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The Enigma of the Antikythera Mechanism

The Machine That Changed History

Or other Possible titles:

Unlocking the Antikythera Mechanism

The Ancient Greek Computer: The Mystery of the Antikythera Mechanism

The Antikythera Code: Ancient Science Revealed

Discovering the Antikythera Mechanism

Journey into the Antikythera Mechanism

Clockwork of the Cosmos: The Mystery of the Antikythera Mechanism

The Bronze Oracle: Decoding the Antikythera Mechanism

The Lost Gears of Time: Science and Wonder in the Ancient World

The Celestial Machine: An Ancient Code of the Universe

Echoes of the Stars: The Antikythera Mechanism and the Mind of the Ancients

Gears of the Heavens: The Science Behind the Antikythera Mechanism

The Astronomer's Secret: Unlocking the Antikythera Mechanism

When Time Had Gears: The First Mechanical Universe

The Whispering Machine: A Journey into Ancient Greek Genius

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# Preface

Have you ever heard of an ancient machine that could measure time, predict the movements of the Sun and the Moon, foresee eclipses, and perhaps even track the planets? And yet, such a machine exists—it is real! Its name is the Antikythera Mechanism. It is one of the most fascinating discoveries of antiquity, the most mysterious and complex device of its time.

Many years ago, in 1901, sponge divers exploring the blue-green waters near the small island of Antikythera discovered a shipwreck full of treasures: bronze and marble statues, amphorae, and other artifacts. Among these, there was an object covered with seaweed and shells, concealing pieces of bronze encrusted with green corrosion. At first, no one imagined that these fragments belonged to an ancient geared mechanism. Something like that seemed more like a modern invention—or at least something from Leonardo da Vinci’s time—rather than an object from the age of Archimedes!

It took decades of research for scientists to realize that the Antikythera Mechanism was an astronomical calculator, built over 2,200 years ago by Greek craftsmen and scholars. With the help of this incredible device, the ancients could determine when the Olympic Games would take place, predict the phases of the Moon, and even forecast eclipses!

This book was written to take you on a journey back to the time when the Antikythera Mechanism was created. You will discover how it worked, what it was used for, who may have built it, how we uncovered all these secrets, and what it teaches us about the brilliance and imagination of both the ancients and modern scientists.

The Antikythera Mechanism reveals something truly important: if you can imagine something, then you can create it! The ancient Greeks were not afraid to combine their knowledge of astronomy, mathematics, and engineering to build a true marvel.

It also proves that the Greeks, in addition to excelling in the fine arts, creating theater, advancing science, and shaping philosophy, were also the first to develop high technology based on scientific principles.

Are you ready to uncover its secrets?

Enjoy your reading and have a great journey into the world of science and inspiration!

# Unveiling the Secrets of the Antikythera Mechanism

The Antikythera Mechanism is an astonishing mechanical calendar based on the movements of celestial bodies such as the Earth, the Sun, the Moon, and Venus. It utilized periodic cycles that later formed the foundation of the Christian (Easter) and Jewish calendars, and it also shares similarities with Hindu and Buddhist calendars.

Beyond being a calendar, it was likely an astronomical clock with continuous motion, operating through a system of weights and counterweights, as described by Archimedes and Hero of Alexandria. Its technology resembles ancient mechanical clocks, such as the one described by Procopius and the Tower of the Winds in Athens.

The Mechanism represents the pinnacle of Greek philosophy, particularly the Pythagorean tradition, which is rooted in mathematics and natural philosophy. It belongs to the legacy of the Ionian philosophers, from Thales and Pythagoras to Archimedes. It embodies the wisdom of Greek science and technology, carrying forward the tradition of Hephaestus, Athena, Prometheus, and Orpheus.

The Antikythera Mechanism is the oldest known computer and an incredibly complex astronomical instrument. It is so advanced that it appears centuries ahead of its time. It likely functioned as an astronomical clock or planetarium, far more sophisticated than the astronomical clocks that appeared in Western Europe after the 14th century.

This remarkable device is exhibited at the National Archaeological Museum of Athens, within one of the most important collections of ancient bronze artifacts. Unfortunately, the technological achievements of Greek civilization remain largely unknown, even to many experts. The Mechanism proves that the Greeks had developed an advanced, science-based technology far beyond what was previously acknowledged.

For a civilization, like the modern one or the Greek civilization from which the modern one originated, to develop sciences with mathematics and, from those, advanced technology, it must first recognize and accept several core principles. These include the understanding of causality and determinism, the existence of laws of nature, and the recognition that these laws are expressed precisely through mathematics. Furthermore, the laws of nature must be experimentally proven or theoretically predicted using mathematics.

More than just a computer, the Mechanism was also an automated astronomical device. Its functions, usage instructions, and surviving ancient texts indicate that it worked as a planetarium, calculating the positions of the Sun and Moon, their phases, and possibly even the positions of the planets in the sky. This makes it the first known mechanical universe, possibly an astronomical clock with continuous motion, as described by the philosopher Proclus, the last head of Plato’s Academy.

Beyond being a planetarium, the Mechanism may also have served as an astronomical observation instrument, measuring celestial angles and distances. It may have had a rotating sighting device, similar to later astrolabes. Its user manual references a golden sphere and a sunbeam, which might indicate measuring tools for tracking the Sun’s movement.

The Antikythera Mechanism, estimated to have been constructed between 150 and 100 BCE, was not unique in antiquity. Ancient sources indicate that similar devices existed before and after its time, suggesting a long tradition of mechanical and astronomical innovation. The descriptions of such devices in ancient texts reinforce the idea that the Antikythera Mechanism was part of a broader Greek scientific and engineering tradition.

There is strong evidence to support the hypothesis that Archimedes played a foundational role in the development of such technology, making him the “grandfather” of the mechanism. Hipparchus, one of the greatest astronomers of antiquity, is considered its intellectual “father,” likely contributing to its astronomical calculations. The roots of this technology can be traced to Alexandria, home to the famous Library and Museum, which served as a research and educational center for centuries. Furthermore, Athens, with Plato’s Academy and Aristotle’s Lyceum, provided the mathematical and philosophical groundwork that facilitated such advancements. Additionally, Ionia, Macedonia, and Thrace, rich in scientific and philosophical traditions, played a key role in shaping the intellectual environment necessary for the evolution of mechanical technology.

The technical expertise required to build such a complex and precise device can be traced to Syracuse, where the tyrant Dionysius established one of the earliest known research centers. This institution attracted some of the most skilled scientists, technicians, and craftsmen, whose primary task was to develop advanced military technologies to defend Greek territories in Sicily and Southern Italy against the Carthaginians, descendants of the Phoenicians in North Africa. This environment of scientific and mechanical innovation likely contributed to the development of intricate devices such as the Antikythera Mechanism.

A few centuries after the estimated construction of the Antikythera Mechanism, Theon of Alexandria (ca. 330–400 CE), a mathematician, philosopher, and astronomer affiliated with the Library of Alexandria, documented detailed descriptions of similar devices. As the last director of the Alexandrian Museum and the father of the renowned mathematician and philosopher Hypatia, Theon appears to have had direct experience with such instruments. In his commentary on the Handy Tables, he describes a mechanism with similar functions, suggesting that such devices continued to be used and developed well into the late antiquity. Similar references appear in the works of Ptolemy, Heliodorus, and Paul the Astronomer, indicating that the Greek tradition of astronomical machinery persisted from the Hellenistic period into the early Byzantine era.

# The Antikythera Mechanism as an Educational Tool

The Antikythera Mechanism is not just an archaeological marvel but also an invaluable educational tool, just as it was in antiquity. Today, it can be used to teach astronomy, demonstrate the importance of mathematics and physics in understanding natural phenomena, and help young people develop self-awareness. Self-awareness is the first step in strengthening self-esteem, which is often lacking among youth worldwide, including in Greece.

The Mechanism and Greek civilization are showcased through exhibitions in 13 languages across the world, supported by NASA, UNESCO, archaeological museums, universities, and schools, from Egypt and Algeria to Iceland and Brazil. Additionally, over 1000 lectures, films, TV and radio programs, as well as publications in 6 languages, have helped spread knowledge while promoting Greece, the National Archaeological Museum, and the University of Athens.

This book is based on the latest scientific findings. It is designed for a wide audience, from students to enthusiasts of philosophy, astronomy, mathematics, archaeology, history, and technology, written in a simple yet scientifically precise manner.

# When it was built

This ancient automaton, likely built in the 2nd century BCE, is the oldest and only such mechanism we possess from antiquity. It represents the peak of Greek technological ingenuity and demonstrates that ancient Greeks not only understood the laws of nature but also recognized the necessity of predicting natural phenomena through mathematical principles, as taught by Pythagoras and Plato.

# Other similar machines

The Pseudo-Callisthenes description of the Pinax bears striking similarities to the Antikythera Mechanism. It mentions the Sun, Moon, planets, decans, and the zodiac, explicitly calling it a clock. The text also describes a device in Philip’s palace that displayed celestial positions, with planet indicators adorned with precious stones.

Comparing this account with scientific discoveries confirms that such mechanisms truly existed. Evidence suggests the Mechanism also displayed the time, a view supported by Proclus. Its external form may have resembled a small temple, richly decorated, possibly with moving statues like the automata of Ctesibius and Hero. Among the Antikythera shipwreck findings are intricately crafted statues, one of which is rotatable, hinting at mechanical applications within the Mechanism itself.

Our study confirms that such machines actually existed, contrary to previous beliefs that they were fictional accounts. The description of the Mechanism allows new hypotheses about its function, possibly as a continuously moving clock, as Proclus suggests. Its exterior may have resembled a small temple, adorned with gilded decorations and figurines, possibly moving ones, similar to Ctesibius' clocks. The shipwreck contained elaborate figurines, one of which was rotatable, supporting the idea that the Mechanism included automata.

The Greeks discovered that gears could perform calculations and transmit motion. Aristotle described their properties, such as changing direction and mechanical advantage. Archimedes recognized their practical applications, like water-lifting devices. Although Aristotle did not provide technical details, his ideas influenced later scientists in developing mechanical systems.

The Greeks were probably the first to realize that gears could be used for both mathematical calculations and mechanical motion. While it is unclear who first discovered that gears could perform automatic computations, Aristotle discussed the paradoxes of gear rotation and the reversal of motion, indicating that their properties were already known to some of his contemporaries.

Aristotle described how gears transfer motion, change the direction or magnitude of force, and provide mechanical advantage. He studied the function of interlocking gears with teeth, which enable one gear to rotate another, allowing motion to be transferred from one part of a machine to another. These principles laid the groundwork for the understanding of mechanical systems.

Archimedes took these ideas further, applying gears in practical designs, such as water-lifting devices and other machines of his time. While Aristotle did not leave behind detailed technical descriptions, his observations influenced later scientists and engineers, who expanded upon his ideas to develop more advanced mechanical systems—culminating in complex inventions such as the Antikythera Mechanism.

People in antiquity likely knew of wooden gears from windmills. Pappus of Alexandria (290–350 AD) describes the construction of complex gears and machines, while Hero educates readers on mechanisms and automata, dedicating a book to air-powered automation.

People in antiquity had likely encountered wooden gears, such as those used in windmills or other mechanical constructions. Pappus of Alexandria (290–350 AD), one of the most significant Greek mathematicians of late antiquity, describes in his work Collection various types of gears, including worm gears and helical-tooth gears, as well as complex machines. His deep understanding of mechanics is evident in his detailed instructions on constructing and utilizing these mechanisms. Hero of Alexandria, on the other hand, dedicates much of his writings to the study of automata and mechanical devices, describing air-powered mechanisms that demonstrate the advanced technological capabilities of the time.

Archimedes was a pioneer in mechanics, combining mathematics and physics to understand motion and mechanical systems. Although no detailed treatises of his focusing exclusively on gears have survived, his work demonstrates a profound understanding of mechanical principles and their applications.

One of his most significant inventions was the Archimedean screw, a device designed to lift water using a rotating helical blade. This invention shows an early comprehension of gear principles, as it converts rotational motion into linear movement to efficiently transport liquids.

Archimedes also developed the compound pulley system, which allowed heavy objects to be lifted with less force. While pulleys are not gears in the modern sense, they operate on the same mechanical principles, such as force distribution and mechanical advantage.

Additionally, Archimedes is famous for his war machines, including catapults, cranes, and other sophisticated mechanical devices. Although specific details regarding the use of gears in these machines are scarce, their reliance on levers, ratchets, and other mechanisms suggests his advanced understanding of mechanical principles.

His studies on equilibrium and hydrostatics were fundamental for the future of mechanics, as they laid the groundwork for understanding force, motion, and mechanical efficiency. His contributions had a lasting impact on the development of gear technology, influencing mechanical engineering for centuries.

