

The Antikythera Mechanism

Fragments of the Antikythera Mechanism as seen at the National Archaeological Museum in Athens, Greece.
www.metmuseum.org



One of the greatest discoveries of ancient artifacts globally, it proves that humans conceived and constructed a mechanical cosmos much earlier than believed.... An epitome of Greek natural philosophy, it models the universe using mathematics, following the Pythagorean doctrine that numbers determine everything and describe nature.

-Dr. Xenophon Moussas, National and Kapodistrian University of Athens



Presented by the Nashville Parthenon
and the following underwriters:



In the fall of 1900, a group of sponge divers working near the tiny Greek island of Antikythera were amazed to discover an ancient shipwreck loaded with treasure. Recovered among the gorgeous statues and jewelry was a strange collection of battered bronze pieces, with traces of gearwheels, dials, and pointers.

The squashed crumbling fragments were so badly corroded that scant metal remained, but over a century later, the Antikythera Mechanism, as the pieces became known, continues to capture the imagination. Scholars believe it once took the form of 37 bronze gearwheels in a wooden case, similar to a mantelpiece clock, with a handle that was turned to move forwards and backwards in time. Instead of hours and minutes, pointers on the large front dial traced precisely the movements of the sun, moon, and planets through the sky. Two spiral dials on the back functioned as a calendar and predicted eclipses. Thought to

have been created around 150 BCE, the mechanism is often called the world's first analog computer. It is an amazing artifact of ancient Greek advancements in astronomy, mathematics, and technology that did not appear in Europe again for roughly 1500 years.

Beginning in the Hellenistic age of the Roman Empire, the story of the mechanism is one of disaster, discovery, scholarship, technology, and adventure that continues into the present. Featuring selected images, videos, and objects, the Parthenon Museum presents this illustrated history of the Antikythera Mechanism.

Special thanks to Dr. Xenophon Moussas for his considerable contributions to the research and production of this exhibit.

This is the rocky coast of Antikythera.

It was in this location around 65 BCE that a Greek cargo ship sailing towards Rome encountered a violent storm. The heavily laden vessel struggled against the gale winds and rain, but ultimately sank less than one hundred meters from the edge of this small island located between the Peloponnesian Peninsula and the island of Crete.

Image courtesy: iStock





Captain Dimitrios Kontos and his crew of sponge divers in two small boats at the Antikythera shipwreck site.

In the fall of 1900, two sponge diving boats were on their way home from the coast of North Africa when an unexpected storm forced them to shelter in the tiny harbor at Antikythera. Three days later, Captain Kontos led one of the boats out to a shallow spot known as Potamos, where diver Elias Stadiatis decided to see what he could find beneath the waves. Sinking 60 meters below the surface he reemerged five minutes later stating the sea floor was covered with the corpses of men, women, and horses –apparently flotsam from a ship wreck.

Kontos donned the wet diving suit and plunged into the clear blue water. Upon reaching the bottom he saw what he realized were marble and bronze statues. They had found a treasure ship. Taking an encrusted bronze arm with him for proof he triumphantly returned to the surface.

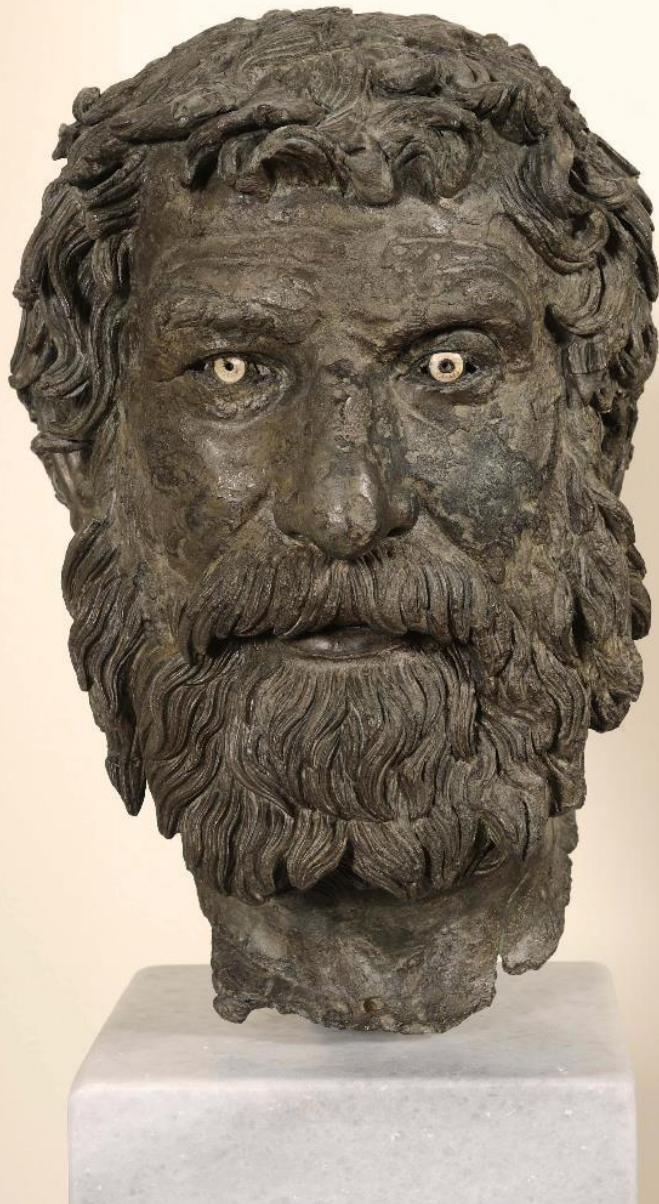
Image courtesy of American Philosophical Society

