Scientific Revolution: Crash Course European History #12

Crash Course: European History
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Hi I'm John Green and this is Crash Course European History.

Okay so look: It has been bleak so far. We've had the Black Death, the 116 Years' War, a series of religious wars that culminated with a 30 Years War that killed 20% of Central Europe.

We've had the little ice age and witch murdering mania and the Atlantic slave trade but now, now we get to turn our attention to the scientific revolution, which profoundly reshaped our understanding of the universe and ourselves. At last, we are going to make real, undeniable progress. What's that?

Oh, Stan tells me that many of these scientists were persecuted for sciencing. Great. But that doesn't stop humans from developing the central insight that reshapes human history.

It's about to get really heliocentric around here... [Intro] Before we get into the scientific revolution, I just want to make one broad comment that might be obvious if you've watched previous videos in this series: For most of human history, people did not expect to live healthier or more prosperous lives than previous generations. Sometimes life got better, and sometimes it got worse. It's true that human populations were increasing and that life expectancy was increasing gradually, but the idea that it is normal for human life to get better over time is very new.

Today, most European countries have high life expectancy, low maternal mortality, and low rates of absolute poverty. But there have been about 10,000 generations of humans, and we are perhaps the 10th generation who could reliably expect disease burden and child mortality and poverty to steadily decrease in our lifetimes. Well, I'm part of the 10th.

You're probably part of the 11th. But regardless, we owe much of this change to the Scientific Revolution. So, like the Reformation, the Scientific Revolution was another break with religious teachings.

The Catholic Church taught that the earth was the center of the universe and had been so since the Creation. The sun, moon, and planets traveled around the earth in perfectly circular orbits like the rings of an onion. And beyond the onion was the realm of the divine, whose light pierced through in the form of stars.

All this perfect motion was the work of God Himself. And any other understanding of the universe was thus a challenge to God's eternal perfection as described in the scriptures. But, like good Renaissance people, the new astronomers, mathematicians, and their colleagues in other fields declared that old theories needed to be reexamined.

The first problem was that the perfect orbits of the planets, and moon, and sun did not fit with observation, causing astronomers to resort to ancient Ptolemaic explanations (basically that planets followed their own circular paths, which also revolved around the Earth). Just before his death in 1543, Polish-born Nicholas Copernicus, a well-connected doctor of canon law and researcher in mathematics, and astronomy, and classical literature, published On the Revolution of the Celestial Spheres. He noted problems with classical astronomical theory and determined that the universe was "heliocentric"—that is, the sun, rather than the earth, was at the center.

The Catholic Church's reaction to this was negative: the Italian monk Giordano Bruno, for instance, was burned at the stake in 1600 for teaching Copernicus's heliocentric findings. But even earlier than that, in 1572, Danish astronomer Tycho Brahe spotted a new star and in 1577 a new comet, further confirmation that the universe was not immutably and perfectly created. Then, Johannes Kepler's laws of planetary motion announced early in the seventeenth century that the orbits of the planets were elliptical—not perfectly circular.

The solar system was a solar system, and it wasn't an onion. Something other than divine will was keeping the planets apart and in motion. Let's go to the Thought Bubble.

By this time, the observations of Galileo Galilei were bringing matters to a head. Galileo was obsessed with science, especially its mathematical features and the calculations at the base of Copernicus's heliocentric theory. Galileo's father had wanted him to become a doctor but mathematics drew him in.

It's the oldest story in the world. He invented many tools like an early thermometer and his own telescope, which he used to dramatically improve human understanding of the universe -he was the first person to observe the moons of Jupiter, and the first to understand that the Milky Way was a collection of stars. The telescope also showed irregular spots on the sun, a further sign of heavenly imperfections that went against the beliefs espoused by the Catholic Church.

Despite Galileo's prestige as a mathematician, his work on the nature of the universe went too far for the Church. In 1615, Galileo went to Rome to teach the clergy about the heliocentric universe and convince them of its accuracy. In 1616, it was condemned as heretical and Galileo promised not to teach that the earth moved.

But, in 1632, he published Dialogue Concerning the Two Chief World Systems in which he described the Ptolemaic system on which the Church based its earth-centered astronomical teachings and the Copernican system. In 1636, the Roman Inquisition found him guilty of heresy and forced him to recant in order to avoid execution. And so Galileo recanted.

In 1992, after a 13 year investigation, the Catholic Church finally publicly acknowledged that the judgment against him had been wrong." Thanks Thought Bubble. Centuries later, Albert Einstein would write, "All knowledge of reality starts from experience and ends in it. … Because Galileo saw this, and particularly because he drummed it into the scientific world, he is the father of modern physics--indeed, of modern science altogether." We talk about this at length of course in our history of science series, but for our purposes here it's important to understand that Galileo and other scientists used experimentation and mathematical calculation to confirm or refute hypotheses--and that scientific method was genuinely revolutionary. The scientific approach also spread to other fields of inquiry.

Ancient medical theories began to unravel, as English medical doctor William Harvey pronounced the heart to be a pump based on dissections he'd performed. He called the heart "a piece of Machinery" that worked according to natural laws. But it's important to note that even as mechanical theories took hold, prominent "new" scientists continued to believed in unseen forces at work in the universe.

For example, astrology, positing that the planets and stars influenced people and events, sought to map those influences. Some scientists found it credible --and they pursued all kinds of mystical, and occult, and alchemical investigations. Any revolution needs good propagandists, and people were advertising that the "new" scientific values and practices were amazing while also pointing out that the ancient and traditional ones were full of errors.

English politician Francis Bacon was foremost among these science propagandists, chiding everyone who was using the old paradigms and models of the universe—calling them worthless ancients. Bacon, like others at the time, created his own careful observations, and

experiments, and sought to use reason. There was, he said, a scientific method to be followed.