Archimedes' studies on equilibrium and hydrostatics laid the foundation for mechanical science, providing key principles for understanding forces, motion, and mechanical efficiency. His influence extended to the development of gear technology, shaping complex mechanical systems for centuries.

The ancient Greeks utilized gears to replicate the movements of the Sun, Moon, and planets. By adding circular motions, they successfully translated celestial motions into mechanical calculations. Gears were specifically designed to interact with each other, transferring movement and driving indicators at precise angular velocities over calibrated scales divided into months and other time units.

These indicators displayed the positions of celestial bodies in the sky, aligning with the zodiac, which served as a sky map. Additionally, other indicators provided the date according to multiple Greek calendars. The mechanism synchronized different calendar systems, including the Egyptian solar calendar and the traditional lunisolar calendars used by the Greeks.

Furthermore, two specialized indicators provided eclipse predictions, allowing the Greeks to determine the exact timing of these astronomical events. This demonstrates how Greek knowledge of astronomy and mechanics was intricately linked, culminating in the creation of computational devices that integrated advanced astronomical and calendrical functions.

The design, technology, construction, mechanics, metallurgy, metalworking, and chemistry of the mechanism are exceptionally impressive, showcasing the advanced knowledge of the ancient Greeks. The construction of the gears is particularly remarkable, as they are all extremely thin, with small equilateral triangular teeth measuring approximately 2 to 2.2 mm on each side. Even today, the fabrication of such delicate and precise toothed wheels remains a challenging process.

The gears were designed based on mathematical calculations that enabled the prediction of natural phenomena, such as eclipses. Each gear was created with a specific number of teeth, carefully selected to perform a predefined mathematical function. Whenever possible, gears were designed with a prime number of teeth—numbers that are only divisible by one and themselves. This was done primarily for efficiency and to optimize the functionality of the mechanism.

The thickness of the gears and the size of the teeth were chosen based on the strength of the material, ensuring smooth movement without requiring excessive force, which could lead to breakage. The engineers designed the gears in a way that eliminated the need for bearings or friction-based supports, improving the reliability of the system.

The size of the machine itself was also a determining factor in the dimensions of the gears and their teeth. Since the mathematical calculations required for the device were fixed, the manufacturer had to balance precision and durability. To prevent larger gears from breaking, they incorporated curved reinforcements, known as safety braces, which held the gears in place, preventing them from bending or snapping.

The gear fabrication process was highly sophisticated. The teeth were shaped using a small compass, while the cutting was done with files and, when necessary, small saws. Additionally, the gear teeth underwent a hardening process to make them more resistant, especially at their edges. This was achieved through forging, and most likely through quenching and annealing.

Annealing is a metal treatment method used to increase durability, reducing brittleness while enhancing flexibility. The process involved heating the metal followed by rapid cooling, and in some cases, work hardening, where the metal was deliberately deformed beyond its elasticity limit. Depending on the intended application—whether for gears, axles, or even swords—the appropriate treatment method was chosen.

Finally, for gear lubrication, the ancient engineers used lead, a technique reminiscent of the lead additives once used in gasoline to lubricate automobile engines until the mid-20th century.

# How these machines were called in antiquity.

"The basis and beginning of wisdom is the examination of the names," said the Cynic philosopher Antisthenes (445–360 BC). Indeed, as Antisthenes states, naming allows for a better understanding of each object. It is particularly important to know what this complex astronomical instrument was actually called in its time, in antiquity.

This peculiar object, which today has come to be known as the Antikythera Mechanism, was called Pinax (πίναξ), meaning "tablet" or "board," for long periods in antiquity. Until a few years ago, it was referred to as the Antikythera Astrolabe, but scientists changed its name because it is far more complex than even the most sophisticated astrolabes of all time.

Such devices in ancient literature, which are also a very significant part of our cultural heritage, were referred to in antiquity as Pinakidia (tablets), Pinakes (tables), Spheres (celestial spheres), or possibly even Astrolabes or little Astrolabes. Some may have simply been called Horologia, like the Tower of the Winds (Horologion of Andronicus of Cyrrhus), when they were large and in the form of a building, such as the clock of Andronicus and the clock of Gaza. From literature, we know of some of the most important mechanisms constructed by Archimedes in Syracuse and by Posidonius in Rhodes. Naturally, a Pinakidion (πινακίδιον) referred to a small Pinax, if it was small and portable. The unique Antikythera Mechanism can indeed be considered small and portable.

In other historical periods, similar devices were referred to as Spheres, such as during the time of Archimedes. Much later, Cicero also used the same term. The term Astrolabe (αστρολάβος) or Astrolabion (αστρολάβιον) was used concurrently with Pinakidion by the same author (Pseudo-Callisthenes).

In certain ancient books, we find various useful texts referring to a similar instrument. One of the names given to such devices is Pinax (πίναξ) or Pinakidion (πινακίδιον), when referring to a small-sized, portable instrument. In a book titled The Life of Alexander [Historia Alexandri Magni (Recensio α)] by Pseudo-Callisthenes, significant information is contained. The author, known as Pseudo-Callisthenes by scholars, is so named because he is considered not to be the well-known and highly important student of Aristotle, Callisthenes, but a later writer from the 3rd century AD, either with the same name or perhaps a pseudonym.

This book is a fictionalized biography of Alexander the Great. It was a popular read across the world and translated into many languages throughout history. Its English title is *Histories of Alexander the Great*. It remained one of the most popular books in the Greek world until the 20th century, as it gave hope to the subjugated Greeks by teaching that they belonged to a great nation that had spread civilization across the world, implying that they could once again regain their freedom and prominence. This book also served as an educational text, as the poor, subjugated Greeks had access to very few books.

It is worth comparing the variations of the texts in different editions of the book across different eras and in the various languages into which it was translated for different peoples. Among other things, the text seeks to present Alexander as having Egyptian blood, claiming that his father was Amun-Ra, in order to make the Macedonian dynasty accepted in Egypt and other regions where rulers were [supposedly] related to the gods to ensure their reverence and acceptance by the people.

# Who could have such a machine?

Only kings or extremely wealthy individuals could own such luxurious devices, often referred to as "royal tablets." The Alexandrian mathematician and philosopher Pappus (3rd-4th century AD) defined a mechanical engineer as someone capable of constructing planetariums that operated using water.

Philosophers, Astronomers, Geographers, Travelers, Captains, Generals were possible users of this type of device τοο.

These mechanisms were remarkable technological achievements, blending engineering and theoretical knowledge. Pappus also discussed other mechanisms, including Hero’s automata and Archimedes’ hydraulic devices, which used compressed air, weights, ropes, or water-based systems for timekeeping.

# How Functions the Antikythera Mechanism

One of the key questions regarding the Antikythera Mechanism is how it operated and whether it was a clock, a planetarium, or something else. Ancient texts indicate that similar devices had small statues of gods (called "demons" [gods] in the texts) at the ends of their planetary pointers, with each statue representing a planet. In one book, Zeus is depicted as angry because humans created a mechanical universe, rendering his divine role obsolete. In other ancient Greek books, the planet Jupiter in such a device is referred to as "the so-called Zeus," suggesting it was a mechanical representation of celestial movements.

The Antikythera Mechanism likely functioned using a system of weights, counterweights, and a water-based float (described as "cork" by Hero). Its motion was regulated by a large prism-shaped water clock, where water rose at a constant rate, lifting a float.

# An stronomical computer

A computer is a machine designed to perform mathematical and logical operations automatically through programming. This programming is done via software, which is written in a programming language. For its operation, a computer requires initial data, which it processes to provide the desired output.

The Antikythera Mechanism is an ancient mechanical computer designed to solve astronomical problems. It is the first known analog computer, utilizing a system of gears instead of modern bits and bytes. The input data includes the date, time, and geographic location. The latitude determines the visible portion of the sky, while the longitude affects the local time. It is possible that the mechanism had interchangeable plates for different latitudes, similar to precise astrolabes from antiquity.

The Mechanism displays the positions of the Sun and Moon, accounting for the Moon’s phases, and may have also depicted the positions of the planets. The results appear on circular and spiral scales, with indicators representing the motion of celestial bodies. The golden pointer shows the Sun’s position, while the silver one represents the Moon, including details on its phases. Additional indicators may have existed but have not yet been discovered.

The Mechanism functions as a permanently programmed system, with astronomical calculations embedded in its gears. Its architecture is comparable to ROM in modern computers, where operational programs are permanently stored. Users input the desired time, and the machine presents the corresponding predictions.

Additionally, the Mechanism includes a calendrical system that synchronizes the various Greek calendars. It employs the zodiac circle, a celestial zone where the Sun, Moon, and planets move, allowing for the calculation of eclipses and lunar phases. Although no clear evidence of an hour scale has been found, ancient texts describe similar devices that also functioned as clocks.

Beyond calculating celestial positions, the Antikythera Mechanism also served as an advanced calendrical device, essential for determining dates and managing the diverse calendar systems used by Greek city-states.

The combination of all the gears and the limited surviving user instructions allows us to draw useful conclusions about the size and capabilities of the Antikythera Mechanism. It is estimated that the dimensions were around 31.5×18.5×5 cm, with the possibility of additional decoration resembling Rococo clocks. The smaller dimension is difficult to determine precisely due to missing parts. Experts estimate the thickness to be around 10 cm. If we assume that there were indicators for the planets, the thickness of the mechanism would increase further. Based on the remaining parts in the National Archaeological Museum, the thickness does not exceed 6-8 cm unless we consider the covers and protective frame, which could slightly increase the dimensions. The height of the mechanism corresponds to the Greek foot, which is about 30.5 cm and is linked to the classical measurement of the Earth's length and the Olympia Stadium. This unit of measurement corresponds to roughly 41.524 kilometers, close to the actual.

# The Great Year

Humans have developed astronomy since prehistoric times, perceiving the music of the spheres, as Pythagoras said, and creating increasingly complex calendars and mathematics. They began to understand time, initially viewing it as cyclical and repetitive, since stars, planets, the Sun, and the Moon move in cycles as observed from Earth. The Greeks defined the Great Year, the period in which all celestial bodies return to the same position. Societies developed beliefs that everything would be reborn when all the stars returned to the same point, a futile hope. Fortunately for the Greeks, the Great Year, the time period during which all celestial bodies return to the same position in the sky, and when everyone might be reborn to start a new life, spans tens of thousands or even millions of years, and thus they did not fall into the delusion of the world’s destruction in 2012, as supposedly predicted by the Mayan calendar.

The period of the Great Year, according to the beliefs of the Greeks and the Chaldeans, represents the rebirth of the World, where everything begins anew. The Great Year could be seen as a multiple of the periods of all the planets, multiplied by the lunar periodicities and the precession of the equinoxes, which is estimated to be around 400,000,000,000,000 years. This time is 30,000 times longer than the currently estimated age of the Universe (13.8 billion years).

Heraclitus calculated the period of the Great Year as 18,000 years, while Diogenes estimated it to be 365 years. Oenopides and Pythagoras estimated the period as 59 years, with other authors mentioning 600, 9977, 7777, 8776, 170620, and 365 years. Aristotle, Eudoxus, and possibly Plato, according to Cicero, calculated the Great Year by multiplying the periods of all the planets by the Saros cycle (30x12x2x1x1x18), arriving at an estimate of around 12,960 years.

# The Meton and Callippus cycles

The Meton cycle, introduced to Athens in 432 BC, was designed to align the tropical year with the lunar calendar through a period of 19 years. Meton's period is considered by some as the "Great Year." His work was well-known among Athenians, and Aristophanes humorously mocked him for mapping and measuring the air and sky, even poking fun at his attempts to solve the unsolved problem of squaring the circle, a topic of discussion among Athenians. The 19-year period, or "Metonic cycle," is the time in which the Moon returns to the same position in the sky relative to the stars, with the same phase (e.g., new moon, full moon, etc.). Ancient Greek astronomers chose the apogee position of the Moon as the reference point, starting with a solar eclipse when the Moon is at its furthest point, creating a ring-like, long-duration eclipse. The restoration of the Moon to the apogee, often linked with solar eclipses, occurred at different periodicities according to various astronomers.

Eudoxus of Cnidus (410-335 BC) was a significant astronomer, mathematician, and philosopher. He argued that the restoration of the phases of the Moon in the same position in the sky, in relation to the stars, happens through the repetition of eclipses and the octaeteris cycle. This view was also shared by Eratosthenes of Cyrene (276 BC – 194 BC), a mathematician, astronomer, geographer, poet, philosopher, and director of the Library of Alexandria, as well as a professor at the Museum, which were the leading universities of the time. Eratosthenes is credited with coining the term geography and accurately measuring the Earth's circumference. Surprisingly, he also accurately measured the distance between the Earth and the Sun, a fact that is not widely known. Furthermore, he created an accurate map of the Earth, using coordinates of latitude and longitude.