A Greek sponge diver from the twentieth century, wearing the standard diving suit of the period. The handmade copper and brass helmet weighed 40 pounds. This type of suit was used by divers during the 1900–1901 Antikythera shipwreck salvage.

A few weeks after their discovery, Kontos and Stadiatis took the bronze arm from the Antikythera sea floor to an archaeologist named A. Ikonumuan at the University of Athens. Ikonumuan connected them with Spyridon Stais, the Greek Minister of Education, who was eager to recover the objects from the Antikythera site. Kontos told Stais his men would dive for the ministry provided they were paid the full value of whatever they recovered.

In late November 1900, a Greek navy transport called the *Mykale* sailed to Antikythera, accompanied by Kontos and his two small sponge boats. For months, divers worked to get the art and artifacts from the sea floor to the deck of the *Mykale*. It was extremely difficult and dangerous work in water over 60 meters deep in places, hampered by inadequate equipment and bad weather. The operation ceased in September 1901 after a diver was killed by decompression sickness, also known as “the bends.” The fact that Kontos’s men were able to reach the wreck site with the equipment they had and complete the heavy work there was a remarkable achievement.





The Philosopher is a bronze head with striking ivory eyes recovered at the Antikythera site. Dated to the 3rd century BCE, it may be of the seminal Greek scholar and poet Philitas of Cos.

The 1900-1901 salvage operation recovered many bronze and marble statues, jewelry, glassware, oil lamps, ceramic amphoras, a sword, a bronze lyre, a giant marble bull and various fragments of furniture, including a throne. Among these treasures was *The Philosopher* whose disembodied hands, feet, and head suggest they originally comprised a complete life-sized figure. Considering that the objects were beneath the sea for over two thousand years, the bronze pieces survived well, but the marble pieces were badly eroded and disfigured.

The statues were transported to Athens and put on public display at the National Archaeological Museum where crowds flocked to see them. In contrast, many smaller fragments and artifacts were shipped directly to storage and remained un-cataloged for many years.

Recovered pieces of the life-sized *Philosopher* on exhibit in Athens.



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Salvaged by the sponge divers in 1901, The *Antikythera Youth* is a bronze life-sized statue, from the 4th century BCE. It is exhibited at the National Archaeological Museum of Athens.

Reassembled from over 20 recovered pieces, this two-meter tall statue from the Hellenic world is considered the prize of all Antikythera sculptures. Nicknamed The Antikythera Youth, he is thought to be Hermes, Apollo, or possibly Perseus holding the head of the Medusa.

Image courtesy of Louvre Museum



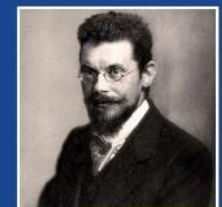
After their recovery many of the marble statues from Antikythera were placed on exhibit in an outdoor courtyard at the National Archaeological Museum of Athens.

Among them was this statue of a boy from the early first century BCE whose one side has been corroded by sea organisms, while the other, which was buried in the sediment of the sea bed, is preserved in excellent condition.

This early photograph of the object later known as “Fragment A” of the Antikythera Mechanism was taken in 1905 by German scholar Albert Rehm.

Among the Antikythera shipwreck artifacts stored at the National Archaeological Museum of Athens was a fractured lump of bronze that was falling into pieces. A museum employee noticed its intricate gear wheels and inscribed Greek letters and showed the pieces to museum director Valerios Stais. Impressed by the object, Stais contacted John Svoronos, an expert in ancient inscriptions to take a look. After considerable study, Svoronos concluded the pieces were part of an ancient astrolabe –a tool used to track the positions of the sun and stars in the sky. He published these findings in 1903.

Two years later, a German historian named Albert Rehm arrived in Athens to study the mysterious pieces. After making careful photographs, Rehm discovered the word “Pachon” on the surface of one of the fragments. Pachon is the Greek form of a month name in the ancient Egyptian calendar. Because the names of months would be useless on an astrolabe, Rehm concluded the object was a type of planetarium turned by intermeshing gears. Rehm’s theory was eventually proven correct.



Albert Rehm, ca. 1900



Image courtesy of X. Moussas

Portrait of Rear Admiral Ioannis Theofanidis, circa 1920.

