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SHE BLINDED ME WITH SCIENCE

Collective Learning and the Emergence of Modern Science

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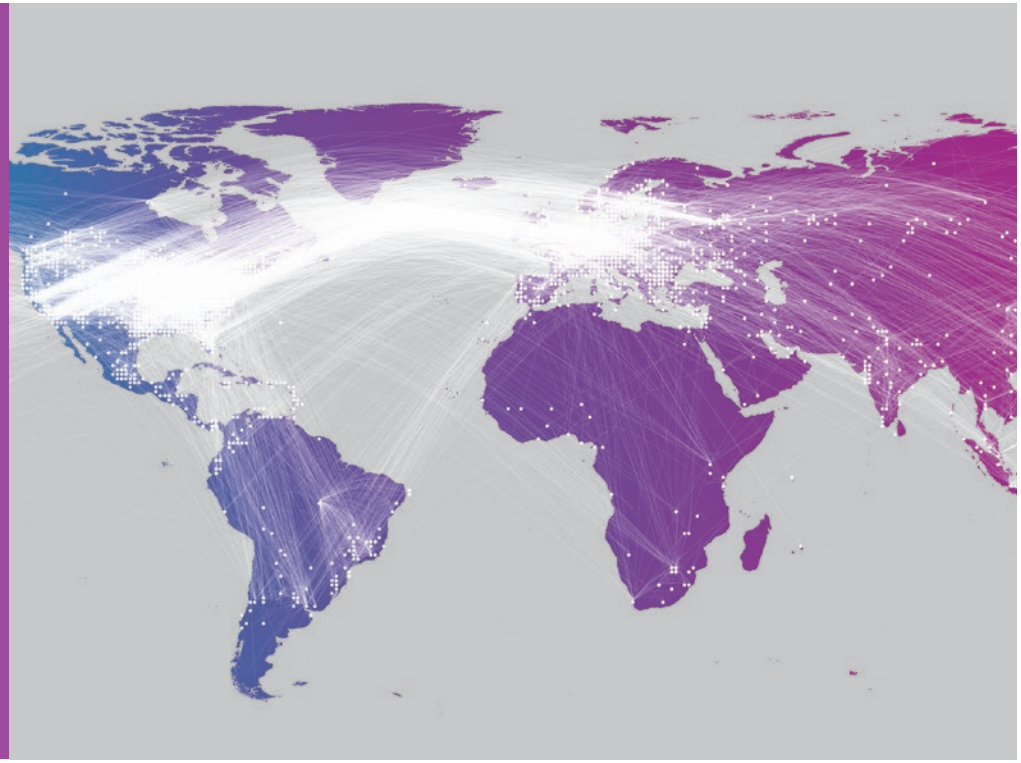

A HISTORIAN'S JOURNAL ENTRY / BY ANITA RAVI

As humans around the world continued to interconnect in greater numbers and at a faster pace than ever before, the exchange of ideas also accelerated.

I remember the three rules that David Christian laid out for us in the article "Collective Learning, Part 3" to explain how collective learning works:

- **Rule 1:** Collective learning increases when more people are connected.
- **Rule 2:** Collective learning increases when there is greater diversity within a network.
- **Rule 3:** Uneven distributions of information produce uneven distributions of power and wealth (11).

These three rules seem particularly relevant to me as I dive into studying the birth of modern science and the European Scientific Revolution. Starting in the fourteenth century, the acceleration of global exchange networks led to the formation of new ideas in science. For thousands of years prior to the reconnection of the four world zones, people had been solving problems in the natural world primarily through engineering. The development of ships and navigation tools by the Chinese and Indians in the agrarian era enabled the Indian Ocean exchange network to develop and flourish for hundreds of years. Systems of roads and carts to haul goods in the Americas and Afro-Eurasia also supported networks of exchange for thousands of years prior to the European Scientific Revolution. Philosophers and thinkers in Asia, the Middle East, and Europe developed ideas and theories about how the Universe functioned and used mathematics to support their ideas. However, during the sixteenth and seventeenth centuries, Europe became a global hub of knowledge as a result of their vastly expanded trade networks. In *This Fleeting World: A Short History of Humanity*, David Christian argues:

> ***The societies of western Europe had been at the margins of the great trading systems of the agrarian era, but they were at the center of the global networks of exchange created during the sixteenth century because they controlled the oceangoing fleets that knit the world into a single system. Western Europe was better placed than any other region to profit from the vast flows of goods and ideas within the emerging global system of exchange. The European scientific revolution was, in part, a response to the torrent of new ideas pouring into Europe as a result of its expanded contacts with the rest of the world. Awareness of new ideas, crops, religions, and commodities undermined transitional behaviors, cosmologies, and beliefs and posed sharply the question of how to distinguish between false and true knowledge of the world. The reinvention and spread of printing with movable type ensured that new information would circulate more easily in Europe than elsewhere. (67 — 68)***

Europeans certainly did not invent science, but the conditions that existed at the turn of the sixteenth century enabled them to amass a great deal of knowledge, synthesize it in new ways, and distribute it throughout the European world. This reinforces Christian's "Rule 3" of collective learning: the unequal distribution of information and knowledge led to unequal development around the world. The European Scientific Revolution is certainly a case where the collection and formation of new knowledge led to an unequal distribution of power in the centuries that followed.