Callippus (370-300 BC) extended the astronomical work of Meton, establishing a new 76-year cycle, which is four times longer than Meton’s cycle. He believed this cycle was more accurate, based on the tropical year length of 365 + ¼ + 1/76 days, which is half an hour longer than the actual value. Callippus worked at Plato's Academy under the guidance of Eudoxus and modeled the motion of celestial bodies, using spheres to represent the movement of the five planets, the Sun, and the Moon. His 76-year cycle, which began in 330 BC with the summer solstice, was used in the Antikythera mechanism and predicted the moon phase with an accuracy of one hour. Some believe Callippus' cycle corresponds to the Great Year, a significant period for the Greeks. However, others argue that the Great Year is when all celestial bodies return to the same position relative to the stars and the Sun, which does not apply to Callippus' cycle.

The mechanism was organized in the form of a strange astronomical clock with two faces, allowing space for many precise and large scales to display the results of calculations. On one side of the mechanism, there are two concentric circular scales with two pointers that indicate the position of the Sun and the Moon, as well as the phase of the Moon. On the other side, five scales predict the phases of the Moon, eclipses, and the Olympiads, using five synodic solar-lunar periods or "calendars," as we might call them. These periods are combined to provide precise predictions and calculations for natural phenomena, based on strict mathematical and astronomical data.

# The Museum of Poseidon

The Museum of Poseidon refers to the discovery of a mysterious shipwreck near Antikythera in 1900. The experienced captain, Dimitrios Kontos, and his divers, coming from Symi and other regions, were heading towards Africa for sponge fishing. Due to bad weather, they were forced to seek refuge at Antikythera, where they dived around Pinakakia to collect sponges and seafood. Diver Ilias Lykopantis discovered the right arm of a bronze statue, later identified as the Philosopher of Antikythera. This discovery led to the remarkable finding of the famous Antikythera shipwreck and the revolutionary discovery of the ancient mechanism, which is linked to the scientific and technological heritage, a technology based for the first time on exact science with mathematics, theoretical proofs and laws of physics, a Greek invention.

To ensure they had food, the divers went to the Pinakakia area near Cape Glyfadia to collect sponges and seafood, such as pinnas, along with Tsikoudia from the Antikythera islands. Diver Elias Lykopandis, or Stadiatis, from the Stades of Asia Minor, discovered the right hand of the bronze statue of the "Philosopher of Antikythera" during a dive in the area. The boats used for the dives were the "Euterpe," a saill boat, and the second was the "Calliope," a sponge fisherman's boat. The ancient shipwreck found at depths of 45-62 meters is the largest known ancient wreck, estimated to have sunk around 80-60 B.C. The ship carried many statues and other treasures from Greece to Rome, as Roman generals and emperors sought Greek artwork to decorate public buildings and their villas, plundering the conquered regions of Greece.

fter discovering the shipwreck, the sponge divers continue their mission in Africa, collecting sponges for six months. In September 1900, they return to Symi, where the Lendiakos (or Lindiakos) brothers, Captain Kontos, and diver Ilias Lykomantis Stadiatis meet with local elders and decide to inform the Greek government about the discovery. It is important to note that the Dodecanese, including Symi, was under Turkish occupation at the time. The divers travel to Athens, and in collaboration with the Professor of Archaeology at the University of Athens, Antonis Oikonomou, also from Symi, they agree with the Minister of Public Education, Spyridon Stais from Kythera, to begin the excavation of the antiquities. With the assistance of the antiquity’s curator Valerios Stais, the minister's cousin, the archaeological research at Antikythera begins.

After many adventures and significant difficulties, the divers from Symi managed to recover part of the valuable cargo now housed in the National Archaeological Museum in Athens. Among the finds are the famous Antikythera Youth and Philosopher. Military naval ships were involved in the archaeological research. According to Mrs. Lisa Mandaliou, granddaughter of chief diver Ilias Lykopantis Stadiatis, her grandfather, who also recovered the Antikythera Mechanism, was among the divers involved in the excavation.

The crew consisted of helmeted divers such as Ilias Lykopantis (or Stadiatis), Kyriakos Mundiadis, Georgios Mundiadis, Ioannis Pilliou (or Roditis), Georgios Th. Kritikos, Vasileios Katsaras, Konstantinos Kalafatis, Vasileios I. Zouroudis, as well as sailors Filimon Koumparios, the Italian Giorgio, Giannis Papakalodoukas, Sotiris Papakalodoukas, Fotis E. Kontos, Kostas St. Chais, Nikitas A. Fassakis, Giannis Fotaras, Stavros Michaloutsos, and Giakos Nik. Diakogeorgakiou.

Each diver received 500 drachmas as payment, although they had initially been promised a much higher amount. However, some divers paid a heavy price, as one of them, Georgios Kritikos, died from the bends, while two others were severely paralyzed. Had these men not sacrificed their lives, we would not have these historical findings today, nor would we have rediscovered the history of technology, astronomy, and mathematics. Their sacrifice is honored with a memorial on Antikythera.

The Antikythera shipwreck is the largest ancient ship ever found. It is estimated to have been 50-60 meters long, 9-12 meters wide, and had a displacement of 500-1000 tons. The wreck was discovered in 1901 and identified in 1902. Since 2014, underwater archaeologists have measured the remains of the ship, which are approximately 45 meters long and 10-16 meters wide. The ship was made of 14 cm thick elm planks, the thickest found on any ancient ship. Its construction followed the method of first placing the hull and then the skeleton. Admiral Ioannis Theofanidis, who dived there several times, suggests that the ship was even larger, over 60 meters. The ship sank near a cliff, with part of its stern protruding above the abyss. However, part of the ship fell to greater depths. Despite damage caused by waves, earthquakes, and landslides, the ship's cargo remained well-protected.

The wreck revealed large Corinthian roof tiles measuring approximately 70×30 centimeters, indicating that the ship had an extensive roof structure providing protection from rain and wind. In addition to the ship’s roof, it is likely that the galley and oven of the ship were also covered. Ships of this type typically had tall towers for defense or attacking enemies. A 60-kilogram lead projectile was found on the wreck, which may have been used for either the ship’s protection or against enemies, such as pirates, who might have sunk the ship. The ship’s stern contained the captain's bridge, and ancient descriptions indicate that such ships had a stern height exceeding 20 meters.

The ancient Greek ships were designed with great attention to their strength and flexibility, enabling them to withstand harsh weather conditions such as storms and high waves. Greek shipbuilders likely used advanced techniques, possibly dating back to prehistoric times, to ensure the stability and pliability of the ships. A key feature of this construction was the internal rigging, which included thick ropes and tendons to bind and reinforce the sides of the vessel. The shipbuilders would apply pre-tension to the ropes, stretching and twisting them to keep the ship strong and durable. The ship needed to remain intact while also being flexible enough to endure the various oscillations caused by the waves. These oscillations could occur in different directions—forward and backward, side to side, up and down, or rotationally. The correct tension in the ropes was crucial to ensuring the ship’s survival in challenging sea conditions.

An extensive layer of lead covering all the ship's hull prevents the accumulation of marine organisms like shells and seaweed, which would otherwise slow down the ship due to the rough surface they create. The layer of lead reduces friction with the water, allowing the ship to move more smoothly. It also protects the ship from decay and from impacts, whether from collisions with rocks or enemy attacks. The weight of the lead provides stability and buoyancy, ensuring the ship maintains its course during storms and strong winds.

On the Antikythera shipwreck, it appears that the passengers maintained fire in the galley and used ovens for baking bread. Hand mills for grains, bulgur, and flour were found, along with snails and olive pits, indicating the food consumed on board. In addition to utensils for the crew, luxurious reddish plates and platters were discovered, likely for wealthy Roman passengers or merchants. Descriptions of dining areas on such rich ships are mentioned by Athenaeus. The ship's ballast, necessary for stability in rough seas, was located at the bottom of the ship based on Archimedes' principle of levers and buoyancy. Archimedes had designed the first large ship using scientific methods, with mathematical theorems and the laws of physics that he himself discovered.

The ballast included heavy objects, and millstones were often used as ballast since they could be sold at the destination or at intermediary ports. There were also sandbags containing small valuable statues, such as the figurine discovered by diver Lefteris Tsavliris during research with the Calypso ship of Cousteau. The figurine was protected inside a sandbag, a method likely used for larger valuable items as well.

Human bones were found at the shipwreck site, including those of women who may have been wealthy passengers or part of the crew, such as cooks. Some intricate earrings with precious stones were discovered, which might have been worn by wealthy female passengers or could have been valuable cargo for Roman Patricians. A beautiful earring featuring a small cupid was recovered by Mr. Lefteris Tsavliris, who found it through a sieve that filtered sand and other fine materials gathered by the diving excavators using a suction device. The divers continuously sifted through the sand to select valuable items that had been buried within.

# The Greek Miracle

The Greek Miracle refers to the rapid emergence of philosophy and sciences in ancient Greece, particularly during the classical period of Athens. The Mechanism is the most representative example of the Greek Miracle, the epitome, as we say, which is globally recognized as the birth of civilization. The Greek Miracle is primarily focused on the birth of philosophy and sciences in Greece, as opposed to other contemporary civilizations. It is based on theoretical scientific thinking, especially in mathematics and geometry, where circular motions translate physical phenomena into numbers and equations through trigonometry and algebra. The scientific and technological heritage of Greece is a valuable legacy for humanity, influencing modern civilization not only in Europe but globally, as well as contemporary philosophy. Mathematics, which developed in Greece, forms the foundation of the sciences and the technology built upon them. Astronomy, physics, biology, mineralogy, logic, and philosophy are among the sciences that flourished in Greece, and the collective achievements of these fields are internationally referred to as the Greek Miracle.

The Greek miracle refers to the birth and development of philosophy and sciences in ancient Greece, based on Pythagorean concepts. These foundations are the basis of what is today known as Western civilization, which is, in fact, Greek civilization, with philosophy at its peak. Philosophy and the sciences, which are branches of philosophy, include mathematics, astronomy, physics, biology, logic, and philosophy itself. Mathematics was born and developed in Greece and serves as the foundation for the sciences and technology. Some of these sciences, such as astronomy and physics, are branches of philosophy. The Greek miracle characterizes the birth of civilization in Greece within a very short period of time, particularly in classical Athens, and it expanded during the Hellenistic period, when sciences and technology based on precise calculations prevailed. Pythagoras, according to tradition, was the first to introduce the use of mathematics to explain the laws of nature.

Pseudo-Plutarch describes Pythagoras as the first philosopher to introduce the concept of numbers and their symmetries as fundamental principles of the universe. Pythagoras believed that these numbers and their harmonies were the essence of reality, forming the foundation of his philosophical system. Aetius highlights Pythagoras' role in introducing these concepts, crediting him with laying the groundwork for a philosophy that integrated mathematics with the universe. Today, following the Pythagoreans, we acknowledge that all sciences become true sciences and are completed through the use of mathematics and the laws of nature. Their results are considered reliable or indisputable only through mathematics and physical laws. Scientific views are revised and improved with mathematics when new observations, experiments, and theories lead to advancements, which inevitably lead to new technology. The Antikythera Mechanism is considered the epitome of Greek Philosophy, as its construction required the application of Ionian philosophers' and Pythagorean thought in practice.

# I am a Pythagorean

The Antikythera Mechanism contains a hidden symbol, a pentagon, associated with Pythagoras. Engraved on one of its gears is the Pythagorean pentagon, a symbol of their mathematical and physical knowledge. The pentagon is not visible, as it is concealed between the gears and can only be revealed by removing them. This symbol is related to the movement of the planet Venus, which makes five revolutions around the Sun in exactly 8 years, a period equivalent to 99 months. The pentagon, therefore, symbolizes the power of knowledge based on mathematics and physics. By including this hidden symbol, the creator of the Mechanism leaves their "signature", boldly declaring their affiliation with Pythagorean philosophy.

# Studies of the mysterious Mechanism

The Antikythera Mechanism represents the culmination of the teachings and understanding of the Pythagoreans, who, through their mathematical approach to Nature, developed the scientific method. Observation, experimentation, and mathematical understanding led Pythagorean philosophers to the discovery of natural laws that can be expressed mathematically. This method became the foundation for formulating the laws of physics and the construction of the Antikythera Mechanism. Modern scientists continue to rely on the same scientific principles established during the Classical and Hellenistic periods. However, humanity experienced a setback in its progress for many centuries, due to political reasons and the Roman resistance to science, which delayed significant achievements such as the moon landing, which could have occurred two millennia earlier.