Admiral Theofanidis began studying the mechanism in the 1920s and eventually confirmed that the large cross-shaped gear wheel on the main fragment engaged the rotation of smaller gear wheels inside. He originally believed the mechanism was used for sea navigation, but later agreed with Albert Rehm's assessment of a working model of the cosmos. Obsessed with solving the mystery of the fragments, Theofanidis sold off two buildings in the center of Athens to finance his reconstruction of the mechanism. His work represented the last major research on the subject before Europe was engulfed in World War II. The fragments of the mechanism were hidden during the German occupation of Greece in the 1940s and then forgotten by researchers for over a decade.



Theofanidis built this geared mechanism model during the 1930s.



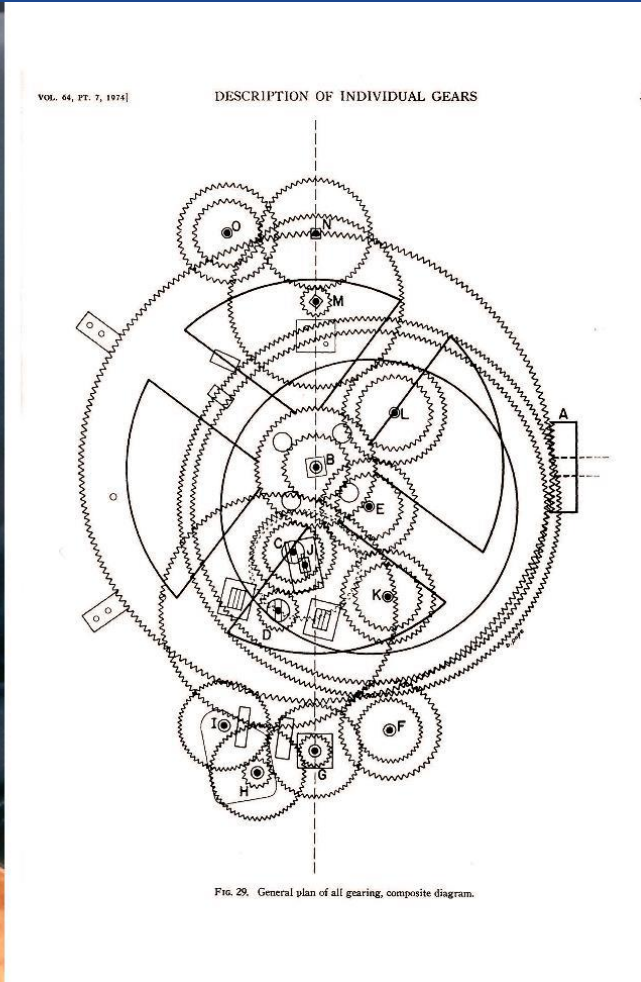
The Antikythera Mechanism: The Fingerprints of Genius, 2011.

This documentary by noted European filmmaker Phillippe Nicolette was funded by Swiss watchmaker Hublot, and is an accurate, concise overview of the mechanism.

Video courtesy of the Hellenic Republic Ministry of Culture



Link to video:
<https://bit.ly/3q5e4dg>



At left, Dr. Derek J. de Solla Price with his gear model of what he named the "Antikythera Mechanism." At right, one of the many diagrams from Price's 1974 study *Gears From the Greeks*.

Price, a British science historian and Yale University professor, began studying the mechanism after World War II. In a 1959 article for *Scientific American* he defined its function as "an ancient Greek computer" for "calculating the motions of stars and planets." According to Price, the mechanism was operated by a crank on its side, and displayed its output by moving pointers on dials located on its front and back. A user could set the machine to a certain date as indicated on a 365-day calendar dial while the gears in the mechanism yielded the corresponding information to that date in the other two dials. This included positions for the Sun, Moon, and five known planets, and the prediction of solar eclipses.

In 1971 Price collaborated with Greek radiologist Charalambos Karakalos to obtain the first x-rays of the mechanism's interior parts. Based on these new images, Price published a landmark 70-page monograph entitled *Gears from the Greeks: the Antikythera Mechanism—a Calendar Computer from ca. 80 B.C.* In this paper, he described and diagrammed 27 gears in the main fragment and estimated tooth counts for each.

Price believed the tooth counts indicated the formulas the mechanism used in its calculations. For example, one of the gear trains emulated an ancient Babylonian lunar cycle. The three dials of mechanism were connected by epicyclic gearing, that is, gears spinning on bearings to turn other gears. Also called planetary gearing, epicyclic gears are known today for extending the necessary mathematical formulas used by planetariums. With *Gears from the Greeks*, Price drew attention to the importance of the Antikythera Mechanism as direct evidence for a high level of mechanical accomplishment in ancient times. No other example of epicyclic gearing is known to have existed in Western technology before the Middle Ages.