One needn't rely on past accounts that were copies of copies of copies--one should ask their own questions, and do their own experiments to find the answer to those questions, experiments that other people could then replicate to confirm--or refute--the findings. And this became the basis for the new scientific method as Bacon laid it out in The Advancement of Learning. His process of reaching the truth and drawing conclusions from specific, reliable facts or evidence is called inductive reasoning.

And a collection of reliable, verified evidence was essential, according to Bacon, not "old wives' fables" or, as another new scientist put it, not "maunderings of a babbling hag"—words that were part of the discourse of witches who were being tried and murdered at the time. And then there was French philosopher René Descartes who moved speculation about the new science to a still different methodological register by looking at the mind. Descartes noted that reason—thinking—was made for verification, so thinking on one's own was crucial.

Because, otherwise there were so many facts that one could essentially become skeptical about whether truth actually existed. Like imagine a world where there are facts, but there are also "alternate" facts, and you have to choose between your set of facts before you reach a conclusion. That would be unlivable!

So Descartes set out to prove the one thing he felt he could be sure of. His own existence. And in doing so, he prioritized his own power of thinking: "I think therefore I am." But he also prioritized doubt, which is central to the scientific method--Descartes also wrote, "We cannot doubt of our existence while we doubt." In short, our ability to conceive of doubt about whether we exist, is proof that we exist.

By privileging the role that thought, and with it questioning, play in discovering truth, Descartes had developed deductive reasoning: that is, faith in the rational power of the mind to generate specific truths from its own theories or power of thinking. (By the way in addition to a Crash Course in the history of science, we also have a crash course in philosophy, where you can learn more about Descartes.) Okay, let's turn our attention to Isaac Newton, who synthesized new methodology and his own findings in his universal laws of motion. Newton was a scientist with a reputation for following every lead, Newton practiced alchemy—that is the quest for secret formulae and practices, especially an entity called the philosopher's stone that could turn lead or other base metals into gold. Which by the way would be an inflationary disaster, but fortunately it's impossible.

But I think that's important to note because it reminds us that not every lead being followed by scientists--then or now--results in big discoveries, but part of the glory of science is learning what doesn't work. Also, it reminds us that in the 17th century, many of the smartest people in the world believed in alchemy, a nice opportunity to reflect on what false promises contemporary humans might believe. At any rate, while studying alchemy, he also pulled together the findings of his predecessors into mathematical laws for the functioning of the universe.

He quantified the major constructs of mass, inertia, force, velocity and acceleration and produced the law of gravitation. And he encapsulated all his findings in his Principia Mathematica in 1687. For Newton, the universe was indeed a fantastic, regular, and all encompassing machine, yet it was a machine still tinged with the mysteries that he continued to decipher, and to be fair that we are still deciphering today.

By the early decades of the seventeenth century, contact with the wider world led to other kinds of scientific investigations. Adventurers brought back to Europe new species of plants, and textiles, minerals, animal life that sparked wonder and scientific probing. One of the first to venture out was Portuguese doctor Garcia da Orta.

He traveled first to Goa, India, studying plants like aloe, cannabis, coconut, and ginger. In 1563, he published Conversations on the Simples, Drugs and Medicinal Substances of India, which advanced the use of plants as medicine. Local people were key to major plant discoveries: Dr. da Orta, for instance, learned from healers in South Asia, while in the 1620s local people in Lima cured a Jesuit priest with malaria by giving him the medicine they used--quina-quina.

Eventually this healing bark was turned into quinine, a malaria medication that allowed Europeans to expand their empires more deeply into Africa and South America. In the cases of both Doctor da Orta and the Jesuits in Peru, European advances, like others that would follow, depended on gathering up scientific and medical knowledge from other people. Within Europe, scientific networks developed around heliocentrism and also around other new ideas just as they had in the Renaissance.

Like Erasmus and his correspondents, Galileo and scientists across Europe wrote one another and published books about their findings. The Royal Society of London had its "republic of letters." And communication like that became pivotal both to verification and to convince as much of the public as possible that these new scientific discoveries were valid. Amid warfare, the little ice age, and famine, these scientists were corresponding about comets, windmills, pumps, and blood vessels.

Theories about vision and atomism passed around in letters, reached as far as the Ottoman Empire and Japan. Governments also got in on the Scientific Revolution, giving scientists like Galileo stipends to support their work, and labeling them "Court Mathematicians," which added prestige both to the scientist and the royal court itself. Louis XIV of France started one of the most prestigious scientific academies—the royal Academy of Sciences—in 1666.

And Theaters of anatomy, where dissections and other physiological demonstrations occurred, also received official sponsorship. Oh, did the globe open at last? Is Yorick in there?

Alas, poor Yorick... I didn't know eyebrows were a skeletal feature. For the first, like, 98 percent of history, we knew so little about how all of this works.

Look, I'm never going to be a ventriloquist, OK? Stan, this isn't a real skull, is it? Ugh!

We will examine the mounting power of the state next week beyond its sponsorship of science. For the moment, let's reflect on the ways in which so-called new scientists during the sixteenth and seventeenth centuries bravely took religious scriptures out of the workings of astronomy and the heavens. Instead of a divine hand at work, by the time of Newton, universal laws for the operation of the solar system and physical bodies had been established.

Although most people believed in God, many of them earnestly so, they also followed a developing scientific method and additionally established faith in their own rational powers. This way of looking at the world would prove so important that less than 350 years after Galileo became the first person to observe the moon's cratered surface, human beings would step foot on that surface. Thanks for watching.

I'll see you next time.