NEW IDEAS, NEW WAYS OF THINKING

From the Middle Ages through the Scientific Revolution, European thinkers took ideas and information from many different sources and applied them to a variety of problems they observed in nature, in man, and in the cosmos. The sources they used came from Arabic translations of Ancient Greek texts and original publications by Muslim authors that had been translated into Latin. However, not all of these sources shared the same beliefs or assumptions about how the world worked. In fact, many of these ideas conflicted with traditional Christian doctrine and the Bible. Sometimes, this got people in trouble with the religious establishment and government for proposing ideas that conflicted with the Church. This was the case with Galileo, whose theory arguing that the Sun sat at the center of the Universe got him imprisoned in 1633, and then placed under house arrest for the remainder of his life. What exactly were these scientists, or natural philosophers, as they were known back then, doing and saying that angered their Church and government so much?

Throughout the Big History course, we've been using a variety of sources of evidence to understand how the world came to be and how humans have shaped communities, identities, and ideas over time. We've learned this habit of mind well, but the use of evidence and the testing of theories through the examination of evidence are relatively modern human inventions. The Scientific Revolution was really a revolution in thought processes that consisted of the following steps:

1. Read and discuss different theories about a phenomenon (for example, whether the Sun is the center of the Universe or not).
2. Draw on different sources of evidence from past philosophers or scientists to formulate one's own theory or hypothesis.
3. Conduct experimentation to observe the phenomenon.
4. Draw conclusions based on all of this evidence.

This is a version of the scientific method. This way of thinking challenged the idea that all human knowledge, both historical and scientific, could be found in the Bible.

But just how did this new way of thinking look in sixteenth-century Europe? Below is an example from Copernicus. As I read "The Earth Moves" from Copernicus' 1543 book, *On the Revolutions of Heavenly Orbs*, I'll look for the pattern of thought I just identified above as the scientific method.

> ***When I had thought for a long time about the uncertainty of the traditional mathematical doctrine concerning the paths of the heavenly bodies, it seemed to me very regrettable that no more correct theory had yet been advanced by philosophers for the movements in that universe which the best and most perfect Architect had made for us...***
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> ***Therefore I took the pains to read through the writings of all the philosophers that I could get together in order to find out if some one of them had not stated the opinion that the movements of the heavenly bodies might be other than the professional mathematicians had claimed. And I did find...that Nicetas [Byzantine bishop and writer on religious topics] had thought that the Earth moves. I read in Plutarch [Greek biographer and historian] that some others also had been of this opinion.... (Webster 885 — 86)***

Copernicus is telling us that he is looking for an explanation of how the Universe is structured and how the planets and stars move and rotate — perhaps to create seasons on Earth. He says that he started by looking at "traditional mathematical doctrine" to see how math explained the rotation pattern of the planets ("heavenly bodies"). It's interesting that he mentions God, the "most perfect Architect," as the one who "made" the Universe. So he's not really considering how the Universe came to be, just how it functions, or how the planets and stars operate in relation to one another. He states that he then read through all the philosophers he could find who wrote about the pattern of how planets move — these would be examples of my steps 1 and 2. His sources of evidence come from a Byzantine bishop and a Greek biographer and historian. It's interesting that neither of these persons is a scientist, even though they seemed to be writing about what we now call the Solar System. I read on and find out what he did next:

> ***When I had received this suggestion I began myself also to meditate upon a motion of the earth. And although this theory might seem nonsensical, yet because I knew that others before me were allowed the liberty to suppose all sorts of circles in order to explain the phenomena in the heavens, so I too would be permitted to try whether building on the theory of the earth's motion I might find more satisfactory explanations for the movements of the heavenly bodies.***
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> ***After I had then assumed the motions which I assign to the earth in the following work, I found, after careful investigation extending through years, that if the movements of the other planets were referred to the motion of the earth in its orbit and reckoned according to the revolution of each star, not only could their observed phenomena be logically explained, but also the succession of the stars, and their size, and all their orbits, and the heavens themselves would present such a harmonious order that no single part could be changed without disarranging the others and the whole universe. In accordance with this theory I have drawn up the plan of my work.... (Danielson 108)***

