HU3101: History and Philosophy of Science

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Question 1. What are the Four Great Chinese Inventions? Do you think the importance of these inventions has been over-emphasized by Western scholars at the cost of many other achievements of the Chinese?

Answer. The Four Great Chinese Inventions, named so by Joseph Needham, are papermaking, printing, gunpowder, and the magnetic compass.

1. *Papermaking.* Paper is a relatively cheap, easily manufactured and distributable medium for writing (it was initially used for wrapping). This means that records of Chinese history are very well preserved. Another consequence is the introduction of paper currency.

2. *Printing.* Block printing fully leverages the power of paper as a means of sharing information. Now, a pattern engraved in a block of wood can be copied accurately onto a surface as many times as required; this technique was used for textile printing before it was applied to writing. The Chinese innovated further with movable type, in which separate characters are engraved onto individual pieces of ceramic or wood, which can be arranged and fixed to create the desired text – later, they can be removed and rearranged for a different text. The use of metal movable type is the finishing touch on this invention.

3. *Gunpowder.* The explosive power of gunpowder had been perfected by the Chinese over centuries. This is a huge technological advancement in the field of war.

4. *Magnetic compass.* While practically all ancient civilisations had developed means of navigation by studying the night sky, this method has obvious drawbacks – it can only be employed on clear nights. The magnetic compass provides a simple, reliable method of navigation. Early versions involved magnetized material floating on a bowl of water (which allows free rotation); later, the needle was suspended by a thread, giving a 'dry compass'.

News of these inventions began to make their way to Europe only during the 16^{th} century by sailors and explorers. These four inventions became instrumental in pulling Europe out of the Dark Ages, and enabling them to colonize the world[1]. In this context, it makes sense why these Four Great Inventions have been highlighted by Western scholars, seeing that they stimulated and accelerated the development of capitalism in Europe.

On the other hand, this is by no means an exhaustive list of China's achievements. Some more inventions include rice planting, silk, porcelain, tea, and fire arrows. These undoubtedly had a great impact on the lives of the Chinese people, and deserve a place in history. It has been argued however that the Four Great Inventions had been underutilized by the Chinese; they were a heavily bureaucratic society, without much focus on exploration. The West took these inventions and created weapons with which they conquered foreign nations. Another observation is that after the founding of the Qing dynasty in the mid 17^{th} century, there aren't any Chinese inventions rivalling the importance of these ones.

[1] To quote Karl Marx, "Gunpowder, the compass, and the printing press were the three great inventions which ushered in bourgeois society. Gunpowder blew up the knightly class, the compass discovered the world market and found the colonies, and the printing press was the instrument of Protestantism and the regeneration of science in general; the most powerful lever for creating the intellectual prerequisites."

Thus, the Four Great Inventions represent a small fraction of the achievements of the Chinese civilization. It is however natural for Western scholars to have attached more importance to these four, given their universal nature and their impact (perhaps indirect, via the West) on the globe.

Question 2. "Under the Abbasid dynasty Baghdad became a great centre for translating scientific and philosophical texts." Discuss.

Answer. The Abbasid dynasty (750 - 1258 AD) coincides with what is now called the Islamic Golden Age. Thanks to their geographical location in Central Asia and Portugal, they were able to learn from and assimilate many aspects of the Greeks, the Indians, the Persians, and the Assyrians. Many of the caliphs during this period were enthusiastic patrons of scholars and scientists. The result was the Græco-Arabic Translation movement. A large number of (mostly Greek) texts were translated into Arabic from languages such as Greek and Sanskrit (note that the original texts were not always available, but neighbouring civilizations such as the Indians had acquired this knowledge and written translations of their own earlier). The center of this movement was the capital city of Baghdad.

The second Abbasid caliph, al-Mansur sponsored many such translations. He invited scientists and learned people to his court, especially astronomers. After Indian astronomers presented the *Zij al-Sindhind* (an astronomical handbook) to him, al-Mansur had this translated from Sanskrit into Arabic. He sponsored the translation of Ptolemy's *Almagest*, Euclid's *Elements* (more than once!), as well as medical texts of Galen and Hippocrates. Al-Mansur also had the texts of Brahmagupta, such as *Brahmasphutasiddhanta* and *Khandakandadhyaka*, translated.

The seventh caliph al-Mamun is also notable in this respect; he was also a patron of astronomy, and built the first astronomical observatories in Baghdad. He even sent scholars to gather and bring home texts from foreign lands, continuing the rich culture of translation. The great Thabit ibn Qurra further translated the works of Ptolemy, Euclid, Archimedes, and Appollonius. It is said that al-Mamun's pursuit of knowledge was inspired by a dream he once had involving a discussion with Aristotle.

We must mention the House of Wisdom which acted as a key academic and scholastic center during this period, well-funded and supported by the caliphs (especially those discussed). This was also a center of learning, at a time when universities did not exist as we know them.