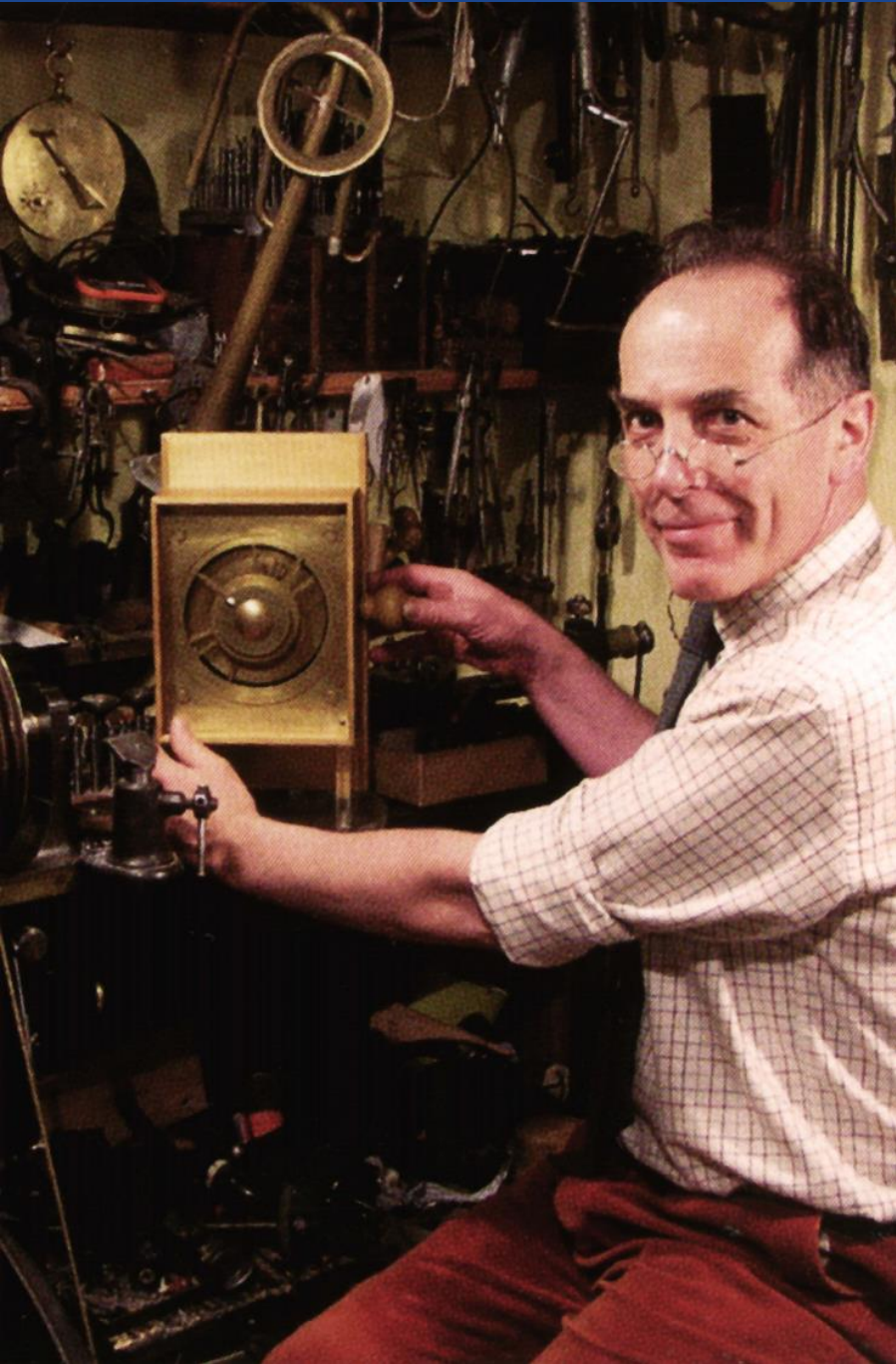
Top: One of Jacques Cousteau's submersibles is lowered into the water at the Antikythera shipwreck site in 1976. Bottom: Cousteau examines an ancient Greek statuette recovered by scuba divers during the same expedition.

Jacques Cousteau and his team reestablished the location of the wreck and first explored the area in 1953. In 1976 they were invited by the Greek government to revisit the site. While at Antikythera they recovered new art and artifacts for the National Museum of Archaeology in Athens while filming a television documentary entitled "Diving for Roman Plunder." During these underwater salvage explorations Cousteau's team discovered numerous coins from the Greek city of Pergamon in Asia Minor (modern day Turkey) –clues to the origins of the cargo ship and the mechanism.



Coins from the ancient city of Pergamon found at the wreck site. Image courtesy of X. Mousas





Michael Wright with his reconstruction of the Antikythera Mechanism, in his home workshop in Hammersmith London, 2006.

Michael Wright, former curator at the Science Museum in London, made the first three-dimensional x-rays of the mechanism during the 1990s. Inspired by Derek de Solla Price, he showed that Price's 1974 model was flawed—especially the gear tooth counts. As Wright continued to study the mechanism, he found evidence that the back dials, which at first look like concentric rings, are in fact spirals, and discovered a revolving ball on the front dial indicating phases of the moon.