Adolf Wilhelm, Director of the Austrian Archaeological Institute, read and confirmed astronomical terms from the mechanism, such as "SUNRAY," suggesting it could be a solar clock or a navigational/astronomical instrument used to measure geographic latitude through the height of the sun and astronomical tables. The determination of geographic longitude might also be possible by tracking the Moon's position. Despite the damage to the mechanism's inscriptions, it may have served as a maritime aid with the correct accompanying astronomical tables. The practice of using astronomical instruments with tables is similar to modern technology, such as GPS. The mechanism was found in a wooden box that had disintegrated after 20 centuries in the sea, although a small part of the wood survived, showing traces of nails. Svoronos, a numismatist and archaeologist, considered it to be an astrolabe and suggested it should be carefully studied by astronomers.

Svoronos, an archaeologist and numismatist who was the director of the Numismatic Museum and edited the volumes of the archaeological underwater excavation proceedings, considered the mechanism to be an astrolabe, i.e., an ancient astronomical instrument. The mechanism was found inside a wooden box (compass) and has usage instructions. Svoronos emphasized the need for careful cleaning of the mechanism, as negligence could damage it, and he recommended that astronomers should carefully examine it. Archaeologists dated the mechanism based on the form of the inscription letters, estimating it to be from the 1st or 2nd century BCE. Others suggested that the inscriptions date to the Roman period. Today, the consensus places the dating between 150-100 BCE (Char. Kritzas, priv. comm. 2005). The mechanism has also been named a Chronological Table, a record of astronomical phenomena such as eclipses, positions of the planets, the Sun, and the Moon.

The author scientifically supports, based on historical data and ancient texts, that the Antikythera Mechanism functions as a clock. This is based on the description by the philosopher Proclus, who states that such machines constantly show the movement of the Sun, thus functioning as clocks. Proclus argues that the reader of his book could construct a mechanism that continuously tracks the Sun's movement, indicating mechanical motion. Time is regulated by the position of the Sun and a sunbeam. Additionally, Periklis Rediades discovered the pin-and-split system connecting two interlocking gears that drives the Moon’s motion according to Kepler’s second law. He argued that the Antikythera Mechanism is similar to Archimedes' "sphere" and could have been a clock if it had a spring, which was not found. The author presents his theory, discovering a possible “spring” that could have powered the motion of Jupiter. He also references descriptions by Hero and others, indicating that such mechanisms operated with weights and hydraulic systems to regulate time, without the need for springs.

The views of German archaeologists Hermann Diels, Albert Rehm, and Schlachter were interesting, as they argued that the object referred to a mechanical celestial sphere, a theory that had already been proposed as early as 1902 by Rehm and Rados, who believed that the mechanism was much more complex than an astrolabe. The study of the mechanism continued in 1910, with Konstantinos Rados, professor of Naval History at the Naval Academy and associate professor of History at the University of Athens, also examining the mechanism. Soon after, Admiral Ioannis Theofanidis, great-grandson of Theodoros Kolokotronis, created the first functional model of the mechanism, confirming that it was more complex than any known astrolabe or other mechanical devices. Around 1930, Admiral Theofanidis created the first operational replica, a complex astronomical clock that indicated the position of the planets and the Moon, using a sliding extendable pointer system. The construction was done by a Swiss watchmaker based on Theofanidis' instructions. The author had the fortune to meet Theofanidis around 1960. In the following decades, many admired the mechanism in the museum. One of the most important scholars was the Englishman Derek de Solla Price, who began studying the mechanism in 1951. Decades later (2006-2011), the author had the opportunity to delve into Price's archives with the help of his grandson, Admiral Danys Theofanidis, who informed him that Price had received his grandfather’s study from the French-Belgian engineer Miller. Miller had forwarded the thesis to Price, who requested that the mechanism be sent to the British Museum.

Charalambos Karakalos, a nuclear physicist from the Demokritos Nuclear Research Center, in collaboration with Prais, used gamma rays to create radiographs of the Antikythera Mechanism, focusing on its internal structure. They employed penetrating gamma rays to study the internal details with precision. Karakalos and Prais worked with Karakalos’ wife, Emelia, who carefully measured the teeth of each gear in the radiographs. Based on these radiographs, they constructed a three-dimensional model of the mechanism using stereoscopic images to better understand its structure. The stereoscopic images were achieved by using pairs of radiographs taken from two different but nearby positions, at a distance equal to the distance between the human eyes. By using appropriate binoculars, the observers could view the two images simultaneously, and their brains would automatically create a three-dimensional image, just as it happens in everyday vision.

Michael T. Wright, along with the late Alan Bromley and the head of the Chemistry Department of the Archaeological Museum, Eleni Magkou, developed an innovative methodology using CT scans to analyze the Antikythera Mechanism. These advanced imaging techniques successfully revealed many previously hidden secrets of the ancient device, shedding light on its internal structure and mechanisms. Wright dedicated years of research to studying these findings, publishing numerous important works that provided deeper insights into the function and purpose of the Mechanism.

# The new research

The idea that astronomers should be involved in studying the Mechanism was first proposed as early as 1907 by the archaeologist Ioannis Svoronos. He suggested that a complete understanding of the artifact required expertise in astronomy. This perspective laid the foundation for the formation of a modern interdisciplinary research team that took on the task of re-examining the Mechanism.

In 2003, a scientific team was assembled, initially consisting of three astronomers from three different universities (National and Kapodistrian University of Athens, Aristotle University of Thessaloniki, and Cardiff University) and a mathematician. After obtaining permission to conduct a new study on the surviving fragments of the Mechanism, the team expanded to include an archaeologist from the Museum and a specialized chemist with expertise in ancient artifact preservation and analysis.

Over time, the research team continued to grow, incorporating engineers, technical experts, and specialists from various fields. This expansion allowed for a truly multidisciplinary approach to the study of the Antikythera Mechanism. The collaboration led to a more comprehensive understanding of the technological and scientific principles behind the device, significantly contributing to modern knowledge of ancient Greek achievements in astronomy and mechanical engineering.

The mechanism analyzed in this text is based on the mathematical logic of gears, where each pair of interlocking gears performs either a multiplication or a division. This mathematical principle enables the deciphering of the mechanism’s functions since the ratio of the number of teeth on each pair of gears reveals the mathematical operation being executed. Through this process, we can determine the purpose of each gear train and the indication conveyed by the corresponding pointer.

By following this method, we uncover the physical theories applied by the ancient Greek creators of the mechanism. These theories are embedded in the laws of physics governing the arrangement of the gears. The knowledge possessed by ancient natural philosophers and astronomers—who used it to predict the phases of the Moon and eclipses—is thus encoded in the design of the mechanism.

By counting the number of teeth on each gear, determining the position of its center and axis, as well as measuring the internal and external radius, we can reconstruct the operation of the entire mechanism. We analyze the interactions between gears, identifying which gears drive others and which receive motion. Even for broken or missing gears, their function can be inferred based on the remaining components, such as other gears, axles, scales, pointers, and inscriptions found in the user manual. The mathematical information encoded in the gears allows for a comprehensive understanding of the mechanism.

Through this methodology, we have discovered how the Sun and the Moon move and how their positions in the sky were determined. Specifically, we studied the eclipse scales, including the Saros cycle, as well as the Metonic cycle, which was used for synchronizing calendar records. The mechanism was used to indicate time and date according to various calendars of the period and ensured their synchronization.

By analyzing the user manual and inscriptions that contain the names of months, the types of eclipses, and their precise times, we combined all this information with the findings from the gears and scales. As a result, the mystery of the mechanism has been solved, revealing how it functioned and what purpose it served in antiquity.

The exceptional collaborative atmosphere and the sense of satisfaction that prevailed during the period of new measurements of the Antikythera Mechanism in September and October 2005. A particularly telling anecdote is mentioned: two of the team members, independently of each other, expressed that this was the most important and meaningful period of their lives. This led to a humorous remark: “Just don’t let your wife find out.”

Thanks to these measurements, a highly precise database has been created, detailing the material density of each section of the Mechanism. This database is available to specialized researchers for scientific studies. Additionally, selected data is shared with schools, allowing students to study the surface of the Mechanism as part of educational programs. These measurements are specifically provided to schools that host the exhibition on the Antikythera Mechanism.

The research has enabled us to understand with absolute precision the structure of this ancient device, which remained submerged in the sea for more than two thousand years. It was found alongside other priceless Greek treasures that were being transported to Rome at the time of the shipwreck.

A significant point raised in the text is the advancement in computed tomography (CT) scanning technology since 2005. The resolution of CT scanners has quadrupled since then, making it essential to conduct new measurements. These updated scans could reveal the secrets of the Mechanism with even greater clarity, providing invaluable new insights into its function and use in antiquity.

The Sun and the Moon have played a central role in human perception of the sky and the regulation of daily life since antiquity. The Sun, as the primary source of light and heat, is fundamental to sustaining life on Earth and ensuring the smooth operation of natural phenomena. The Moon, while not emitting light on its own, reflects sunlight and has had a significant impact on human activities, particularly before the invention of artificial lighting, when it was used as a natural timekeeper for work and celebrations.

Virtually all energy on Earth, except for nuclear energy, originates from the Sun. The Earth's orbit around the Sun and the Moon’s orbit around the Earth lie in slightly different planes, which form a small angle of approximately 5.25 degrees. This angular difference explains why eclipses do not occur at every Full Moon or New Moon but only when the three celestial bodies – the Sun, Moon, and Earth – align perfectly.

Eclipses are classified as either solar or lunar. A lunar eclipse occurs when the Moon enters the Earth’s shadow during a Full Moon, often giving it a reddish hue due to the refraction of sunlight in the Earth's atmosphere. This phenomenon is visible from the half of the Earth that is in nighttime. Conversely, a solar eclipse takes place when the Moon passes between the Earth and the Sun, casting its shadow onto a small portion of the Earth's surface. Because the Moon is significantly smaller than the Earth, its shadow covers only a limited area, making solar eclipses visible from only specific regions.

Eclipses occur with a near-periodic regularity due to the consistent motion of the Earth and the Moon. Typically, solar and lunar eclipses happen every six synodic months (approximately 173 days), with probabilities of 65% and 63%, respectively. Less frequently, eclipses occur within a span of five synodic months (23% and 24% probability), and in extremely rare cases, two eclipses can take place just one month apart (11% probability for solar and 13% for lunar eclipses).

One of the most remarkable technological achievements of antiquity related to eclipses is the Antikythera Mechanism. This sophisticated analog computer uses an intricate system of interlocking gears to predict solar and lunar eclipses with remarkable accuracy. Its creators had a deep understanding of the mathematical relationships and periodicities of celestial events, effectively encoding the fundamental laws of physics within a mechanical system. The Antikythera Mechanism is a testament to the extraordinary advancements in ancient Greek science and technology, demonstrating a level of ingenuity that would not be surpassed for many centuries.

# The variable orbit of the Moon

The Antikythera Mechanism includes references to the periodicity of the Moon's phases. The Moon returns to the same position in the sky with the same phase every 19 and 76 years. For example, the position of the Moon at 10 p.m. tonight will be repeated in 19 years. These periodicities were regarded as "laws of physics" by ancient Greek philosophers, who sought to understand celestial phenomena. Although the formulation of such laws evolves with scientific progress, it is likely that people were aware of the periodicities of the Moon’s phases and eclipses as early as the 2nd millennium BCE, in regions such as Crete, the Aegean, Mesopotamia, Pre-Hispanic America, and China.

One of the most remarkable discoveries related to the mechanism is the system of gears that represents the Moon’s motion. This system allows for the simulation of the Moon’s variable angular velocity, which accelerates at perigee and slows down at apogee. Even more astonishing is the possibility that the mechanism accounts for the Moon’s elliptical motion by combining a small elliptical movement with a circular one, ultimately producing an elliptical orbit. This is achieved through the circular motion of gears in combination with an elliptical motion of a pin that connects two eccentric gears, transferring motion from one to the other. This sophisticated mechanical design enables an accurate representation of the Moon’s elliptical orbit, showcasing the advanced understanding of astronomy and engineering possessed by the ancient Greeks.

They mechanism replicates the Moon’s variable speed in accordance with Kepler’s Second Law. This is achieved through a system of four gears, two of which are slightly eccentric. These gears are linked by a pin moving within a groove, allowing the simulation of the Moon’s variable speed. This system is an early example of an epicyclic mechanism that closely follows Hipparchus’ mathematical model of lunar motion. Archimedes suggests had constructed an even more advanced mechanical model, where celestial bodies moved with variable speeds and retrograde motions. Cicero mentions that Archimedes’ mechanical celestial sphere could accurately replicate the motions of the Moon, Sun, and planets. This device was taken by the Roman general Marcellus after the fall of Syracuse in 212 BCE and brought to Rome.

The Antikythera Mechanism is evidence of the remarkable scientific achievements of the ancient Greeks, who were ahead of their time by two millennia.

Eudoxus created a model of the universe based on 27 concentric spheres, successfully explaining planetary motion, including retrograde motion and variations in planetary inclination relative to the ecliptic. Callippus later refined this model by adding additional spheres for greater accuracy, increasing the total to 33. He also introduced a 76-year cycle, which represents the longest calendrical period recorded in the Antikythera Mechanism.