The fruits of this translation movement are evident in the works and achievements of Abbasid scholars. By bringing together so many classic texts from neighbouring nations, they were placed at a considerable advantage. They made use of this knowledge in the fields of mathematics, astronomy, geography, medicine, optics, and chemistry. For instance, al-Khwarizmi studied the works of Indian mathematicians, learning Sanskrit for this purpose, and developed algebra. The numbers we use today are known as Hindu-Arabic numerals; these most likely originated in India and reached the rest of the world via the work of Islamic scholars. Thus, the Islamic scholars inherited and furthered the scientific knowledge of many civilizations, preserving it and helping it spread.

Question 3. Describe how the paper industry gave a boost to the Baghdad economy.

Question 4. Thales or Uddalaka Aruni – whom would you consider the first scientist of the world?

Answer. Uddalaka Aruni was a Vedic sage from the 8^{th} century BC, preceding Thales by roughly two hundred years. The *Chandogya Upanishad* speaks of him, and his questions about nature (regarding truth, reality, the possibility of eternal and unchanging things) reveal that he was a philosopher. This makes him one of the first recorded in history. However, we are concerned with whether or not he was a *scientist* too; if so, this would place him ahead of Thales as the first scientist in (recorded) history.

We swiftly recapitulate why Thales is considered a scientist: he 'discovered nature', in the sense that he sought to explain natural phenomena as the result of the interaction of matter in accordance with natural laws. In doing so, he did not involve mythology or the gods. In an attempt to explain the origin/nature of matter, he proposed that the 'primary principle' is water. Furthermore, the earth floats on water, and its motion on this ocean of water causes earthquakes. His name is perhaps best known to mathematicians; Thales Theorem[2] is one of the most well known theorems in geometry, and is perhaps the oldest theorem to be named after a person.

Uddalaka Aruni's philosophy exhibits a clear materialistic bent. He too was interested in understanding the origin of matter in terms of first principles. Note that he rejects the idealist Vendantic ideas of everything arising from 'non-being'; he questions how can such a thing be possible, being arising from non-being? From his observations, everything around him seemed to arise from some basic substances, and understanding those basic substances would reveal the true nature of things. For instance, every clay utensil and object is at its heart just clay; every copper ornament is just copper in a different form; every iron scissors is just iron. He means this in the sense that these fundamental things underlie the 'infinite variety' of things of the world. He identifies three basic principles: fire (tejas), water (ap), and food (anna), and posits that everything in the universe (living and non-living, material and mind) evolved from these. He theorizes that water arises from fire (heat causes people to sweat) and that food arises from water (crops flourish during rain).

Perhaps the most striking achievement of Uddalaka Aruni is that he is the first person in history to show a clear connection between material food and the conscious mind. In order to demonstrate this to his son Svetaketu (who had returned after years of studying the Vedas), he instructed him to fast for fifteen days. After this, he quizzed Svetaketu on what he'd learnt, and saw that his son couldn't answer! Only when Svetaketu had eaten and recovered could he recall his hymns and melodies. Uddalaka explains how the body can be divided into sixteen parts, the last representing 'breath' (life) and only needing water to survive. By fasting, the fifteen parts of his body had been depleted, making him unable to retain his memory. Upon eating food again, his faculties returned, just as how a fire can be rejuvenated by replenishing its fuel. Uddalaka further explains his theory of how different parts of food contribute to different parts of the body: some entering the flesh, some the bones, and some constituting the mind. While the exact details are not relevant, we must note that he gives the human mind an explicitly material origin, arising from the subtlest parts of the food one consumes.

Looking back at Uddalaka's work, we see the seeds of a scientific approach of making observations, creating hypotheses, and testing them via experiment. Uddalaka much like Thales invokes a materialistic origin of everything, without speaking of any religious mysticism or idealism. Thus, it is certainly fair to call Uddalaka Aruni the first scientist in the world.

Question 5. What were Karl Popper's chief arguments against Logical Positivists?

Answer. Karl Popper's chief arguments can be condensed into the following.

1. *The Problem of Induction.* Many philosophers, notably Popper and David Hume, have considered the complete verification of certain (perhaps scientific) statements to be impossible. To illustrate, consider the statement "All swans are white". In order to 'verify' such a statement, one would have to gather many swans and check their colours; however, there always seems to be a logical gap between

$$\text{All swans that we have checked are white} \overset{??}{\implies} \text{All swans are white.}$$

   Thus, the problem arises when we want to generalize. In doing so, we are performing a sort of inductive reasoning, which may or may not be justified. In this scenario, an arbitrarily

[2] Any triangle inscribed in a circle such that one of its sides is a diameter must be right angled.

large amount of supporting evidence (white swans) cannot satisfactorily establish our statement.

2. *Confirmation bias.* The idea that a statement is meaningful only if it can be verified encourages one to seek this confirmation wherever one can find it, ignoring any contradictory evidence in the process. Thus, a principle of verification is not enough; one must not only accept, but actively seek out contradictory evidence in order to properly test one's hypothesis.

3. *Meaningful vs Scientific.* Logical positivism seems to maintain that all meaningful (verifiable) knowledge equates to scientific knowledge, or that anything which fails our 'scientific test' is automatically meaningless. This eliminates many parts of metaphysics, some of which Popper considers essential for driving science forward, for instance questions about how things originate, consciousness, free-will, etc. Thus, not all knowledge is scientific.