Wright also confirmed some of Price's insights, namely that the mechanism was a planetarium with a lunar calendar in the upper back dial based on the 19-year (235-lunar-month) cycle called the Metonic cycle. This calendar is named after fifth-century BCE astronomer Meton of Athens—although it had been discovered earlier by the Babylonians—and is still used today to determine the Jewish festival of Rosh Hashanah and the Christian festival of Easter. Later, Wright discovered a pin and slot device that glided back and forth to recreate the elliptical orbit of the Moon. He incorporated his research into a new reconstruction of the Mechanism, followed by the paper "The Antikythera Mechanism Reconsidered." Wright presented his reconstruction to the National Hellenic Research Foundation in September 2005.

Video of CT (Computed Tomography) scans of Antikythera Mechanism 'Fragment A' produced by X-Tek Systems, Hewlett-Packard, and the Antikythera Mechanism Research Project, 2005.

In the mid-2000s, an international collaboration of scientists and scholars called Antikythera Mechanism Research Project (AMRP) assembled to "completely reassess the function and significance of the Antikythera Mechanism." The team included astrophysicist Mike Edmunds of Cardiff University, mathematician-filmmaker Tony Freeth, Greek astronomer John Seiradakis and astrophysicist Xenophon Moussas of the University of Athens. Working with the National Museum of Archaeology for access to the now 82 mechanism fragments, they partnered with the companies X-Tek Systems and Hewlett-Packard for digital scanning technology to explore the mechanism's interior details. The results were digital x-rays that moved through the layers of the pieces, as seen in this clip examining the insides of Fragment A.



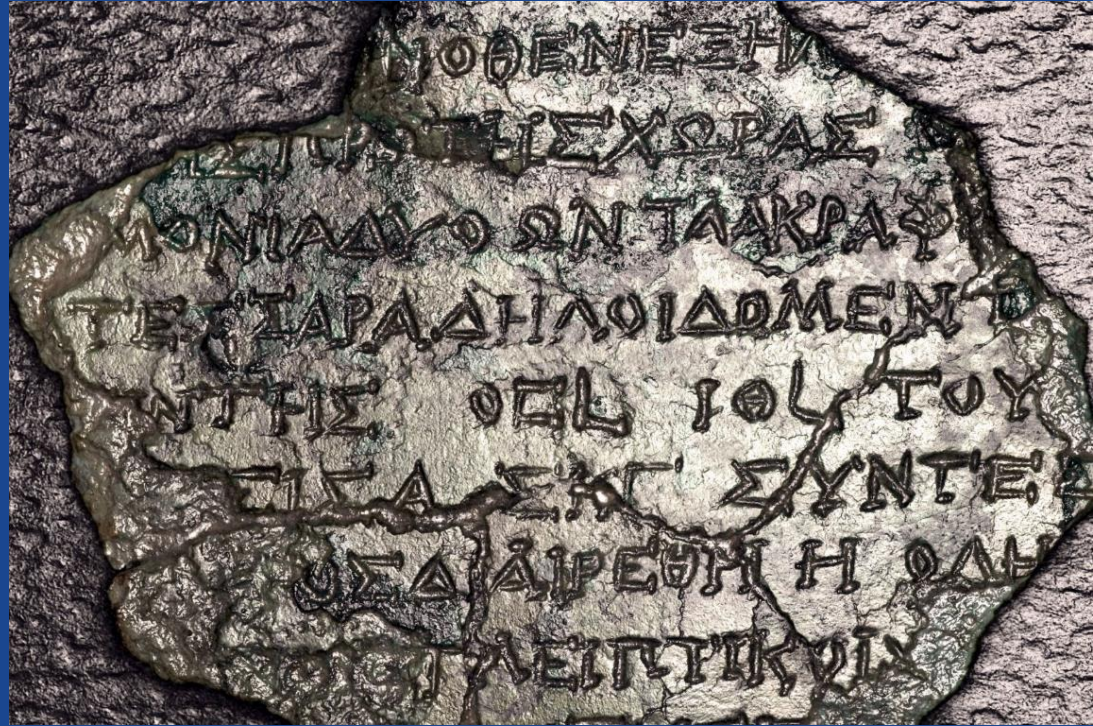
Link to video:
<https://bit.ly/3cRH9DH>

Video courtesy of the Antikythera Mechanism Research Project.

Scan of Mechanism 'Fragment 19,' a piece of the back cover inscription plate, computer enhanced to make the characters more readable.

By June 2016, the Antikythera Mechanism Research Project (AMRP), using image enhancement technology, had identified over 3500 characters of finely inscribed text from the Mechanism. This doubled the number previously known to have existed. AMRP member Alexander Jones, a professor of the history of science at New York University reported, "Now, we have something that you can actually read as ancient Greek. We can tell what these texts were saying to an ancient observer." Researchers found that inscriptions on the cover of the back face of the device contained an inventory of all of the dials and what they mean. According to Xenophon Moussas, it was as if "we had discovered the user's manual, right inside the machine."

