference of the earth. The second way in which they confirmed the earth to be spherical was through the observation of lunar eclipses; the shadow passing across the face of the moon was seen to be curved, as opposed to flat. And although one notable Greek philosopher and astronomer, Aristarchus, claimed in about 230BC that the earth orbited the sun, it would be over 1,700 years later that the work of Copernicus would invite such a view to be taken seriously. Aristarchus was considered a crackpot for espousing such a position.

Instead, theories about the universe presupposed an earth centred system – this was ably supported by the mathematics of Ptolemy. Ptolemy's model had the Earth at the centre of the universe with the Sun, Moon, planets and stars moving round it in circular orbits. Ptolemy assumed that each planet moved in a small circle (an "epicycle"), the centre of which (the "deferent") itself moved around the Earth in a perfect circle. The model matched empirical observations and explained how the planets occasionally double back on themselves as they move against the background of stars. The stars themselves were believed to be stationary.

For these reasons – Ptolemy provided good justifications for his beliefs – his work remained the basis (or paradigm) from which other scientific theories were developed until 1543 when Copernicus published his book *On the Revolutions of the Heavenly Spheres*. The model of the universe with the Earth at its centre was later supported by the Catholic Church and it was considered heresy to contradict the edicts handed out by the Vatican. Indeed, one of Copernicus' scientific followers, Giordano Bruno, was burned at the stake - one of his crimes in the eyes of the Church was that he believed the Earth to be in orbit around the Sun. The Catholic Church did not officially accept the Sun-centred model of the solar system until 1991!

***<u>Explanation of the Ptolemaic and Copernican Models of The Solar System</u>***

The retrograde motion that Mars describes through the sky (below).

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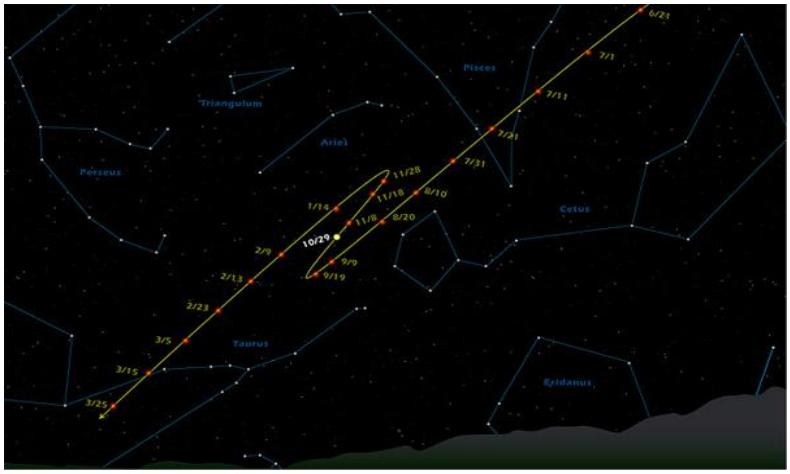
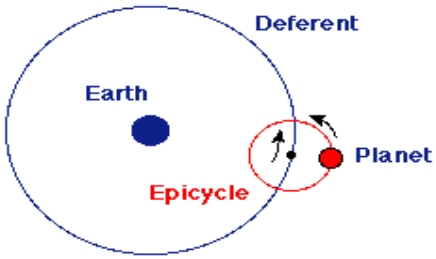
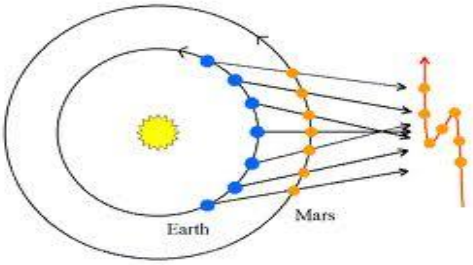



Left: the Ptolemaic model of the universe that was used to explain the meandering of the planets across the sky (see above).

These orbits described by the planets were called "Epicycles", and the concentric spheres to which they were attached were termed the "Deferents".

Retrograde motion of Mars as explained by Copernicus and Galileo (below)




This, of course, gives us reason to revisit the notion of *justified true belief* (J+T+B) as sufficient for knowledge – not something I will do now but it is a point of discussion!

Now that a potted history has been sketched, we can turn to an examination of the scientific method in greater detail, starting with Aristotle.

Outside of academia, Aristotle's method is now perhaps the most widely accepted version of the scientific method; there are good reasons why we should not think of it as defining science however, and I will cover these in more detail in subsequent classes.

***Aristotle's Inductive-Deductive Method***

This can be understood as follows:

1. Observations >>> 2. Inductive reasoning to explanatory principles >>> 3. Knowledge of reasons for the fact.

Thus, we might start with observations of a lunar eclipse as a darkening of the moon's surface with a curved boundary between light and dark (1). From what is understood about shadows and previous observations of the heavens, we can induce (2) that light travels in straight lines, that the moon is always full when lunar eclipses occur and that the full moon is always at its zenith (highest in the sky) at about midnight (or 1am adjusting for BST). From this we can induce that it is opposite the sun in the sky and deduce (3) that, at the time of an eclipse is entering the shadow cast by the earth. In other words, we have progressed from factual knowledge (from observing the moon's darkened surface) to an understanding of why it has happened.

There are however, two distinct forms of induction (inductive reasoning) that Aristotle believes to be necessary for scientific knowledge. The first is the kind we have encountered already – that of making numerous observations and, from them, proposing a general principle.

x1 has P
x2 has P
x3 has P

-----∴

All x's have P

The second form of induction is known as ***Intuitive Induction*** or ***Inference to Best Possible Explanation*****.** In short, it is the ability to distinguish the essential from the inessential in one's experience. One might, for example, note that the bright side of the moon is always faced in the direction of the sun and, as such, conclude that the moon shines by reflecting the light of the sun.

Once we have reached generalisations from induction we are then able to use them as premises (starting points) for deducing statements about our initial observations. BUT Aristotle placed limits on what could count as a premise for a deductive argument.

1. All S are P (S wholly included in P)
2. No S are P (S wholly excluded from P)
3. Some S are P (S partially included in P)
4. Some S are not P (S partially excluded from P) * Note that 4 is not equivalent to 3.

Of these premises, 1 is the most important because it allows for the development of the syllogism.

All M are P
All S are M
∴
All S are P

P = major term
S = minor term
M = middle term
(Think of it as a Venn diagram)

This is valid as the conclusion necessarily follows from the premises.

Now we can see how this pays dividends:

All points of light that shine steadily are near the earth (inductive generalisation)
All planets are bodies near the earth (inductive generalisation)
∴
All planets are bodies that shine steadily

Of course, we now know that premise 2 is false and so the conclusion may need to be reassessed – certainly, it cannot be supported using this form of deduction. Once it is reassessed however, the process can begin again and this is how Aristotle conceived of science progressing – a kind of steady linear form of sequential development. But we will soon see that things were (and are) not quite as tidy as he believed them to be!