The complex astronomical and the mathematical theories of epicycles were translated into a mechanical computation through gears. This demonstrates the extraordinary level of ancient Greek expertise in mechanics, metallurgy, mathematics, and physics. The designer of the Mechanism appears to have possessed a profound understanding of the physics of his time—perhaps even formulating some of the principles upon which the Mechanism was based.

The text examines the relationship between the Moon’s motion, Kepler’s laws, and the Antikythera Mechanism. It begins by noting that the Moon orbits the Earth in a slightly elliptical path, moving faster at perigee (closest to Earth) and slower at apogee (farthest from Earth). This movement was already known to the ancient Greeks and possibly other civilizations.

# Kepler’s laws in the Mechanism

The ancient Greek philosophers understood that the lunar, solar, and planetary orbits could not be accurately described by a single circular motion, because the distance of the bodies baies and the speed is not constant. To reproduce the orbits Greek astronomers developed the mathematical theory of epicycles, combining two circular motions to approximate celestial orbits. This concept of *epicycles* was introduced by Apollonius of Perga (262-190 BCE), who studied conic sections—the circle, ellipse, parabola, and hyperbola. These geometric curves are the sections of cone intersected by a plane. Kepler used them two millennia later for celestial orbits.

The Antikythera Mechanism realistically simulates the motion and phases of the Moon. Using four gears, the system reproduces the Moon’s position and phases with great accuracy, improving predictions of the New Moon, Full Moon, and eclipses. The mechanism appears to implement Kepler’s Second Law, formulated in 1619 in his work Harmonices Mundi, which describes planetary motion in elliptical orbits. The discovery that the Antikythera Mechanism practically applies Kepler’s Second Law to the Moon’s motion was unexpected.

Ancient Greek astronomers were aware that the Moon’s velocity changes as it moves along its orbit: it accelerates at perigee (the closest point to Earth) and decelerates at apogee (the farthest point). Hipparchus, in the 2nd century BCE, had already calculated the Moon’s orbital eccentricity with remarkable accuracy. Centuries later, Kepler, building on the highly precise observations of Tycho Brahe, formulated the three laws of planetary motion, beginning with his study of Mars’ orbit.

One of the most remarkable features of the Antikythera Mechanism is its representation of the Moon through a circular system approximately 8 cm in diameter. At the center of this circular diagram is the Earth, while the Moon is depicted on its perimeter. Surrounding the Earth is a carefully designed ellipse, which, however, does not place the Earth at one of its two foci, as modern celestial mechanics would predict. The significance of this ellipse remains unclear—it may have been deliberately designed to depict the Moon’s orbital eccentricity or to suggest a deeper ancient understanding of celestial motion.

# Who and where the eclipses of the Antikythera Mechanism have been observed?

A major discovery was determining the exact time and place where the eclipse observations were made. Astronomer Göran Henriksson, using data from the Antikythera Mechanism, found that these eclipses were recorded over a period of 54 years and one month. To everyone's surprise, all the observations were traced to Sicily, specifically Syracuse. Even more astonishing was the fact that one-third of the solar eclipses were recorded during Archimedes' lifetime, while the remaining ones were documented after his death. This revelation provides strong evidence that Archimedes, besides being a mathematician and engineer, was also an outstanding astronomer. Moreover, it indicates that an academic tradition existed in Syracuse, with his students continuing his work even after the Roman conquest.

# Calendars

As Earth moves along its orbit, the point on the horizon where the Sun rises and sets shifts daily due to the axial tilt. The angle of the Sun’s rays changes throughout the day, influencing the length of daylight and the maximum height of the Sun at local noon. During the winter solstice (December 21), the Sun rises at its southernmost point, and the day is the shortest of the year. After this day, the sunrise gradually shifts northward, and the days lengthen until the summer solstice (June 21), when the Sun reaches its highest point in the sky. At the equinoxes (March 20 and September 22 or 23), the Sun's rays fall perpendicular to the Earth’s axis, making day and night equal in length. These changes of the solar energy during the year create the seasons.

## The Sun, the Moon and Greek festivities

The Antikythera Mechanism featured an annual calendar, which was not a fixed part of its front plate but rather a detachable ring. This ring was placed in a special slot within a circular groove, allowing it to rotate for leap years. The purpose of this rotation was to adjust the calendar scale to account for the precession of the equinoxes, a phenomenon discovered by Hipparchus. The precession is caused by the continuous shift in the Earth's rotational axis, which behaves like a spinning top. Hipparchus found that the Earth's axis traces a conical motion over approximately 26,000 years, leading to a gradual shift in the positions of the equinoxes.

In practical terms, this means that the vernal equinox occurs slightly earlier over time. For instance, in recent years, it falls on March 20, whereas in past decades, it was on March 21. The Gregorian calendar, which we use today, corrects for this shift by implementing a 400-year cycle to ensure that equinox dates remain aligned.

The Antikythera Mechanism incorporated this knowledge: the user could rotate the disk with the decans, allowing a gradual shift in the star positions by a fraction of a degree to account for precession. This shift amounts to approximately one degree every 72 years.

An interesting feature of the calendar ring is the presence of a secondary ring at the base of the groove, which contains 365 small holes. This structure allows the rotation of the calendar scale relative to the astronomical scale, demonstrating the mechanism’s precise design for managing the calendar and its synchronization with astronomical reality.

The calendar ring of the Antikythera Mechanism includes a fascinating detail: a secondary ring at the base of the groove containing 365 small holes. It is possible that the user could remove the ring, offering an additional function for the mechanism. Some of the 365 holes may have been used to mark the Decans, the 36 significant stars employed in astronomy and calendar calculations. This structure allows for calendar management in connection with astronomical phenomena, rising and setting of star with the Sun. Probably the ring of the calendar is removed and decans are marked with pegs in the holes to adjust the mechanism for a given latitude. Then the ring of the calendar is reset in position, ready for this latitude on Earth.

With the help of inscriptions on the Parapegma of the Mechanism, located on the side that features the Sun and Moon, the date could be adjusted. The adjustment was based on the rising or setting of a star in conjunction with the rising or setting of the Sun. The calendar could be fine-tuned every ten days using the Parapegma, a type of astronomical table placed in the center of Greek cities.

The positions of the Decans changed depending on geographic latitude, as the horizon’s inclination relative to the celestial axis and equator varies. In the circular calendar scale, the Decans were positioned according to the latitude of the observer, ensuring that their risings and settings in conjunction with the Sun maintained an accurate calendar system.

Additionally, two significant time cycles within the mechanism were 76 years (the Callippic period) and 54 years (the Exeligmos cycle), as these intervals mark noticeable changes in the coordinates of stars near the celestial equator.

The mechanism also accounts for leap years. The addition of an extra day was managed through a circular scale with 365 holes, which shifted by one position for leap.

Throughout history, people have used the tropical year for agricultural activities and state affairs while maintaining lunisolar calendars for movable feasts such as Easter. Between the 11th and 13th centuries, the Easter date began to be calculated using the Metonic cycle, a lunisolar system also incorporated into the Antikythera Mechanism.

The instruction manual of the mechanism references planetary periodicities spanning half a millennium. Calendars are based on resonances between the movements of Earth, the Sun, and the Moon. These resonances, known as the "music of the spheres" or the "dance of the planets," were transmitted by Pythagoras and the Pythagoreans, who formulated the diatonic musical scale based on these astronomical harmonies.

For political and mainly independence reasons, each city-state had its own lunisolar calendar for agricultural activities and festivals, along with a second calendar based on either solstices or equinoxes for official state affairs. In some cases, an additional tropical calendar was used for administrative purposes.

# Precession of the Earth's axis

The *obliquity of the ecliptic*, as we call the angle formed by the Earth's axis with its plane of orbit around the Sun, changes over the millennia. In recent millennia it has been decreasing around 0.013th every century due to the influence of other planets and is constantly changing.[[1]](#footnote-1) At the time of construction of the mechanism Helium was 23.73°. The change of this angle slightly changes the position on the horizon when the Sun, the Moon and all celestial bodies rise and set, it changes the length of day and night. The spring point was during the Minoan and Mycenaean periods in Taurus, then in the region of Aries over the sky and later in Pisces, and in six centuries (2600 AD), it will be in Aquarius. This happens because the axis of the Earth changes direction in the sky, today it directs towards Polaris, but with a periodicity of 26000 years the axis of the Earth orbits in a cone. Therefore, every 2160 years, the pole of the Earth moves 30 degrees, or one degree every 70 years, as measured by Hipparchus.

# The movable feasts of the Greeks

**Plato: "*Feast time according to laws*", Definitions.**

The movable festivals of the Greeks were regulated based on the phases of the Moon and the season of the year so that people could see at night. The use of lunisolar calendars, such as the Octaeteris (Eight-Year Period) and the 19-year Meton period, combines the movement of the Sun and Moon, defining the days of feasts and other important events. The ancient Greeks and other peoples used such calendars to record the phases of the Moon and the movement of the Sun, thus combining religious festivals with the circular movements of celestial bodies.

The Octaeteris is an ancient calendar based on 8-year cycles, equal to 99 synodic months (29.5 days each). The Octaeteris was a system that facilitated accurate calendar keeping by combining the cyclical periods of the Moon and Venus, which allows people to plan holidays and celebrations.

The winners of the Olympic Games, which had ceremonial significance, were crowned with wreaths of olive trees, laurel etc. The dates for their celebration were determined according to the phases of the Moon. The Octaeteris 8-year cycle resulted in the organization of the Olympic Games and other crown games based on the full moon and summer solstice.

The Octaeteris seems to be associated with the myths of Greek tradition, such as the myth of Apollo and Python, as well as with priestly sacrifices, such as that of seven Athenian young men and seven girls in Crete for the Minotaur. It seems that form millennia there was a Pan-European calendar, as in Scandinavia to they had the same 8-year calendar associated with the sacrifice of 8 men and animals to keep this period alive in society until the 12th century. In Greece, the observance of these circular calendars continues to Christian holidays.

The Octaeteris is of particular importance, as it combines the cycles of the Sun, Moon and Venus and determines the time periods for adding the 13th month and setting up holidays such as Easter. It is a prehistoric tradition calendar used by the Greeks and other cultures.

From prehistory, humans have gazed at the sky, and this observation laid the foundation for their astronomical knowledge. They recognized the periodicity of celestial phenomena, such as the movement of the Sun, the Moon, and the planets, and understood their connection to time and seasons.

The Meton cycle, a 19-year period, is central, as many astronomical phenomena related to the Moon repeat within this period. This cycle was and is still used for the calculation of key dates, such as Easter, based on the Metonic period, which was important for aligning solar and lunar cycles.

The ancient Greeks used a solar calendar system in parallel, with key units of time measurement: the year (365.25 days), six months of 29 days and six months of 30 days, with additional 11 intercalary days around fall equinox. This was replaced by 12 months of 30 days and 5 additional days at the end of August.

The 19-year period of Meton, refined or invented in 432 BCE, was integrated into social life in Athens.

This period was in use for millennia to determine the dates of major festivals, and it is still in use for Easter ans Passover being the most well-known example. One notable figure in this was Anatolius, a philosopher and astronomer, who introduced the Meton cycle to the Church for the calculation of movable feasts, including Easter.

# Meton’s 19-year and Callippic 76 year period

Meton’s observatory, the Heliotropion in Athens, was used to study the movements of the Sun and Moon, preparing the astronomical cycles. Similar observatories existed in the Roman and Byzantine Empires, such as in the Church of Saints Sergius and Bacchus in Constantinople, where scientific instruments and mechanisms were preserved.

The Metonic cycle (19 υεαρσ) and the Callippic cycle (76 υεαρσ) are both ancient Greek calendrical cycles designed to reconcile the lunar and solar calendars by identifying periodicities in the motion of the Sun and the Moon. They were crucial in the development of lunisolar calendars and played a significant role in astronomical calculations, including the functioning of the Antikythera Mechanism.

## Metonic Cycle (19 Years)

The Metonic cycle, introduced by the Athenian astronomer Meton in 432 BCE, is based on the observation that 19 solar years are almost exactly equal to 235 synodic lunar months. The cycle can be summarized as:

* 19 tropical years ≈ 6,939.6 days
* 235 synodic months ≈ 6,939.7 days
* 254 sidereal months ≈ 6,939.7 days
* 255 draconic months ≈ 6,939.1 days

Since 19 years are nearly an integer number of lunar months, the Moon’s phases repeat on the same dates every 19 years. This periodicity was used in ancient Greek lunisolar calendars to intercalate months and synchronize the lunar year with the solar year.