Jones elaborated, "That's where we get the key information that there was a full-blown display of planets moving through the zodiac on the front." The ancient text indicated that the display had pointers with small spheres representing the Sun, Moon and planets known at the time (Mars, Jupiter and Saturn) arranged in a geocentric system orbiting the Earth. Researchers going back to Albert Rehm in 1905 had proposed the existence of this feature, but this was the first definitive physical evidence.



Greek astrophysicist and Antikythera Mechanism Research Project member Xenophon Moussas presents a contemporary reconstruction of the Antikythera Mechanism.

Image courtesy of Greek Reporter



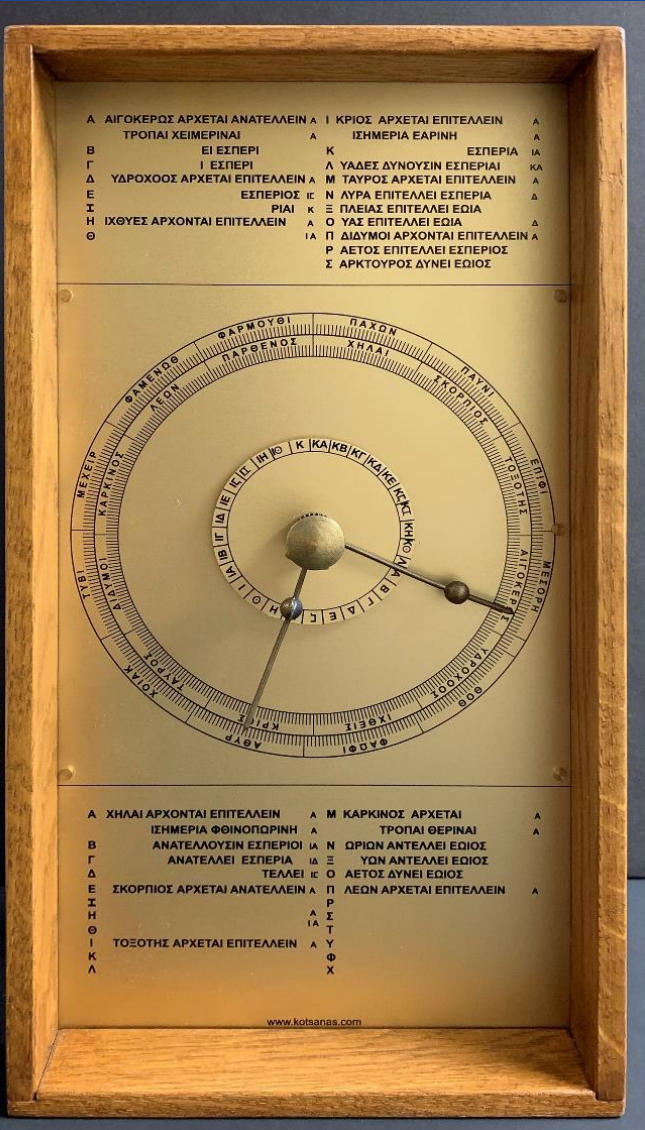
See Statues and Mysterious Disk Found in Ancient Greek Shipwreck Documentary video by National Geographic, 2017.

In 2012, marine archeologist Dr. Brendan Foley (formerly of the Woods Hole Oceanographic Institution in the United States and since 2017 at Lund University, Sweden) received permission from the Greek government to conduct new dives around the island of Antikythera. With project co-director Dr. Theotokis Theodoulou, divers conducted a three-week survey of the area using rebreather technology allowing extended dives to a depth of 230 feet. The team completed an underwater circumnavigation of the island, documented new finds, relocated the Antikythera wreck, and identified a second ancient shipwreck nearby.



Link to video:
<https://bit.ly/3wAtEzT>

Following this initial survey, the Hellenic Ephorate of Underwater Antiquities, in cooperation with Woods Hole Oceanographic Institution and Lund University, continued annual explorations, doing marine archeology and conducting underwater mapping of the wreck site. New objects from the ancient ship were found, including deck planks, lead anchors, glassware, and jewelry. *National Geographic* produced this video during the 2017 expedition, and exploration continued in 2018 and 2019. Unfortunately, no new pieces of the Antikythera Mechanism were discovered. The Hellenic Ephorate plans to continue exploration following the Covid-19 pandemic.



Antikythera Mechanism Model

by Kostas Kotsanas
(Front face)

This working model was built by Kostas Kotsanas, founder of the Museum of Ancient Greek Technology in Athens. It was presented in 2021 to the Parthenon by Dr. Xenophon Moussas, Professor of Astrophysics at the National and Kapodistrian University of Athens. Dr. Moussas describes the function of the mechanism's front face (seen at left) as:

"This tracks positions of the Sun, the Moon, and the planets as the solar and lunar pointers show their position in the sky during the year and the lunar month respectively. The Moon changes phase during the month as the two hemispheres have different colors and the sphere rotates around the axis to show the age of the Moon. The position of the moon is determined with four gears that give a good approximation of Kepler's second law, going faster at perigee when close to Earth and slower when at apogee, far from Earth."

