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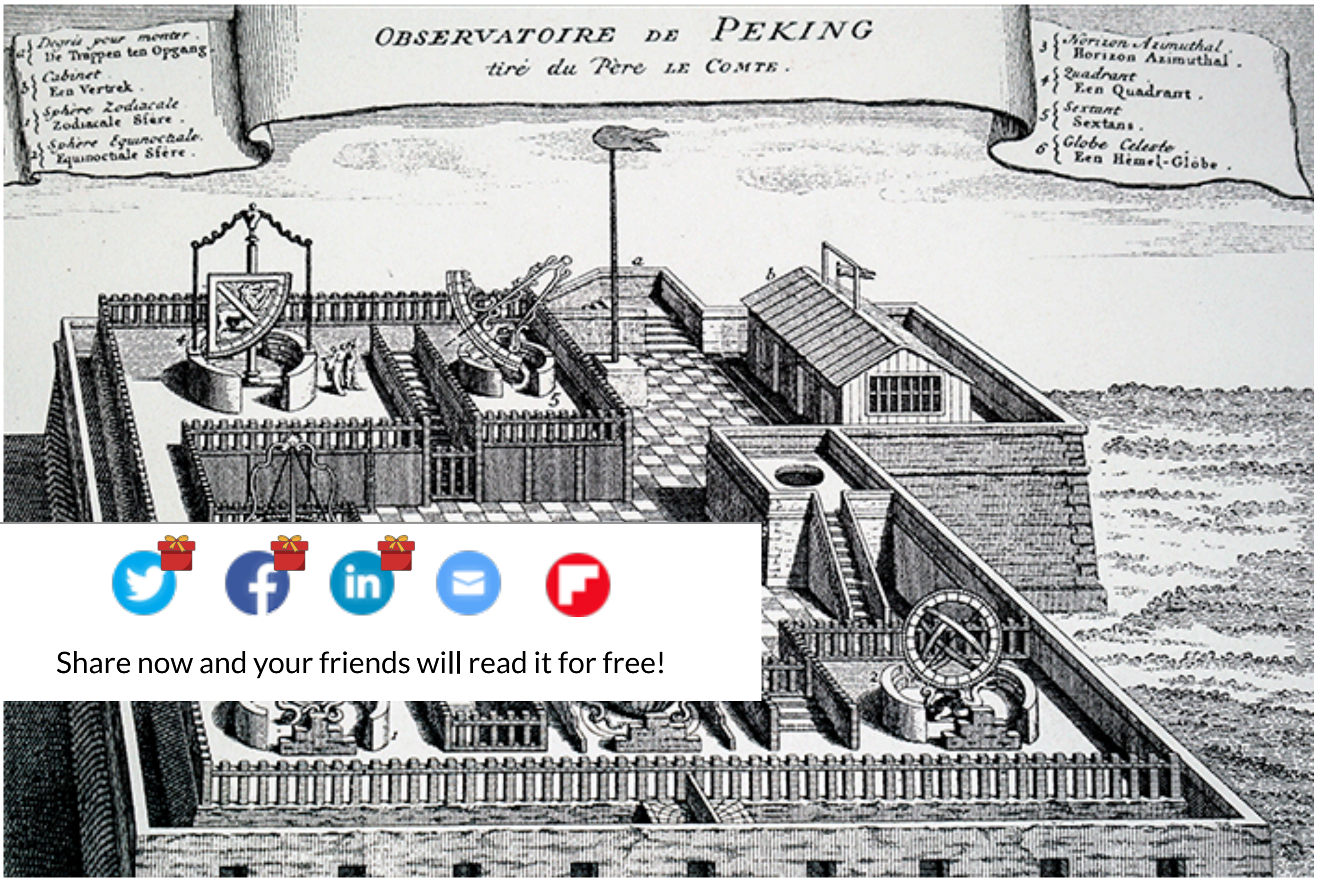
WEEKEND LONG READ

Weekend Long Read: Why the Scientific Revolution Did Not Occur in China

By Ya Shalong



An engraved plate depicts the Pekin Observatory, now known as the Beijing Ancient Observatory, in the 17th century. Photo: Universal History Archive/VCG

Many would have heard of the “Needham Question” which asks: Why was China overtaken by the West in terms of science and technology, despite the ancient Chinese society’s superiority in these fields?

While this sounds straightforward, it actually involves two distinct concerns: one about science, the other about technology. Today we often think of science and technology collectively, but historically, these were distinct domains. And science often confronts the question of applicability — what is the practical use?