## Callippic Cycle (76 Years)

The Callippic cycle, proposed by Callippus of Cyzicus around 330 BCE, is a refinement of the Metonic cycle. It consists of four Metonic cycles (4 × 19 = 76 years) but corrects the small discrepancy in the Metonic cycle by removing one day:

* 76 years = 27,759 days
* 940 synodic months ≈ 27,759.3 days

By adjusting the calendar in this way, Callippus improved the precision of the lunisolar system.

Importance and Applications

* The Metonic and Callippic cycles were used to construct Greek lunisolar calendars and later used by other civilizations.
* They were incorporated into astronomical instruments like the Antikythera Mechanism to track lunar and solar positions.
* The Callippic cycle was later used by astronomers such as Hipparchus and Ptolemy to refine celestial calculations.

These cycles demonstrate the remarkable observational skills of ancient Greek astronomers and their ability to develop sophisticated methods for tracking celestial phenomena.

**The Papapegma**

The parapegma (plural parapegrmata or parapegmas) was an astronomical calendar used by the ancient Greeks, where each line corresponded to a specific date. It contained information about the rising and setting of particular stars, which helped to keep an accurate the calendar.

In cases, the parapegma also included weather predictions associated with the appearance or disappearance of these stars. For example, the Pleiades, when they set in the autumn, signaled the arrival of colder weather. A similar use is found in Hesiod’s Works and Days, where he mentions the seasonal significance of astronomical phenomena for agricultural activities. Hesiod’s Works and Days was written around the late 8th or early 7th century BCE.

The Antikythera Mechanism included a table with 36 lines, each corresponding to the rise or set of specific stars at the same time as the rise or set of the Sun. These stars are called decans, as they mark dates spaced about 10 days apart ot 10 degrees in the zodiac. This table of the mechanism, called Parapegma, was used for determining the date based on the simultaneous heliacal rise or setting of these stars with the Sun, andto predict the weather based on climatic knowledge.

This type of table was known as parapegma. Such parapegmata were placed in the center of every city at the agora. Next to each line of the parapegma was a hole, and a pointer was inserted and moved every 10 days or so, corresponding to the time when the particular star rose or set along with the Sun. Each line of the parapegma corresponded to a specific date, and in some cases, weather predictions were also included. For example, the Pleiades, when they set in the fall (about 3,000 years ago), signified the onset of cooler weather. A similar usage is found in Hesiod’s Works and Days, where he mentions the seasonal significance of astronomical phenomena for agricultural activities.

The parapegmata were valuable tools for agriculture, navigation, public life, and daily activities, as they allowed people to know the date and predict weather changes based on both the calendar and climatic data.

**The Antikythera Mechanism, the Decans and the Parapegma**

The Antikythera Mechanism included a panel listing 36 celestial events. These celestial events concern the rising or setting of bright stars that are near the Sun's path, the ecliptic. These stars are known as decans. The parapegma is a catalog providing instructions for determining the date based on the simultaneous rising or setting of these stars at sunrise or sunset. These tables are called Parapegmas and were placed in the Agoras of the cities.

**Adjusting the Mechanism for Different Latitudes**

Since this system of the Parapegma is only valid for a specific latitude, the Mechanism featured an advanced adjustment system. It contained 365 small holes on a special ring beneath the annual calendar (which was on a detachable ring). The 36 decans were placed in these holes according to the observer’s latitude. By slightly altering their positions, the Mechanism could function for different locations.

**The Survival of the Tradition in Medieval Clocks**

The system of decans on a circular ring with multiple slots seems to have survived in medieval clocks. The Prague Astronomical Clock originally featured a similar mechanism, although it was later lost. A modern reconstruction in Stará Lesná, Slovakia, based on the old Prague clock, reintroduced this system, offering clues about the original function in the Antikythera Mechanism.

**Applications of the Mechanism by Users**

The user of the Mechanism could assign a decan every ten or so days, tracking when it would rise or set together with the Sun. This allows us to keep a good calendar. The user based on climatological data could predict the weather. The mechanism synchronizes all calendars used by the Greek and other people. The prediction of the eclipses helps a ruler, a king, tyrant, general, to assure people that the disappearance of the Sun or the Moon will happen on that day and that this is a natural phenomenon, and not a bad omen. This is important as people are superstitious. The Mechanism predicts the phases of the Moon and its position in the sky, and possibly shows the position of the planets.

# The 365 Holes

## Adjustment of the Mechanism for Different Latitudes

Each Parapegma (the astronomical calendar) is applicable only to a specific geographic latitude. Because the mechanism was portable, it featured an advanced adjustment system for different latitudes. It contained 365 small holes on a special ring beneath the annual calendar, which was on a detachable ring. The 36 decans were placed in some of these holes depending on the observer's geographical latitude. By slightly adjusting the position of the decans, the mechanism could function for different locations.

## Survival of the Tradition in Medieval Clocks

The system of decans on a circular ring with 365 holes seems to have survived in medieval clocks. The Astronomical Clock of Prague initially had a similar mechanism, though it was later lost during the Second World War. A modern reconstruction in Stará Lesná, Slovakia, based on the old Prague clock, revived this system with the decans, providing insight into the original function of the Antikythera Mechanism.

# Use and Applications of the Mechanism

The user of the Mechanism could predict the weather based on the date and climatic data and this was the main use. The mechanism synchronizes all calendars used by the Greeks and other peoples and define the day of festivities, including Olympic games.

The prediction of eclipses helps a ruler, king, tyrant, or general reassure people that the disappearance of the Sun or the Moon on a particular day is temporary, predictable, and a natural phenomenon, rather than a bad omen. This is significant as some people were and still are superstitious. The Mechanism predicts the phases of the Moon and its position in the sky, and likely shows the positions of the planets. It was extremely useful for travel, for determining geographic latitude and longitude. The Mechanism was also useful for education and teaching to philosophers, astronomers, cartographers, geographers, military personnel, and ship captains.

* The Mechanism was useful for teaching at philosophical schools, for astronomers, for travelling at sea or land, a good navigation aid. Very useful for the military, for state people. To know when an eclipse will happen, as people were superstitious and afraid of eclipses. A state person, a general knowing when to expect an eclipse could inform the people, the soldiers so that they could not be alarmed.
* Today is very useful for teaching. It shows that science can explain natural phenomena and predict some of them.

Figure caption Fragment D of the Antikythera Mechanism, a small yet enigmatic piece measuring approximately 4 cm. Using the X-Tek Systems Blade Runner CT scanner, specially designed for this research by Roger Hadland and his team, tomographic scans were conducted at the National Archaeological Museum in October 2005. The images revealed a small gear that appears to engage with a slightly larger hollow-toothed system. Additionally, a metallic strip, possibly a spring, was detected beneath the gear. This strip may be part of an automated mechanism interacting with an ellipsoidal object, potentially causing its rotation. The strip consists of two parallel layers bonded together, suggesting a sophisticated mechanical function.

# **The Mysterious Gear**

The Antikythera Mechanism remains one of the greatest mysteries of ancient technology, continuously revealing new information as research progresses. Analyzing its structure, gears, pointers, scales and the inscription on the Tablet provides valuable insights into the operation of its planetary system. The presence of planet names and the mention of the term "stationary point" of a planet changing direction, suggest that the Mechanism probably incorporated a sophisticated system for predicting celestial movements.

One of the most intriguing elements of the Mechanism is Gear 45, which appears to be embedded in a small fragment known as Fragment D. This gear, studied through computed tomography, exhibits a unique design indicating the possibility of epicyclic motion. If a pointer were added, this gear could replicate the movement of an outer planet, following the epicyclic model later developed by Kepler.

The study of this gear and its interaction with the external cylindrical casing suggests that the Mechanism may have contained at least 45 gears, highlighting its complexity. Additionally, the gear ratios appear to correspond to the actual distances of the planets from the Sun, indicating an advanced understanding of astronomy by the ancient Greeks. This is a remarkable example of the ancient astronomers' effort to "save the phenomena," as they used to say, i.e. describe nature with mathematics, the laws of physics as were formulated at that time.

# Ancient Clock: A "Rococo" Timepiece!

Plato: "Time is the motion of the Sun, a measure of [its] movement." Definitions.

Based on ancient texts, we estimate that the Antikythera Mechanism must have also functioned as a clock. Philosopher Proclus informs us that such devices continuously displayed the motion of the Sun, making them clocks by Plato’s definition. Its aesthetic may have resembled a Rococo-style timepiece, featuring an ornate and elegant frame, possibly adorned with precious materials such as gold and ivory. The Hellenistic gold jewelry preserved in the National Archaeological Museum demonstrates an aesthetic that, while luxurious, would have been far less expensive than the Mechanism itself.

Findings suggest that parts of the Mechanism’s casing were made of wood and included metal elements, such as nails. Decorative embellishments might have surrounded the frame, as suggested in ancient texts. The design of the Mechanism could be compared to later astronomical clocks found in ancient observatories and modern technology museums.

The Antikythera Mechanism is one of the most significant archaeological discoveries in the world and the only surviving scientific instrument from antiquity, as it was not recycled. Copper was precious and expensive in antiquity, making the Mechanism's preservation remarkable. Its survival was due to its presence in a shipwreck, where it remained underwater for 20 centuries, protected by limestone deposits, corals, and shells.

It is likely that the Mechanism also functioned as an anaphoric clock, continuously displaying the positions of celestial bodies, much like a planetarium. An anaphoric clock is an astronomical timepiece that not only indicates the time but also the positions of the stars, the Sun, the Moon, and the planets. A similar function appears to have been served by the *Tower of the Winds*, the *clock of Andronicus* of Cyrrhus in Athens, which featured engravings of the eight winds aligned with the eight cardinal directions.

# The User Manual of the Antikythera Mechanism

Like all scientific instruments, the Antikythera Mechanism came with a user manual that included instructions for its operation, potential setup, and an overview of what the user could expect from this mechanical cosmos. This manual was a densely written astronomical text, with letters about 2 millimeters in size, containing the physical laws used to program the computer.

The laws of physics used to predict solar, the motion and phases of the Moon, and the motions of the five known planets, in detail are mentioned. The description of planetary orbits includes the stationary points of the planets ("Stirigmos").

For the first time, it becomes clear that the Greeks were aware of extremely long planetary periods and resonances of the planets, such as 462 years for Venus and 442 years for Saturn. The 462-year period represents 289 synodic periods of Venus, a value not recorded in any other known astronomical literature. The manual also focuses on the forward and retrograde motions of planets, providing extensive details.

The Pythagoreans had recognized harmony and resonances of the planets, linking them with equivalent rations to musical notes. This is discussed by Ptolemy, underscores the deep connection between ancient Greek astronomy and musical theory. Ioannis Laurentius in his book "On the Months" underlines how planetary periods were associated with musical scales and vowel harmonies.

The manual is inscribed on all available flat surfaces of the mechanism, including the covers and the circular or helical scales. Many sections have been lost. The text that has survived permits us to understand a lot. Inscriptions related to the Zodiac cycle, the Parapegma (a table of 36 stellar heliacal risings and settings of stars), and calendar indications connected to equinoxes, solstices. These were used to predict the weather based on climatic knowledge. Τhe Metonic cycle inscriptions, allowing for a better understanding of the Greek calendars.

# The Antikythera Mechanism as a Planetarium

The manual of the Antikythera Mechanism provides a detailed description of planetary periodicities as observed from Earth. The text contains crucial information about the depictions of the planets on the mechanism, suggesting that it may have functioned as an ancient planetarium, like the two planetaria created by Archimedes. Proclus, the last philosopher in Athens says, engineers [mechanicoi] are only those that construct mechanical planetariums.

One of the most significant details recorded in the text is the motion of the planets of the then-known planets and their pointers. Each planet is depicted as a small sphere mounted on a poiter. This finding supports the theory that the Antikythera Mechanism was not only an advanced astronomical and calendrical calculator but likely also served as a mechanical model of the Solar System, offering a visual representation of the motion of celestial bodies.

The fact that the manual explicitly mentions the forms and movements of the planetary pointers strengthens the hypothesis that the Antikythera Mechanism was a sophisticated tool for education and understanding planetary motion, possibly using rotating disks and gears to simulate planetary orbits. In ancient Greek and Latin books there are descriptions of some planetaria.

# Is The Antikythera Mechanism Greek?

The Antikythera Mechanism is undeniably Greek, representing an extraordinary achievement of Greek culture and science. It is proven through Greek inscriptions, Pythagorean philosophy, and its deep connection with Greek science and mathematics. It was discovered in the Aegean on a ship filled with Greek treasures destined for Rome, further confirming its origins in the Greek world.

Its Greek nature is also highlighted by its user manual, written in Greek script and dated between 150 and 100 BC, as determined by epigraphist Dr. Charalambos Kritzas. The dating method relies on the shape of the letters, a well-established archaeological technique. Even if the Mechanism had been found in Antarctica or on Mars, it would still be Greek, as there were no non-Greek philosophers or scientists at the time capable of constructing such a device. Furthermore, its use of epicycles in astronomical theories is distinctly Greek.