Object courtesy of X. Moussas



Antikythera Mechanism Model by Kostas Kotsanas (Back face)

Xenophon Moussas describes the functions of the twin dials of the back face (seen at right) as:

"The upper dial is a spiral scale for the prediction of the phases of the Moon using the 19 year or 235 month lunisolar cycle of Meton (4th Century, BCE, Athens.) The period of Meton is used for the determination of Easter and Passover. It is similar to Buddhist and other lunisolar calendars. The small circular scale to the left shows the Kallipic lunisolar cycle of 76 years that takes into account leap years. The scale of the Olympic games (small circular scale to the right) using a four-year period of Olympics. Determines when to start the Crown games, Olympic Olympia, Pythian at Delphi, Isthmian at Corinth, Nemea at Nemea, Naa at Dodona, Aliea at Rhodes."

"The lower dial indicates the prediction of eclipses using the 18 Year, 11 day, 8 hour periodicity of Saros and the Exeligmos periodicity of 54 years and one month (three times the Saros period) The small circle indicates how many hours to add to the inscribed value for the second or third Saros period."

Object courtesy of X. Moussas





Figure 7. Computer model of the cosmos display. In the centre, the dome of the Earth, the phase of the Moon and its position in the Zodiac—then rings for *Mercury, Venus, true Sun, Mars, Jupiter, Saturn and Date*, with “little sphere” markers and smaller markers for oppositions. Scale marks and index letters for the synodic cycles of the planets are inscribed on the planet rings. Surrounding these, the Zodiac and the Egyptian Calendar². The true Sun ring has a “little golden sphere” with “pointer”, as described in the BCI: “When the Moon and Sun pointers coincide, the Moon sphere shows black for New Moon; when the pointers are on opposite sides, the Moon sphere shows white for Full Moon¹³”. The Head of the Dragon Hand shows the ascending lunar node; the Tail the descending node. Small triangles on the true Sun ring, near the pointer, show wider and narrower eclipse limits. Eclipses are possible if the Dragon Hand is within these limits. When the Moon pointer is before the Head of the Dragon, the Moon is South of the nodes; after, it is North of the node—conversely for the descending node. A Date pointer is attached to a narrow date ring, showing the date in the Egyptian calendar².

indexing hypothesis. It is difficult to understand how the information in the FCI could have been easily accessed by the user without such an indexing system, which in turn justifies our ring system of outputs.

The FCI^{2,7} enumerates intervals in days between synodic events—probably calculated from epicyclic models, not observations, since the actual intervals are so variable (Fig. 1b). The embryonic trigonometry of the Hellenistic age²⁸ would have made calculating these difficult. Here we propose that the Antikythera Mechanism itself calculated these synodic intervals by counting days on the Calendar Dial between synodic events indicated by the synodic scale marks on the planetary rings—entirely without trigonometry.

Conclusions

Figure 7, Supplementary Figs. S24, S25, Supplementary Videos S1–S3 visualize our new model: the culmination of a substantial cross-disciplinary effort to elucidate the front of the Antikythera Mechanism. Previous research unlocked the ingenuity of the Back Dials, here we show the richness of the Cosmos at the front. The main structural features of our model are prescribed by the physical evidence, the prime factors of the restored planetary period relations and the ring description in the BCI. Hypothetical features greatly enhance and justify the Cosmos display: a Dragon Hand thematically linking the Front and Back Dials; and an Index Letter Scheme for the synodic events of the planets.

Because of the loss of evidence, we cannot claim that our model is a replica of the original, but our solution to this convoluted 3D puzzle draws powerful support from the logic of our model and its exact match to the surviving evidence. The Antikythera Mechanism was a computational instrument for mathematical astronomy, incorporating cycles from Babylonian astronomy and the Greek flair for geometry. It calculated the *ecliptic longitudes* of the Moon¹, Sun² and planets^{1–2,9,11}; the *phase* of the Moon⁶; the *Age of the Moon*⁶; the *synodic phases* of the planets; the *excluded days* of the Metonic Calendar⁹; *eclipses*^{6,8,25}—possibilities, times, characteristics, years and

Scientific Reports, March 12, 2021 “A Model of the Cosmos in the Ancient Greek Antikythera Mechanism,” Figure 7.

In early 2021, a team at University College London (UCL) led by Tony Freeth, from the Antikythera Mechanism Research Project, presented new findings about the mechanism in the journal *Scientific Reports*. This study, built upon the findings of Rehm, Price, Wright, and the 2005 X-ray data, presented a new display of the ancient Greek solar system within a complex gearing system at the front of the mechanism. According to Tony Freeth, “Ours is the first model that conforms to all the physical evidence and matches the descriptions in the scientific inscriptions engraved on the mechanism itself.”

