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War Machines of Archimedes

Martyn Shuttleworth 59.5K reads

Archimedes (c. 287 BCE - c. 212 BCE) was a truly great inventor, mathematician and philosopher, writing many insightful and extensive treatises on geometry and applied mathematics. His work on pulleys and levers was a scientific landmark, one that would directly influence the work of both Islamic and Renaissance scholars.

Most of his inventions were designed to test his theories practically and he saw himself as a mathematician first, inventor second, although inventions such as the Archimedes screw are still used today. He is truly one of the greatest minds of all time, and earned his place in the history of science as one of the great scientists and mathematicians whose name echoes down through the ages.

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Archimedes and the Siege of Syracuse



One area in which Archimedes excelled was in the design and construction of great war machines, a useful talent in a dangerous world where his home city of Syracuse was under constant threat from the Romans. His legendary war machines struck fear into the Roman soldiers and sailors and ensured that Syracuse held out for three years against an extended Roman siege. Theater at Syracuse (Creative Commons) [1]

The evidence and knowledge of his work on machines of war comes to us second hand, from later historians such as Polybius, Livy, and Plutarch and, naturally, it picked up a lot of mythology and embellishment during the process. We will explore some of these great machines and see if any of them worked, helped by the work of experimental archaeologists.

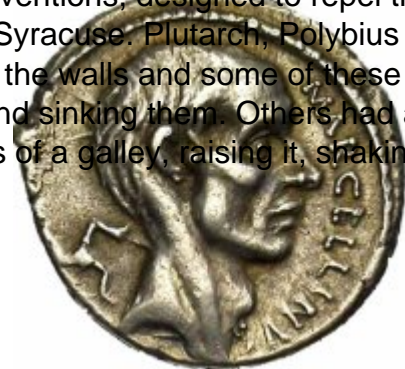
The Siege of Syracuse

In 215 BCE, the Roman navy and army attacked Syracuse and, to help the hard-pressed city folk, Archimedes [2] designed a number of war machines to fight back. Some of these titanic machines seem to have been stone throwers or large crossbows, but the ancient historians tell of other inventions. These include the notorious Archimedes Claw, which used a crane and grappling hook to reach down and grab Roman galleys, eventually capsizing them.

His other alleged idea was using mirrors or polished shields to focus sunlight into a point and set fire to wooden ships, an invention commonly referred to as the Archimedes Death Ray. With a name like that, it is asking to be built and tested, something that the Mythbusters [3] could not resist!

The Archimedes Claw

The Archimedes Claw is one of the most notorious of his inventions, designed to repel the powerful fleet of Roman galleys from the seaward walls of Syracuse. Plutarch, Polybius and Livy all speak of huge beams that could be swung out over the walls and some of these dropped huge weights, punching holes through the ships and sinking them. Others had a claw or grappling hook, which grabbed hold of the rigging or rails of a galley, raising it, shaking it and capsizing it. For example, Plutarch wrote:



Plutarch (45 CE -120 CE)

Parallel Lives: Marcellus

At the same time huge beams were run out from the walls of Marcellus (Public Domain) Roman ships: some of them were then sunk by great weights dropped from above, while others were seized at the bows by iron claws or by beaks like those of cranes, hauled into the air by means of counterweights until they stood upright upon their sterns, and then allowed to plunge to the bottom, or else they were spun round by means of windlasses situated inside the city and dashed against the steep cliffs and rocks which jutted out under the walls, with great loss of life to the crews. Often there would be seen the terrifying spectacle of a ship being lifted clean out of the water into the air and whirled about as it hung there, until every man had been shaken out of the hull and thrown in different direction, after which it would be dashed down empty upon the walls.

Translation by Ian Scott-Kilvert in *Makers of Rome: Nine Lives*, Penguin Classics, New York, 1965.

Did the Archimedes Claw Actually Exist?

The question is whether this device actually existed and worked or if the later historians embellished the tales. To investigate this requires two stages, firstly looking at the work of Archimedes and establishing that he had the mathematical and mechanical knowledge to build such a device, before looking at whether such a war machine would have worked.

Even though Archimedes left no designs for this device, so we cannot be sure that he designed or built one, his expertise in other fields certainly brings it within the realms of possibility. His work, 'On Levers', showed a sophisticated knowledge of forces and equilibria, and designing the claw with pulleys and a counterweight is theoretically possible with this level of knowledge.

'On Buoyancy' suggests that he was fully aware of the delicate equilibrium that prevented a Roman galley from sinking and the relatively small amount of force needed to capsize one. Speculatively, we can state that he was capable of devising and building such a device, so the next question is whether such a device is practical.

The Archimedes Claw and Experimental Archaeology

The main issue is whether such a device would be practical rather than theoretical - it is all well and good knowing how to make such a machine but, given the weaknesses inherent within natural materials and imperfect manufacturing techniques, would such a device have actually worked?