Popper introduced the notion of *falsifiability* as a better test than *verifiability*. While our statement about white swans cannot be adequately verified even by a mountain of evidence, a single counterexample is enough to prove it false.

$$\text{This particular swan is black} \implies \text{Not all swans are white.}$$

The logical step is perfectly clear in such cases. Note that our statement comes equipped with its potential falsification; it admits a scenario (the existence of a swan that is not white) which would render the statement false. Such statements are *falsifiable*. Popper's idea is to label these statements *scientific*. Some statements (such as those in metaphysics) may be unscientific, but that is no reason to call them *meaningless*. After all, certain statements may not be falsifiable in one era, but with the progression of science and technology become falsifiable in the next. Thus, the means by which science ought to progress is by *conjecture and refutation* instead of induction.

Popper can thus create a clearer distinction between the *scientific* and the *pseudoscientific*. An example of the latter is astrology; by the yardstick of verification, one might cite multiple instances on which astrological predictions held true and present this as supporting/confirming evidence. However, Popper's standards demand that we look at counterexamples instead of ignoring them. Similarly, those statements which continuously 'move goalposts' in light of new evidence are also to be considered pseudoscientific, since they resist falsification by changing the conditions at every turn.

Question 6. What were the major differences between the Chinese and the Indian philosophers and how did these differences influence the development of science and technology in the two civilizations?

Answer. While there are many similarities between the Greek and Indian approaches to science and philosophy (with the latter directly borrowing many elements from the former), the development of science in China has been regarded to be fairly unique. Following are some features which characterize this.

1. *Bureaucracy.* This factor is not directly a philosophical take, but it sets the stage and context for these developments. The Chinese society revolved heavily around the State. While civilizations such as India produced thinkers like Aryabhata, Brahmagupta, Bhaskacharya, etc. who pursued knowledge independently, the Chinese State was far more involved in the process of gathering and organizing facts. This resulted in a organized, consistent development of technologies and ideas which spread quickly throughout the country. However, the same State involvement often hampered the progress of science and the acquisition of knowledge for its own sake; the motive behind these pursuits was often simply to increase

revenue or gear for war. A famous example is that of general Cheng Ho in the 15^{th} century, who conquered Ceylon and sailed as far as the African coast until he was ordered to return by the Mandarinate. While the Chinese were clearly capable of such expeditions, rivalling those of Columbus by a century, they were uninterested. The Emperor was more focused on problems closer to home, namely invading Tartar tribes. Furthermore, China was primarily an agricultural society, thus its economy had no real dependence on foreign trade. In conclusion, the development of science received little to no funding from the State (which was resistant to change and new ideas). Civil service was the most important objective for the people.

2. *Laws of Nature.* The Chinese civilization had little interest in abstract codified laws. This seems to be a result of the tyranny and authoritarian nature of politicians belonging to the Legalist school of thought. As a result, they did not develop what we would call 'Laws of Nature'. The Confucian school of thought was concerned with order and structure, both within society and in the universe; the patterns of nature arise as a by-product of this harmonious co-ordination. Thus, they lacked the abstract thinking which made the Indian and Greek scientists and philosophers so well known even today. This is perhaps illustrated best in the field of astronomy; in order to speak of modelling the solar system like Aryabhata, or to begin contemplating the rudimentary ideas of gravity and how the earth lies in space like Bhaskacharya, a groundwork of abstract thinking and a concept of extrapolating from daily observations (formulating universal laws) seems essential. In retrospect, the Chinese did not use the modern systems of observation, experiment, and inference.

3. *Creator beings.* The most popular Chinese schools of thought did not speak of a Creator being, since their philosophies and explanations for how the world works did not require one. As we have already said, the Confucian school dealt with organization of society and nature. While things like 'good behaviour' (ethics, morality) may have been considered *holy*, there was no need for them to be *divine* in the sense of mirroring an all-powerful being. This is of course unlike the Indians who revered the Vedas and maintained a pantheon of gods and goddesses. They considered these beings to be the creators of everything, including the Laws of Nature which they strived to decipher and understand; thus, the concept of a Creator gave thinkers a clear motive/direction. In contrast, the Chinese were not as motivated to uncover such abstract laws; even if a supreme being did establish these Laws of Nature, the Chinese argued that lesser beings such as humans could not hope to understand them. We note this focus on materialism in the Confucian philosophy, compared to the Indians who believed in the concept of reincarnation and thus valued the mind/soul as some eternal entity.

   The Taoist school of though was against Confucianism and sought to become closer to Nature by living outside society and making observations. However, they too did not make the necessary jump of hypothesis and experiment, and hence made little progress. They were also distrustful of reason and logic; a bold step.

The Chinese approach can be summarized succinctly as 'practice over theory'. They made huge technological leaps, were diligent observers and classifiers of knowledge, and maintained an efficient and cohesive society. However, they did not make the transition into the modern approach towards science. In contrast, the achievements of the Indians are much more pronounced in the areas of abstract forms of thinking.