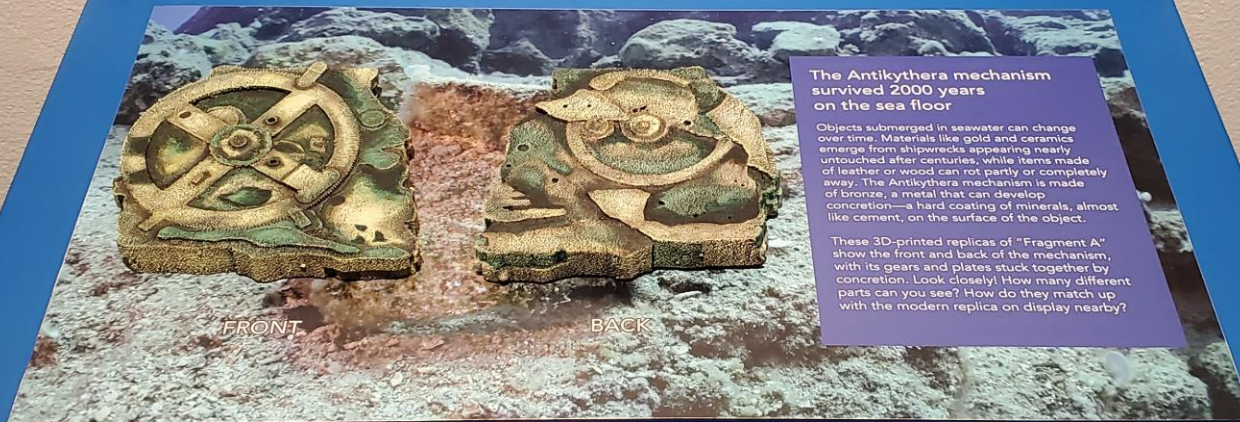
In their conclusion, the UCL team presented this computer generated illustration of the front of the mechanism. Described as “the culmination of a substantial cross-disciplinary effort to define the front of the mechanism,” the UCL team declared,

“Previous research unlocked the ingenuity of the Back Dials, here we show the richness of the Cosmos at the front. . . It is the first known device that mechanized the predictions of scientific theories and it could have automated many of the calculations needed for its own design—the first steps to the mechanization of mathematics and science. Our work reveals the Antikythera Mechanism as a beautiful conception, translated by superb engineering into a device of genius. It challenges all our preconceptions about the technological capabilities of the ancient Greeks.”

Image courtesy of University College London

Hands-On Replica

Touch these replicas of the *Antikythera mechanism*!
What details can you find?



These 3D printed models shows what the mechanism looked like when discovered on the sea floor.

Education Programming

With the Antikythera Mechanism exhibit, visitors of all ages can:

- Learn from experts with our virtual Symposia series.
- Explore a touchable replica in the exhibition.
- Create with gears to make something spectacular.



The poster features a white background with colorful circular icons: a blue atom, a red gear, a green musical note, a purple classical building, and a yellow calculator. The text is in blue and black. At the bottom left is the Metro Nashville Public Schools logo. At the bottom right is a circular QR code with 'SCAN ME' written inside.

STEAM NIGHTS

AT THE PARTHENON

Free admission to MNPS students and their families, from 4:30-6:30 p.m. on

• June 9 • August 11
• July 14 • September 8

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MNPS students are invited to bring their entire family to the museum for free anytime during Summer 2021!

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Virtual Symposia

Dig deeper this summer with a series of virtual talks by archaeologists and conservators. All lectures are free and open to the public.

Register at NashvilleParthenon.com/Events:

June 16 Underwater Archaeological Discoveries
with archaeologist Dr. Steven L. Tuck

July 21 Conserving Bronzes at the
National Archaeological Museum, Athens, Greece
with conservator Dr. Georgianna Moraitou

August 18 Underwater Archaeology
with archaeologist Dr. Anne Duray

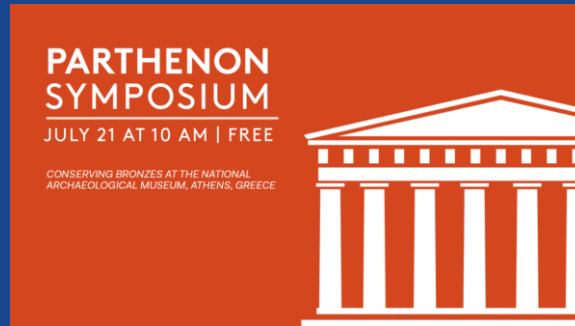
Watch the recordings on the [Symposia Playlist](https://YouTube.com/NashvilleParthenon) on
YouTube.com/NashvilleParthenon.

Symposia Survey

Whether participating live or watching a recording, please complete a short survey to help us evaluate each program.

<https://www.surveymonkey.com/r/T2JVN8D>

The results of this survey will be used to show program impact metrics for grant reporting purposes.



Gear up for some fun!



The Antikythera Mechanism has over 30 gears. Each gear has small teeth that work together to move dials and display information.

What will you build with gears?

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