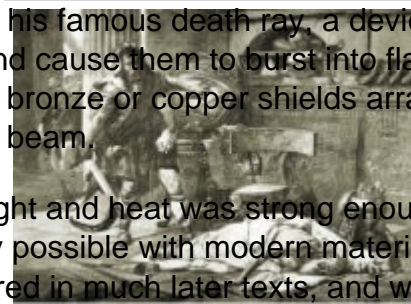
Experiments with scale models showed that the principle of lifting the entire bow out of the water and lifting it might not have been necessary for the claw to work. The operators of the machine could have dropped the grapple next to the ship and then dragged it sideways, as found in the BBC documentary, "Secrets of the Ancients", in 1999, and by a Discovery Channel program, "Superweapons of the Ancient World", in 2007.

They capsized scale models of galleys and, considering that the Roman galleys would have had siege ladders raised, making them even more unstable, then this device seems plausible. Although there is no direct proof that Archimedes did build such a device, there is little doubt that theoretically and practically, it would have worked.

Even if the Archimedes Claw did not exist, it is entirely possible that the Syracuseans installed beams to swing out and drop heavy weights on the decks of the attacking ships. Undoubtedly, the attacking forces came under a hail of stones and arrows from various war machines while approaching the walls, and these great beams would further demoralize the Roman sailors.

The Archimedes Death Ray - Fact or Fiction

The most controversial of Archimedes' war machines is his famous death ray, a device that could focus sunlight onto the wooden Roman galleys and cause them to burst into flames. The device consisted of a large array of highly polished bronze or copper shields arranged in a parabola, concentrating sunlight into a single, intense beam.



According to the later historians, this intense beam of light and heat was strong enough to set ships aflame, a principle well known today and certainly possible with modern materials and manufacturing techniques. However, this device appeared in much later texts, and was not mentioned by the ancient historians of antiquity; Lucian (120 CE - 180 CE) and Galen (130 CE - 200 CE) reported that Archimedes set fire to ships through artificial means, using mirrors or highly polished shields to focus the rays of the sun.

Again, in all probability, Archimedes would certainly have had the knowledge for this invention, but the problem is that it is open to question whether such a device was practical. A group of students from the Massachusetts Institute of Technology tested the invention with 30cm (12") mirror tiles, and did manage to create a charred patch and some flames at a range of 30 meters (100 feet), but this was under perfect conditions and there was little sign of the test ship bursting into flames.

The TV show, Mythbusters, tested the principle using authentic methods to build the array and asked the MIT group to try again, but the results were again underwhelming. There is still some doubt, but the evidence from experimental archaeology and literature suggests that reports of the Archimedes Death Ray were embellishments. However, the myth certainly isn't dead.

Archimedes - Catapults and Stonethrowers

Historians tend to look at the Archimedes Claw and the Death Ray as the prime examples of the contributions of the inventor to protecting his home, but there is little doubt that it was the less distinguished weapons that had the greatest impact.

Archimedes created huge stone-throwers that could hurl 500lb boulders at approaching ships and soldiers but, crucially, Polybius (c. 200 CE - c. 118 CE) stated that the operators could change the range of the weapons. The historians also related how Archimedes constructed the defenses of the city to incorporate smaller and smaller weapons, ensuring that the Romans had to endure a constant barrage of projectiles while advancing.

This layered defense culminated in 'The Scorpion', a small catapult fixed at loopholes in the wall, firing deadly iron darts at the enemy. Even if the Claw and the Death Ray owe more to legend than reality, there is little doubt that these simpler weapons would have been enough to demoralize the Romans, striking fear into the troops.

Eventually, Marcellus resorted to laying siege and attempting to starve the defenders of Syracuse rather than send in more troops; it was only when pro-Roman defender betrayed the city and let in the Romans that the city finally fell.

The War Machines of Archimedes - Fact or Fiction

Archimedes, while a brilliant mathematician and inventor, certainly attracted a lot of

mythology, achieving an almost legendary status. We can never be certain that he built any of his war machines, although there is little doubt that he had the theoretical ability to do so. Certainly, the historical literature and the reconstruction attempts suggest that a version of the Archimedes Claw was used at Syracuse and that it caused fear amongst the Roman besiegers.

The Archimedes Death Ray appears to be more fanciful, and it is unlikely that such a device would be practically unusable with the materials and manufacturing technology available at the time, although the theory is certainly sound. The records of Lucian (c. 120 - 180 CE) and Galen (c. 130 - 200 CE) were written after the event, and Lucian merely suggested that Archimedes burned ships through artificial means, without further elaboration. There have been some tenuous suggestions that he invented Greek Fire, an ancient form of napalm, but he lived a few centuries before it came into widespread use.

Ultimately, much of the speculation surrounding Archimedes appears to be fictional, albeit built around a core of truth. Archimedes had such a brilliant and creative mind that it is little surprise that he attracted exaggerations, but these do not detract from his work and merely add an extra aura of mystery and magic to the story of his life.

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[1] <http://commons.wikimedia.org/wiki/User:Dedda71>

[2] <https://explorable.com/archimedes>

[3] <http://dsc.discovery.com/tv-shows/mythbusters>