# Roman Engineering: Crash Course History of Science #6

Crash Course: History of Science
https://youtube.com/watch?v=GcReek3z_38
https://nerdfighteria.info/v/GcReek3z_38

**===== (00:00) to (02:00) =====**

[intro music]

Hank:

The Romans invented concrete over 2000 years ago and built roads that are still around today. They used arches and domes to create monumental buildings with big airy interiors that looked truly Olympian - also still around! And they moved thousands of tons of water using aqueducts to keep a bustling population unthirsty. These old buildings, all still around!

But did Romans come up with the ideas about physics, like why arches support weight differently than right-angled structures? Did they ask proto chemistry questions like "what is stuff?" and "what is the tiny things that make up good concrete"? Nope. Let's look at what knowledge the Romans made in order to set up a debate that - SPOILER ALERT - is still going on!

Do you understand something when you can explain why it's true in the abstract? Or do you understand something when you can do things with it, even if you can't explain why?

[intro]

The Romans inherited much of their knowledge from the Greeks. From 323 to 31 BCE, the geometry, physics, astronomy and other disciplines developed by the pre-Socratics Plato and Aristotle spread throughout the Hellenistic world. This world combined parts of Asia, Africa, and Europe, influenced by Greek thought, due in large part to Alexander's brief supervillain rampage.

In Alexandria, Egypt - the biggest of 70 cities that Alexander named after himself - the kings paid for the museums or house of muses. This wasn't a museum in the modern sense of the word, but more like a research university. In Pergamon, and what's now Turkey, the kings paid for the library, which was - wait for it - a really big collection of books! These institutions lasted for centuries drawing visitors from far and wide. Alas, over the same period of time that these Greeks were supporting research, a tribe from central Italy called the Romans, went on a new supervillain rampage, [that also lasted for centuries.]

**===== (02:00) to (04:00) =====**

[...the Romans, went on] a new supervillain rampage, that also lasted for centuries. The Romans would continue to spread classical Greek thought. We even called their culture Greco-roman. But natural philosophy during Greco-roman times didn't advance much. Today we remember the roman for their engineering or ability to improve some real-world system - and not their deep thoughts about why the world is the way it is.

Roman engineering - built on Greek engineering, and making knowledge is political. And most politicians really want the same things - bigger catapults and lots of ships. So Greco-roman leaders did what heads of state everywhere have always done. They paid smart people to make bigger weapons.

In the ancient Mediterranean, the job of building war machines was called architecton, or architect. Most of these architects were anonymous, did not write down their theories. But, a few of them did. The most famous architecton, Archimedes of Syracuse, fought for the Greeks against the Romans. Archimedes is famous today as a mathematician. He worked out many geometrical proofs including the area of a circle and pioneered infinitesimals and exponents. Archimedes also invented a lot of useful contraptions including the water screw and compound pulley. Water-screw pumps water by turning a screw inside of a pipe. This was immediately useful in irrigation. And a mechanical way to move water uphill is just plain cool!

Archimedes also designed various war machines to kill the Romans who were trying to take over his hometown. He was so impressive that the Roman general ordered his troops to capture, not to kill him. But one soldier, particularly low on chill got frustrated when Archimedes wouldn't stop working on a mathematical proof. In a sense, Archimedes kept it so real, that he got himself, and symbolically an era of Greek science, killed.

Archimedes was interested in some of the natural philosophy that explained his machines. But for most other thinkers of his time, astronomy, physics, and math were important for abstract quasi-religious reasons. Making weapons was a matter of political power. The heavens from which rain fell were perfect and abstract.

**===== (04:00) to (06:00) =====**

Shipbuilding was an art - something that was learned from practice. It was not a matter of understanding hydrodynamics or the chemical properties of wood that made it bendy and floaty.

Aristotle came up with a handy division between these types of knowledge that we still use today. He classified knowledge as either useful or theoretical. Useful knowledge was called techne - which is where we get technology. Technology has until recently, in historical terms been connected to the idea of art. Meaning something you can learn by doing and can see in the real world.

Theoretical knowledge, on the other hand, was episteme the root of our word epistemology, the study of knowledge. Episteme is the sort of knowledge that we most associate with science. Science is abstract, represented by formulas. When historians of science talk about the possibilities of what we can know, they use the word epistemic.

One of the most influential thinkers working on epistemic questions during the greco-roman period was Claudius Ptolemy, a Greek or Greek speaking southern Egyptian living in roman held Alexandria. In addition to optics and the science of music, Ptolemy took up plato's old problem of how to fit the observed data about how the planets all moved, to the theory of the cosmos made up of perfect circles with earth at its center. He got really really into this, mixing together three kinds of solutions in order to make the math work.

Epicycles, for example, were the tiny circles that the planets moved along around bigger circles. Ptolemy's version of the cosmos, a mathematically neater version of aristotle's and plato's, became the basis of the understanding of the universe across much of the medieval christian and Islamic world. His great astronomical work the "mathematical syntaxis" was named by Arabic scholars as the "almagest" or the greatest.

Fun fact: the almagest may have been edited by one of the first recorded female natural philosophers, Hypatia of Alexandria. So we're on episode 6 of history of science and yes, this is the first mention of a woman.

Ptolemy was also pretty much the authority on earthly geography in the greco-roman world. His book on the subject called "Geography" [discusses the data he uses and why.]