# The Language and Authenticity of the Antikythera Mechanism

The Antikythera Mechanism is written in common Greek, closely related to the Ionic dialect. This is particularly evident in its astronomical terminology, which is predominantly Ionic rather than Doric, as one would expect if it had been constructed in Syracuse.

The solar year months inscribed on the device have Egyptian names, indicating a strong connection to Alexandria and its scientific tradition, particularly the influence of the city's Museum and Library. Additionally, the calendar includes Epirote (Corinthian, Doric) months from the lunisolar cycle, reflecting the cultural and economic influence of Corinthian colonies throughout the Mediterranean. These specific month names suggest a possible link to the mechanism's wealthy owner, who may have been from Epirus. The lettering style of the inscriptions suggests that the mechanism was made between 150 and 100 BCE, within the Hellenistic world shaped by Alexander the Great.

The possibility that the mechanism originated from a passing European ship of the 17th or 18th century is entirely ruled out for the following reasons:

- The script proves it is ancient.

- The language is authentic Hellenistic Greek.

- The astronomical content follows Greek traditions and incorporates the theories of Hipparchus—most likely the mechanism’s designer—and Apollonius of Perga.

- It contains usage instructions in Greek from the Hellenistic period.

- It references the Olympic Games, which were banned in 393 CE by Emperor Theodosius and were not revived until 1896.

Even if one were to assume that an eccentric individual included an indicator for the Olympic Games, no known clock from any era has such a feature. Furthermore, who would have thought to include the Isthmian, Pythian, Nemean, Naa, or Alieia games? What European scholar or historian of the time would have known their exact dates? We only learned their precise timing thanks to the Antikythera Mechanism’s dials.

Additionally, no known European clock of the 17th century includes the names of planets as they appear on the Mechanism, nor does any record eclipses with Greek symbols and Greek numerals. Finally, no European clock or calendar has been found with instructions written in Greek. All this evidence proves that the Antikythera Mechanism is an authentic masterpiece of ancient Greek technology and astronomy.

# How to Build a Mechanical Cosmos

The ancient Greeks invented the system of using gears for mathematical calculations, a computer, as demonstrated by the Antikythera Mechanism. The existence of such computational machines is confirmed by ancient texts, where Aristotle discusses paradoxes related to interconnected wheels.

The Antikythera Mechanism is a marvel of science, technology, and philosophy. It is an incredibly complex astronomical instrument based on physical and astronomical theories formulated with precise mathematical models. These models reproduce natural phenomena, such as planetary movements relative to the Earth. Its construction is based on the Pythagorean notion that the Universe, Nature, can be described correctly only through mathematics. These mathematics express the laws of physics. The Greeks use geometric constructions, primarily circles and epicycles to describe and predict orbits of celestial object (Sun, Moon, planets).

Circles can easily be translated into gears, which in turn move pointers on scales. Ancient Greek scientists favored circles because they are simple geometric shapes that can be precisely constructed and replaced by gears. The use of toothed wheels allowed for the mechanical reproduction of calculations necessary for determining the position and phase of the Moon, the Sun, eclipses, and possibly even the planets.

# From the Neolithic Era to the Antikythera Mechanism

The Antikythera Mechanism is an ancient computer that employs a system of gears to perform a series of complex numerical and geometrical calculations, ultimately determining all celestial events. It is considered a computer because it is an automatic device designed to carry out pre-programmed calculations. It is programmed through specially crafted gears that execute the necessary multiplications and divisions to predict eclipses, the position and phase of the Moon, and possibly the planets.

The Antikythera Mechanism is an advanced evolution of ancient temple-observatories, which may have also functioned as astronomical calculators, much like the orientations found at late Mesolithic and Neolithic Sesklo (7th millennium BC) and Dimini. as well as megalithic structures such as Stonehenge in England. Astronomy was essential for ancient Greeks for agriculture, and as early as 6500 BC, they had already developed astronomical knowledge.

At Stonehenge, apart from the megalithic structures with astronomical alignments, there are 56 Aubrey holes, are part of an ancient astronomical calculator that may have been used to predict eclipses. These holes form one of the earliest phases of Stonehenge, constructed during the Late Neolithic period between 4000 and 2000 BC. It is speculated that they once held wooden posts or monoliths or were used to position movable markers to track dates, lunar phases, and eclipses. The 56-year cycle they represent corresponds closely to the 18.61-year nodal cycle of the Moon.

The astronomical function of the Aubrey holes was highlighted by professor of astronomy Gerald Hawkins. Using astronomical calculations, demonstrated that various geometric features and alignments at Stonehenge could have been used for observing and predicting astronomical phenomena. Using the 56 holes, ancient astronomers could have predicted lunar eclipses, which recur approximately every 346.62 days.[[2]](#footnote-2)

Many ancient civilizations, dating back to prehistoric times, used luni-solar calendars based on the Moon’s motion across the sky and its risings and settings at the horizon. The Moon’s orbit around the Earth is complex, exhibiting many periodicities, including an 18.61-year cycle related to the Moon’s maximum and minimum declinations relative to the celestial equator. Since 18.61 is not an integer, ancient cultures, as Plutarch informs us, used a period three times this value—approximately 56 years (55.83 to be exact)—to predict lunar eclipses recurring at the same horizon position. Fred Hoyle suggested that the Aubrey holes could have functioned as a calendar with 28-day months, using moving markers to track the Moon and the Sun, with the latter advancing two holes every 13 days. Over time, this movement would enable ancient astronomers to predict eclipses. The Antikythera Mechanism operates in a similar manner. Gerald Hawkins and Anthony Johnson noted that Plutarch (in his Moralia, V) mentioned that Typhon or Seth in Egyptian and Greek mythology was identified with the Earth’s shadow covering the Moon during eclipses. Moreover, the Pythagoreans associated Typhon with a regular polygon of 56 sides, possibly linking it to the Aubrey holes.[[3]](#footnote-3)

Ancient sources describe Greek cultural and trade connections with the Hyperboreans—people living in a northern land where the north wind does not blow. Some of them, residing on a large island comparable in size to Sicily (perhaps Britain or Iceland?), were said to worship Apollo in a circular sanctuary adorned with offerings and musicians. The Hyperboreans revered the Greeks, especially the Delians and Athenians. Greek inscriptions have been found in their sanctuaries, left as offerings to Apollo.

It was said that Apollo visited this island every 19 years, a period known to the Greeks as the Great Year of Meton. This cycle was incorporated into one of the primary calendars used in the Antikythera Mechanism. From the construction of megalithic observatories like Stonehenge to the creation of the Antikythera Mechanism, roughly 1,500 years elapsed, during which astronomy evolved from a practical discipline to an theoretical science based on exact mathematics, theoretical prrofs amd theorems. In Greece, the use of mathematics and natural made astronomy, physics science using theorems and proofs.

With the development of astronomy, mechanisms like the Antikythera Mechanism replaced structures like Sesklo, the Aubrey holes and megaliths with gears, evolving into sophisticated astronomical computers that became compact and even portable. Rather than moving wooden or stone markers in holes to track the sky, ancient astronomers turned gears with specific tooth counts to move pointers, predicting and displaying celestial phenomena with remarkable precision. This method is like the one proposed by Tsikritsis for the Minoan computer that has been constructed at the same time as Stonehenge.

# Who Built the Mechanism?

## Archimedes and the Mechanism

It is difficult not to relate the greatest engineer of antiquity Archimedes with the Antikythera Mechanism. The greatest mathematician was physicist and astronomer too, as was his father. He had a philosophical school and workshop, where he taught mathematics, physics, engineering, and astronomy. With his students, he conducted accurate astronomical observations, construction of specialized instruments and measurements over many years. He was one of the best to measure time. He invented clocks. Using his clock known from many Arabic manuscripts, which featured automated moving parts for added spectacle. He could predict when and where an eclipse would occur and observe it. It is important for the history that some astronomers, his students, continued these activities in Syracuse for decades after the killing of the elderly Archimedes in 212 BC. The Roman soldiers killed him out of revenge. The Greek sage had single-handedly held off the Roman army outside the mighty Greek city of Syracuse with his inventions. He set their ships on fire, destroyed them using giant cranes and grappling hooks, launched iron projectiles with repeating mechanical catapults, and had ballistae firing hundreds of iron arrows. He has constructed two planetaria, automatic celestial spheres, reproducing celestial motions. Unfortunately, his book on construction of planetaria, *spheropoiea*, did not survive.

## Hipparchus as designer of the Mechanism

The Antikythera Mechanism was built between 150 and 100 BC, many years after Archimedes' death. The instructions inscribed on it are not in the Sicilian dialect, which would have been expected if it had been his creation. At the time the Mechanism was built, the greatest Greek astronomer, Hipparchus, was active on the island of Rhodes. Hipparchus introduced numerous astronomical innovations and developed various instruments. Rhodes had long-standing expertise in metallurgy and workshops specializing in precision mechanics. It is highly likely that Hipparchus was involved in the construction of the Mechanism. Therefore, Hipparchus is the most probable creator of the ancient astronomical computer.

Poseidonius (~135 BC–51 BC) lived a little later in Rhodes too. We know that he possessed a device similar to the Mechanism, as described by Cicero, who was one of his students in Rhodes. Many prominent Roman politicians and future emperors studied in philosophical scools of Rhodes.

# Other similar ancient technological achievements

There are several similar machines that indicate advanced knowledge in the physical sciences, mathematics, astronomy and technology. Similar mechanisms include the "Sphere of Hipparchus". These discoveries highlight the advanced use of complex mechanical systems in ancient Greek science.

## Minoan Computer:

The Minoan computer is a matrix, a mold used to create multiple identical objects in metal. Constructed around 1800 BCE, it displays significant features that indicate advanced astronomical knowledge. Its structure includes an eccentric ellipsoidal shape and 18 markings, which may be related to the periodicity of eclipses, specifically the Saros cycle, which was used to predict solar and lunar eclipses. Additionally, there are 28 small marks arranged in an ellipse, which most likely represent the lunar month. This device is a stone-carved matrix, allowing for the mass reproduction of copies in bronze. The existence of this mold proves that such portable astronomical computers were not unique artifacts but were produced on a large scale, indicating that astronomical knowledge had practical applications and was likely taught more widely.

The Prehistoric Computer of Crete shares important similarities with Stonehenge, though it also has differences. It functioned as a portable lunisolar calendar, used for tracking the phases of the Moon, determining the beginning of months, and possibly predicting solar and lunar eclipses—a capability remarkably advanced for its time. The similarities between this mechanism and Stonehenge suggest the presence of an international scientific and educational network in prehistoric Europe. There appears to have been interaction between scholars and astronomers across Europe, enabling the exchange of knowledge, ideas, and practices. This intellectual interaction explains why similar architectural and astronomical structures appear in different geographical regions.

## Archimedes' Planetarium and Clock:

There are references to Archimedes' famous planetarium, a highly complex mechanism designed to model planetary movements. According to Cicero, Archimedes built two such devices that accurately depicted planetary motions. These motions were not uniform, which proves that Archimedes incorporated advanced mathematical knowledge into his construction. It is likely that he was the inventor of the first planetarium. Many texts describe Archimedes' mechanical and automatic Celestial Sphere, which functioned as a planetarium, displaying the positions of the planets and celestial bodies. Archimedes (287–212 BCE) was born in Syracuse, a Greek city with a strong tradition in science and technology, especially from the time of the tyrant Dionysius the Elder. His scientific knowledge was influenced by his environment, as his father, Phidias, was a mathematician and astronomer. Archimedes was a pioneer in mathematics, geometry, and astronomy. He constructed astronomical instruments and clocks and measured the angular diameter of the Sun. At the same time, he developed advanced war machines for the defense of Syracuse against the Romans, such as catapults, cranes with metallic grappling hooks, and the legendary use of mirrors to set the Roman fleet on fire—a technique reminiscent of the mirror arrangement in the James Webb Telescope, which I once suggested should be named "Archimedes." His contributions to mechanics were significant, as he studied levers and formulated the famous phrase: "Give me a place to stand, and I will move the Earth." Additionally, he created complex automatic clocks that operated with hydraulic technology, as mentioned in many Arabic texts. Archimedes' Celestial Spheres are described by Greek and Latin writers such as Cicero, Pappus, and Proclus. One version was made of glass and accurately represented the movements of celestial bodies. His lost work On Sphere-Making described the construction of such mechanical spheres, but it did not survive, likely due to the difficulty of understanding it. Archimedes applied his knowledge of instrument-making to both celestial spheres and war machines, contributing to the prolonged defense of Syracuse. Although we lack detailed technical descriptions of his mechanisms, Arabic manuscripts mention his students, such as Ariston, who learned to build hydraulic clocks directly from Archimedes.