The ‘uselessness’ of science

Papermaking is a technological process. But did Cai Lun, its Chinese inventor born in A.D. 63, have any need for scientific theory? The answer is no. Similarly, neither Chinese innovator Bi Sheng, born in 972, nor Johannes Gutenberg, the German inventor in the 15th century, applied scientific theory in their development of movable-type printing. Neither did James Watt, the 18th century Scottish inventor, have any need for advanced scientific theories during the course of improving the steam engine.

The Scientific Revolution, as represented by Isaac Newton, and the Industrial Revolution, as represented by Watt, were two distinct processes.

The production of steam engines did not require an understanding of Newton’s laws of motion, or even an understanding that the earth revolves around the sun. In the book “A History of Science, Technology and Philosophy in the 18th Century,” author Abraham Wolf reveals how little an impact science had on technology in that era. Despite a few exceptions, this was the general trend.

So just what use was the Scientific Revolution? For a long time, almost none. While Newtonian physics revolutionized the way scientists looked at the world, this was not converted into increased productivity. Nor did it raise the U.K.’s GDP at that time.

But everything changed in the 19th century, when science and technology were integrated. While scientists’ absence during the First Industrial Revolution was conspicuous, the Second Industrial Revolution, during the era of electricity, could not have been achieved without scientists.

The ‘useless’ became the most useful.

But, back in the day, few could have foretold practical uses of science. Whether we consider Galileo or Newton, scientists of that era worked to seek knowledge, satisfy their curiosity and unveil the mysterious workings of the world, rather than to enhance humanity’s well-being.

Why did China lag behind?

Let's return to the Needham Question. Why didn't the Industrial Revolution take place in China? The reasons are complex and historians have offered numerous explanations.

So, let's leave that aside and ask a different question: Why didn't the Scientific Revolution occur in China? This obviously involves many factors, but one important one lies in the difference between science and technology.

In ancient times, China held a world-leading position in many fields of technology, with China's four great inventions playing merely a small role in the nation's technological lead.

Science was another matter. In terms of astronomy, the ancient Chinese could predict precise solar and lunar eclipses, and had observed supernovas explode, which the West had failed to do. But we had to yet develop astronomical theories like the Ptolemaic model of the solar system.

Chinese astronomers were simply not terribly interested in planets' orbits.

Since the inner workings of astronomy are complicated, let's look at a simpler example: During the early Ming dynasty in China, thanks to China's advanced shipbuilding techniques, Zheng He was able to lead seven treasure expeditions in the 14th and 15th centuries. The techniques of astronomy used during those voyages were very advanced — even if it didn't lead Europe by a large margin, it definitely did not lag behind. But here's the odd thing: Zheng He's fleet sailed 100,000 miles, and reached Africa. One of his boatmen, Ma Huan, recorded these voyages in detail. But his writings never mentioned the shape of the African continent.

Is the earth round or flat? If it's flat, where is the edge? If it's round, how large is it? Shouldn't these have been some of the most interesting questions for voyagers crossing the ocean? These questions did not even get a mention from Ma.

Not only that, the whole fleet appears to have paid little attention to this topic. It is weird that such epic voyages did not trigger intelligent discussion concerning the shape of the earth.

Perhaps this was because ancient China was more inclined toward solving practical issues, and less attracted by abstract scientific points.

Lacking a principled approach

Let's look at the purest of the sciences: mathematics.

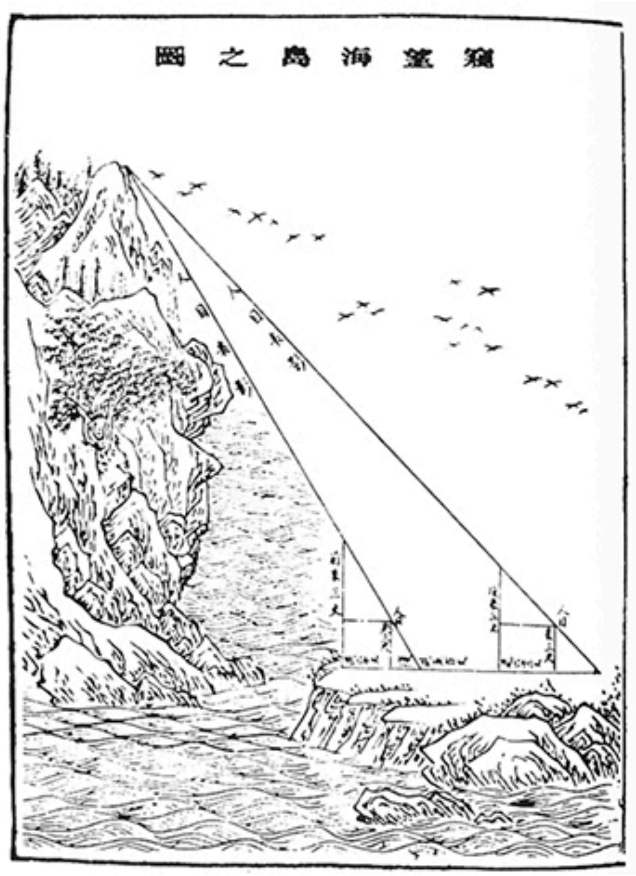
The "Nine Chapters on the Mathematical Art" is ancient China's most classic mathematics book, which many mathematicians have studied and annotated over thousands of years. It can be seen as the equivalent to Euclid's "Elements" in Western mathematics.