**===== (06:00) to (08:00) =====**

[His book on the subject called "Geography"] discusses the data he uses and why. It provided a source for other scholars to use in more accurately picturing and drawing the world for centuries. Oh, and

none of these thinkers thought that the earth was flat! Flat earth theory may have more proponents today than it did in greco-roman times.

As Ptolemy shows, epistemic work was important to a few Greco-Romans. But what they really are remembered for is their techne, their engineering. For example, people had been mixing together water and rocks to make cement for generations. But by 150 BCE the Romans began mixing volcanic ash, rocks, water, and lime to make roman concrete or "opus caementitium". Which is one of those technologies that he smartypants like to call "a big frickin' deal".

This new stuff was super durable and could be poured into weird shapes like domes. The pantheon, or really big temple, in Rome is capped by a 143-foot diameter dome of concrete that has stood for almost 2000 years. But the Romans found out that arches support more weight than straight joints. This matters when you're trying to move something really heavy, like water. Thus, Romans were able to move water long distances using archy aqueducts. This, in turn, allowed roman cities to grow in population, mines to run, and dry lands to be irrigated.

The Romans changed their lands in other ways too. They drained the marshes of their home city using innovative sewer system called the "cloaca maxima". Which literally means "biggest sewer". So great name my dudes.

The Politician and civil engineer Sextus Julius Frontanus wrote a landmark comprehensive two-volume report on the design for the aqueducts and sewers of Rome, which luckily a renaissance scholar found a copy of, just as the city recovered from roughly 1000 year downturn in population. Yes, that's right. Roman infrastructural engineering lasted through a millennium of neglect and still worked. But as great as gigantic open rooms, fresh drinking water, and big big sewers are, the most important feat of roman engineering may have been their highways. We hear a lot about infrastructure today and [states have always...]

**===== (08:00) to (10:00) =====**

[We hear a lot about infrastructure today and] states have always made roads to foster trade and move troops, but roman road builders took the art of logistics to another level. Show us what a big deal this was, thought bubble.

Consider the Appian Way, running from Rome south east through the hill (?) Italy, it connected several not very urbanized regions of the peninsula. Its first leg was built in 312 BCE before roman concrete was perfected, using cement over layers of fitted stones and gravel. Drainage ditches lined its sides and the road was cambered to allow water to drain off. The appian way allowed roman troops to efficiently crush their enemies. It was expanded over the centuries, and the appian way is still around. The cement has eroded away but you can see many long very straight sections. It's lined by trees and marked by monuments and haunted by history.

And the Appian way is only one of several well-preserved 2000-year-old roman roads crisscrossing Africa, Asia, and Europe. Metaphorically, all of these roads led to Rome. For citizens paid taxes toward many large-scale public works such as highways. Perhaps the most important technology the Romans optimized was the state itself: they developed a complicated legal system, a well-supplied army, public food assistance, and massive public games.

One side of these games was the flavian amphitheater, also known as the Colosseum. It had a retractable roof that was staffed by sailors who used complicated rigging to move the canvas coverings around, and it was sometimes flooded to allow for naval war games. How many engineers today know how to properly rig giant sun sailor, safely flood a public venue without using plastic? Thanks thought bubble.

But these public works were intended for Romans, not for their property. Before the industrial revolution, public works such as aqueducts, sewers, and roads, required quarrying lots of materials but also required lots and lots of labour. And by labour, i mean slaves. Some estimates [hold that one in three people...]

**===== (10:00) to (12:00) =====**

[Some estimates] hold that one in three people in roman Italy were enslaved. These people were involved in knowledge creation, if against their will, by building and maintaining all of these great roads and other structures. Roman slavery was a little different than plantation slavery in the American south. Slaves could be highly educated. Many physicians were even slaves. They could buy their freedom and become voting citizens but most remained chattel, meaning property.

In 73 BCE, the gladiator Spartacus famously led a slave revolt in Italy. The freed slaves fought the army for two years but they were eventually defeated. The survivors of the rebellion were crucified along the appian way from Rome to Capua, over a 100 miles to the south. Brutal story, but worth telling in the context of roman engineering. Because the technologies that engineers make are, like the sciences, political - only as good or as bad as the humans who use them.

Roman thinkers left behind written sources including religious texts, histories, plays, proto-novels, poems, legal manuals. But only a few roman texts deal with natural philosophy. Frontius's guide to aqueducts was one exception. Another was vitruvius's architecture. He wrote about building but also about urban planning and even the plan of the human body. By linking the limbs of the human body to mathematical principles, vitruvius inspired daVinci's vitruvian man. Vitruvius's architecture sums up the concepts about knowledge common to the Hellenistic and greco-roman worlds. It's a technical manual also concerned with a beautiful harmonies of form inherent to bodies as well as the efficient management of cities: the body politic.

Next time we'll meet mechanical wonders and the wonder of public health care in the Abbasid Caliphate's great capital, Baghdad.

Crash Course History of Science is filmed in the Dr. Cheryl C Kinney studio in Missoula, Montana and it's made with the help of all of these nice people and our animation team is Thought Cafe. Crash Course is a Comlexely production. If you want to keep imagining the world complexly with us, you can check out some of our other channels like the Financial Diet, the Art Assignment, and Healthcare Triage.

**===== (12:00) to (12:17) =====**

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