Here he states that he is attempting to form his own theory and then says that the work presented here (this is the introduction to that larger work) is the result of "careful investigation extending through years." This speaks to my step 3 of the scientific method. He spent years tracking what I assume is the path of specific stars through observation and through mathematical projections. That is some commitment! But, then again, I know modern scientists also spend years collecting data and refining their theories in relation to that data. He states that these observations led him to conclude that the Universe is "a harmonious order" — in other words, a system. Let's see how he ends this section:

> ***The first thing for us to realize is that the universe is spherical. This is so either because, of all forms, the sphere is most perfect, requiring no joins; or because it is the most capacious, and so best fitted to enclose and preserve all things; or because all things strive to be bounded thus, as we observe in drops of water and other liquids. There can be no doubt, then, about the rightness of assigning this shape to the heavenly bodies. (Webster 885 — 86; Danielson 108)***

What's interesting about this conclusion to me is that it seems so obvious. And yet, until Copernicus spent years gathering data, the idea that the Solar System is a sphere had never been technically proven. This refers to my step 4, above. And it is also the heart of what the scientific revolution was about — using multiple sources of evidence to describe humans, the world, and the Universe. What we now accept very generally as the basis of how knowledge is formed came about a mere 500 years ago.

To see another example of this pattern of thinking in action, I'm going to turn to Francisco Redi's work on insects from his 1668 book, *The Generation of Insects*. Again, I'm going to look for his pattern of thought: Does he move from his theory, to evidence, to conclusion?

> *It is not only the popular belief, but it is also stated authoritatively by both ancients and moderns that the rotting of a dead body, or any sort of decayed matter, can give being to worms just by itself. Desiring to trace the truth of the case, I made the following experiment.*
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> *I ordered three snakes to be killed…[and] placed them in an open box to decay. Not long afterwards I saw that they were covered with worms…intent on devouring the meat…. When the meat was all consumed, the worms eagerly sought an exit, but I had closed every opening. Nineteen days later, some of the worms ceased all movements…and appeared to shrink and gradually assume a shape like an egg… I placed these…separately in glass vessels, well covered with paper, and at the end of eight days…from each came forth a fly….*
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> *I continued similar experiments with the raw and cooked flesh of the ox, deer, buffalo, lion, tiger, dog, lamb, kid, rabbit; and sometimes with the flesh of ducks, geese, hens, swallows, etc. Finally I experimented with different kinds of fish…. In every case, flies were hatched. Almost always, I saw that the decaying flesh and the cracks in the boxes where it lay were covered not alone with worms, but with the eggs from which, as I have said, the worms were hatched….*
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> *Having considered these things, I began to believe that all worms originated from the droppings of flies, and not from the decay of the meat. I was still more confirmed in this belief by having found that, before the meat grew wormy, flies had hovered over it, of the same kind that later bred in it. Belief would be vain without the confirmation of experiment.*
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> *Therefore, I put a snake, some fish, some eels…and a slice of veal in four large, wide-mouthed flasks. Having well closed and sealed them, I then filled the same number of flasks in the same way, only leaving these open. It was not long before the meat and the fish, in these second vessels, became wormy and flies were seen entering and leaving at will.*
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> *Outside the closed flasks, on the paper cover, there was now and then a deposit, or a maggot that eagerly sought some crack through which to enter and feed. But in them I did not see a worm. Meanwhile, the different things inside the flasks had become putrid and stinking…*
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> *I thought I had proved that the flesh of dead animals could not generate worms unless the eggs of live ones were deposited therein. (22 — 36)*

There's nothing like a bunch of rotting meat to teach us about bugs! In this passage, Redi begins by referencing "popular belief" by "ancients and moderns" that worms came from decaying bodies. He then set out to prove or disprove this belief by watching lots of different types of dead meat decay over time and tracking what he observed. His first experiment with dead snakes revealed worms did indeed appear, but so did eggs that produced flies. He then reproduced the experiment multiple times with different types of meat (above he lists 13 different animals!). This is a key technique in modern scientific experimentation: The results of one experiment must be confirmed by results from multiple replications of that experiment with the same conditions. Finally, he chose to produce a control group of meat (uncovered) and a new treatment for the meat (sealed). By comparing the results of the control with the new treatment, he then deduced that the worms came from eggs, not from the dead meat itself. This explicit pattern of experimentation would become the gold standard of scientific proof. This, in essence, was the birth of modern science.

These brief passages explored above were part of large texts published and distributed throughout Europe. They are just two examples of how these thinkers — now called scientists — approached the problem of explaining phenomena in the world. Copernicus, Redi, and their peers around Europe contributed to establishing reason, evidence, and proof as central in human thought. They helped to usher in the Age of Enlightenment and a reliance on observation and experimentation over religion to study and explain the natural world.

Working Bibliography & Notes

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This short journal entry is an example of how historians go about exploring important questions and looking at new information. They use a mixture of historical documents and the writings of other historians to inform their thinking. All sources are listed in the working bibliography.