The ancient Greek mathematician Euclid and a partial diagram from his series of books on geometry, "Elements."

But a careful reading reveals that the two are completely different. The latter first gives postulates and definitions, then derives theorems, in a way that seems very abstract. It outlines an abstract mathematical system. The former, on the contrary, does not.

We might consider the "Elements" more "advanced," but does this mean that Chinese people were not intelligent?

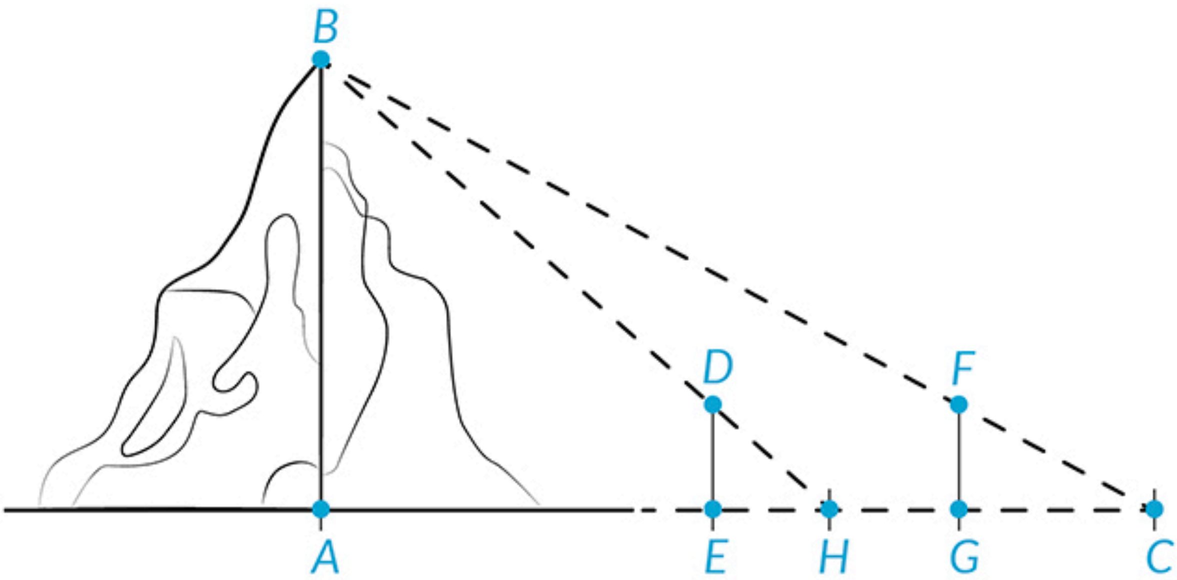
Of course not. Ancient Chinese mathematicians were very smart and comparable to those of ancient Greece. Let's take Liu Hui as an example.



Liu Hui, the Chinese mathematician from the Three Kingdoms (220-280) era and his "haidao suanjing" diagram.

Liu was a renowned and gifted mathematician of the Wei and Jin dynasties in the 3rd century. He had proposed the cyclotomic method, a method theoretically capable of evaluating pi (π) to infinite accuracy, but this is complicated due to the limitations of space. Thus, let's look into another one of his contributions: The method of multiple measurements.

The method is recorded in his book "Haidao Suanjing" (Sea Island Mathematical Manual). Here is a general outline of this work:



$$AB = (DE \times EG) / (GC - EH) + DE$$

Suppose there is a mountain on a distant island. A surveyor wants to know the height of this mountain, but does not know distance from the island. How can he measure it?

First set up a pole E (pole height = DE). Looking from the ground toward the measurement point (H), the tip of the pole is on a straight line with the island peak. However, lack of distance data means it is still impossible to calculate the height of the island (AB). The solution is to set up another pole F (pole height = FG), and measure again.

The following formula provides the answer:

Height of mountain on island, $AB = (DE \times EG) / (GC - EH) + DE$. Where:

EG refers to the distance between the poles; EF refers to the forward offset (distance from eye to pole); and GC refers to the backward offset.

I'll leave derivation of this formula to the reader. This method uses two measurements. The book also introduces more complex methods, involving three and four measurements, all of which involve sophisticated mathematics. Considering this work, American mathematician Frank Swetz concluded that "in the endeavor of mathematical surveying, China's accomplishments exceeded those realized in the West by about one thousand years."

This is, of course, a remarkable achievement.

We should note that Liu only provided methods of measurement; he did not provide any proof of process. The geometric principles used in such derivations and whether these were rigorous or not, do not appear to have been so important to him, as long as he gave the correct result.

In his view, the concern was practical measurement, not abstract mathematical propositions.

This was not just Liu's usual practice, but common amongst the ancient Chinese mathematicians. This was what led Xu Guangqi (a Ming dynasty Chinese mathematician), to exclaim, after reading the "Elements," that compared with western mathematics, Chinese mathematics had roughly the same calculation methods, but it lacked a principled approach.

What was the reason for this?

It's not that ancient Chinese mathematicians had not thought of principles, but rather they preferred to solve practical problems and had less interest in abstract theoretical systems. Theirs was an "engineering culture," rather than a "mathematics culture." As a former engineer, I know the difference between those two cultures very well. Engineers focus on the problems at hand. As a Chinese proverb says: "It doesn't matter whether the cat is black or white, so long as it catches mice." As for why cats catch mice, that's something we don't concern ourselves with.

So back to the Needham Question.

Revisionist historians believe that the Industrial Revolution was purely serendipitous, and China could well have pioneered the revolution. I dare not say whether this is right or wrong, but from a logical standpoint, it does seem possible. As for the Scientific Revolution, however, that would have been absolutely impossible during the Ming and Qing dynasties. Needham's question is based on the premise that "technology" and science" are lumped together.

So why did the Scientific Revolution take place in the West?

I think one key contributing factor was the influence of Greek culture.

Greek culture is an outlier in world history, an unusual occurrence. The intellectuals of ancient Greece weren't too concerned about specific technical problems; Greek agriculture lagged far behind China's, and Greek road-building technology was nowhere near that of Rome. But the Greeks were very good at establishing scientific systems.

In geometry, for example, Euclid's "Elements" is a book whose precision and grandeur placed it far ahead of all contemporary books of its kind. But it was seldom used to make actual measurements. Ancient Greeks did not discover the surveying method documented in Liu's "Sea Island Mathematical Manual." They surely could have deduced that method, but just hadn't thought about it. They didn't see geometry as something of practical use.

A page with margin notes from the first printed edition of "Elements," dating back to 1482. Photo: Folger Shakespeare Library Digital Image Collection

But why were they so passionate about complex abstract systems?

Some hold that this interest arose due to the Greek system of slavery, which supported a group of intellectuals free from the need to worry about mundane concerns, who therefore turned to abstract problems. This makes sense to some extent, but doesn't seem like a complete answer. Ancient Rome also had slavery, and produced numerous intellectuals free from concerns about their daily needs, but they were not so interested in abstract sciences.

So the notion that Greek intellectual culture was an anomaly is possible.

The seeds of Greek culture took root in medieval Europe. Possibly because of the narrowness of their horizons, and the meagerness of their knowledge, medieval intellectuals retained a love of abstract systems. All they wanted was to be logically unassailable. In the "Summa Theologia," for example, Thomas Aquinas expounded five logical arguments to prove the existence of God. Did the Chinese ever use logic to prove the existence of the Jade Emperor?

So, despite the fact that medieval Europe was less developed, and poorer, than China in terms of both material and knowledge, it possessed a way of thinking that was indeed closer to the edifice of Newtonian physics, its eventual offspring.

Engineer versus scientist

It's hard to say whose way of thinking is better, engineers' or scientists'? We can only say that ancient Chinese people were pragmatic, lacking interest in abstract theoretical systems but great at solving practical problems. To some extent, this thinking continues in China to this day. The respect Chinese people feel for science now mainly reflects its "usefulness." If science failed to deliver utilitarian benefits, I doubt we'd respect it anywhere near as much.

Before the 19th century, however, science was simply not that beneficial. The sudden change in modern industrialization triggered by the Scientific Revolution was a completely unanticipated one.

And having realized that science is so useful, we — as pragmatic people — will certainly respect and even worship it. Many of those calling upon the Chinese government to stress basic science have emphasized its great significance, arguing the following: "Breakthroughs in basic science may drive the next scientific and technological revolution. If China does not focus on developing it, we could lag behind others!"

That's certainly true. But it also reflects a continuing utilitarian perspective that brought us to where we are.

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