The loss of most of his works is due to their complexity, as they were not frequently copied in libraries. Despite the absence of these texts, Archimedes' legacy remains unparalleled, and his influence is still evident in modern science and technology.

## Proclus' Automata:

The philosopher Proclus, the last successor in Plato’s Academy, mentioned sophisticated automata that operated either with compressed air or hydraulic systems, like those of Hero of Alexandria. These mechanical devices, using ropes, strings, chains, weights, and counterweights, could mimic the movement of animals and humans, demonstrating a remarkable level of technological advancement for their time. Proclus’ house and school have been found in Athens, near the Herodeion, and objects from his school are displayed at the New Acropolis Museum.

## Argestius Chromatius planetarium

We learn from an ancient text that someone in Rome paid 200 pounds of gold (approximately 43 to 65 kilograms) to acquire such a precious and gold-adorned mechanism, decorated with gemstones on the indicators for the Moon and Sun. It was housed in an elaborate glass container (cubiculum vitruum) to both protect it and enhance its impressive appearance.

Argestius Chromatius, governor of Rome in the 3rd century AD, informs us that he owned such a mechanism, whose indicators were shaped like Daimones (deities) and used their hands to point to the positions of the planets. His grandfather had paid 200 pounds of gold for it. The mechanism was enclosed in a glass casing for protection but was later destroyed by its owner, as it was deemed "diabolical" and therefore dangerous. Could the mechanism of Argestius Chromatius be the planetarium of Archimedes, which Marcellus had taken to Rome? It is difficult to know.

## Archimedes Gear in Sardenia

Archimedes, the great Greek mathematician, physicist, astronomer, and engineer, created many complex devices, ranging from clocks to automatic weapons capable of launching a hundred iron arrows. Recently, the so-called "Gear of Sardinia" was discovered in the ancient Greek city of Olbia in Sardinia, along with objects dating back to Archimedes' era. Italian professor Giovanni Pastore, who gave a lecture at the University of Athens about this finding, adopted the term "Gear of Archimedes" after the author introduced it. Although some Italian experts dispute its antiquity, suggesting it may be a modern object accidentally deposited in ancient layers by water, further study is needed to reach a definitive conclusion.

## The mechanism of Dodona

Another interesting mechanism with a toothed wheel and a ratchet to be exact, is the "Mechanism of Dodona," possibly from a war machine such as a catapult or crane. It could also belong to a *hysplex*, a device used in ancient stadiums to ensure simultaneous starts for runners in races.

## The Tower of the Winds, the Clock of Andronicus of Cyrrhus

The Tower of the Winds, also known as the Clock of Andronicus of Cyrrhus, is an exceptionally impressive monument in Athens that combines a sundial and a mechanical-hydraulic clock. Built around 100 BC by the architect and astronomer Andronicus, this octagonal marble tower features reliefs of the eight winds, which gave rise to its popular name, "Aéridhes" (The Winds). Due to its unique architectural and technological significance, the structure was replicated in various countries, including England and Russia.

The tower has nine sundials on its outer surfaces and a hydraulic mechanical clock inside, which operated using water flow, a float, a winch, and counterweights—similar to how the Antikythera Mechanism is believed to have functioned. A study by Ms. Evi Panou identified an underground prismatic water reservoir at the back of the tower, measuring 1.60 meters deep with a narrow drainage tunnel of about 15 centimeters in diameter. Inside this tunnel, multi-strand copper wires were found, possibly components of the clock’s regulation mechanism.

The tower's interior housed a referential astronomical clock displaying the movements of the Sun and the Moon and possibly the planets. The clock’s hands were likely controlled through circular grooves on the floor, where a chain or wire transmitted the movement. Therefore, Andronicus’ clock was not merely a timekeeping device but also functioned as a form of a planetarium, accurately showing the positions of celestial bodies.

## A Greek Mechanism in France

The Chevroche Disk, an interesting discovery in France is part of an ancient astronomical mechanism. Similar objects with evident astronomical functions have been discovered across Europe, spanning different historical periods.

The Chevroche Disk is an instrument designed for astronomical and meteorological purposes. It has three concentric rings, on which the names of Egyptian and Roman months, as well as the zodiac signs, are inscribed all in Greek. The inscriptions are estimated to have been engraved around 230 AD (A. Tselikas, priv. comm. 2009), with a likely Alexandrian influence, though French archaeologists suggest that it may have been produced 40-50 years later.

Given the strong metallurgical tradition of the Gauls and the well-documented Greek influence on Gallic culture, it is possible that the Chevroche Disk was crafted by the Gauls following Alexandrian models. The zodiac signs and Egyptian months displayed on the disk are identical to those found on the Antikythera Mechanism. The disk has the shape of a spherical sector, meaning it is a segment of a sphere approximately 100 mm in diameter. Its dimensions are 65 mm in diameter and 18 mm in height.

Near its center, there is an off-center hole about 5 mm wide, with an axis connecting it to the rest of a celestial sphere or another device. A tin solder joint is visible on the underside of the disk. The eccentricity of the spherical sector suggests that its rotation could realistically replicate the movement of the Sun.

These types of mechanisms appear to have had multiple functions:

* Calendrical: They were used to synchronize the Roman, Greek and Egyptian calendars.
* Astronomical: The disk likely tracked the Sun’s movement throughout the year.
* Astrological: It may have provided information on celestial positions along the ecliptic.

It is possible that the Sun, and even the planets, were mounted on arms that rotated around the Earth, which was positioned at the center of the mechanism. This would have allowed the user to adjust the placement of celestial bodies near the ecliptic.

Other parts of similar calendrical mechanisms have been discovered in the ancient Gallic city of Alesia, in Hungary (at the Hungarian National Museum), and in Iceland, where three wooden examples have been preserved.

Another interesting example is the large Austrian Anaphoric Clock, of which only a quarter of the original disk has survived. These mechanisms bear inscriptions in either Greek or Latin, primarily related to months, and are estimated to date to the early centuries AD.

Ancient solar clock and calendrical mechanism from the Byzantine period. It operates with gears and can be adjusted for various cities, including Alexandria, Antioch, Rhodes, Athens, Sicily, Thessaloniki, Rome, Dalmatia, and Caesarea. It is housed in the Science Museum in London. J. Field and M. Wright studied and reconstructed the mechanism.

## The remarkable Byzantine clock

The mechanism is a remarkable Byzantine artifact—a portable solar clock equipped with calendrical gears. It combines essential functions, using the position of the sun at a given latitude to determine the date through complex gear mechanisms.

The Byzantine calendrical instrument was likely constructed during the reign of Justinian (527–565 AD). Its dating is based on epigraphic and historical evidence, placing its construction between 480–560 AD. It is a complex device that features both a solar clock and a calendrical function, displaying the day of the week and the month while also indicating the phases of the moon. It has a suspension arm and an axis with an escapement wheel (with seven lobes) and toothed wheels (with seven and ten teeth), allowing the instrument to advance once per day.

The Byzantine mechanism uses gears to determine the date and seasonal changes for the observer’s latitude (city), based on the changes in the sun’s altitude. The craftsmanship reflects Greek astronomical and calendrical knowledge in Byzantium. The device’s mechanics parallel earlier Greek mechanical traditions, particularly the Antikythera Mechanism, demonstrating the continuity of technological innovation in the Byzantine era.

Its main components include a front disc (135 mm) displaying the months of the Julian calendar, geographic coordinates for 16 cities and provinces, and a ring featuring seven depictions of the gods corresponding to the days of the week. The lunar disc (with 59 teeth) rotates around an axis and reproduces two lunar months (29 and 30 days). The use of two months instead of one is necessary since the synodic month lasts 29.5 days.

## Al-Bīrūnī’s Mechanisms

Al-Bīrūnī (973-1048), one of the most prominent astronomers of the Islamic Golden Age, developed two key instruments in astronomy: his eclipse calculator and astrolabe. These devices illustrate his ability to simplify complex astronomical calculations for practical use and highlight the mathematical principles behind eclipse prediction and celestial motion analysis.

Al-Bīrūnī’s eclipse calculator is based on geometric and astronomical principles for predicting solar and lunar eclipses. His contributions to astronomy were significant, as his ability to combine theoretical understanding with practical tools for observing the heavens had a major impact on the development of Islamic science. His invention of the astrolabe and specialized eclipse prediction tool provided a practical means of calculating and tracking the phases of the Moon and the movements of celestial bodies.

Al-Bīrūnī’s calendrical mechanism shares many similarities with the Byzantine calendrical mechanism, underscoring the mutual influences and common astronomical views between the two traditions. His astrolabe utilized Hipparchus' method of stereographic projection to represent the three-dimensional motion of celestial bodies on a two-dimensional plane. This technique allowed astronomers to better understand the motions of celestial bodies and map the sky more accurately.

One of his most impressive tools is his "eclipse plate," described in his work *Understanding the Possible Ways of Constructing the Astrolabe*. This plate attaches to the back of the astrolabe and allows the calculation of the Moon’s phases, the time of the Moon's rise or set, and the prediction of lunar eclipses.

## Τhe Gaza clock

The Gaza clock was an impressive and complex automatic machine, described by Procopius in his work *On Buildings*. It is believed to have been constructed around 520 AD by Anthemios of Tralles, although there are indications it could have originated in the Alexandrian or Hellenistic period. The clock was housed in a small temple in the Agora of Gaza, featuring 12 doors for the day and 12 for the night hours. Each hour during the day, the clock presented Hercules performing one of his twelve labors, using automata to sequentially display the events. Simultaneously, the chariot of Apollo rotated to show the Sun's path on the clock's circular disk.

Anthemios of Tralles, mathematician, physicist, and architect of Hagia Sophia, had studied and worked in Alexandria and was an expert in automata, influenced by the tradition of Tralles, known for creating complex automata mimicking living beings. The construction of the Gaza clock could be attributed to Anthemios due to his mechanical and mathematical achievements and his influence on the technology of the time. In his work, Anthemios described various types of machines and automata, including Archimedes' astronomical clock, which used weights, counterweights, and water for motion.

Procopius’s description mentions that the clock had three levels and functioned with blasts and strikes made by Perseus on Medusa’s head, much like the automatic mechanisms of Archimedes' clock. These clocks operated with a system of ropes and cylinders, where the ropes were wound around the cylinder each hour and opened the doors when they reached the required length. The use of these mechanisms to present movement and display the time in real-time was a technological achievement of the period.

Additionally, the Gaza clock featured moving automata, including Hercules and Perseus, as well as a Medusa that opened her eyes every hour, following exactly the same system used by Archimedes’ astronomical clock. The city of Gaza was renowned for its fine machines and automata, and the Gaza clock could be seen as part of this technological legacy. While its origin is often attributed to Anthemios, it might date back to the centuries before the Byzantine period, demonstrating the advanced knowledge of the ancient world in automaton technology.

## The Damascus Clock

The Damascus or Yazid clock, crafted by the Persian horologist Muḥammad al-Saati, was installed at the Gate of Hours in the Umayyad Grand Mosque of Damascus around 1160-1170. His son, Riḍwan al-Saati, described its mechanisms in his 1203 book *On the Construction of Clocks*. The monumental clock, measuring 2.8 meters in height and 4.2 meters in width, featured 12 doors that opened automatically each hour and 12 lamps that sequentially illuminated during the night, like the clock of Gaza. This clock is also referenced in the works of Ismail Al-Jazari, who described various mechanical devices and automata. Al-Jazari’s clock was based on earlier inventions, including the clocks of Archimedes and Gaza, and employed automation mechanisms similar to those of Archimedes.

## The Elephant Clock

The Elephant Clock, created in the 12th century by Ismail al-Jazari (1136–1206), was a hydraulic timepiece based on water flow. It is described in his work The Book of Knowledge of Ingenious Mechanical Devices, which includes various automated constructions. Designed in the shape of an elephant, the clock contained a mechanism with floats, ropes, and pulleys. A float inside a water container rose as it filled, triggering a pulley system. Every hour, a mechanical figure dropped a small ball, marking the passage of time.

It incorporated elements from Greek and Arabic engineering traditions, linking it to the works of Archimedes and Heron. It demonstrates medieval engineering advancements and the use of automation. Modern reconstructions reveal its functionality, making it one of the most remarkable technological achievements of the Middle Ages.

Al-Jazarī relied on the inventions of the Banū Mūsā brothers, who followed the Greek engineering tradition of Ctesibius, Philo of Byzantium, and Hero of Alexandria. Although he improved the valves, most of his devices were merely copies of his predecessors' work with only minor modifications or innovative enhancements.

## The wooden mechanism of Iceland

Proclus mentioned the existence of various mechanisms made of gold, silver, ivory, precious stones, bronze, marble, and wood. It appears that mechanisms like the one of Antikythera continued to be built after Archimedes' time. At the National Museum of Iceland in Reykjavík, three such wooden gear-driven devices were found, calculating dates, feasts, and weeks in the Danish language. The museum’s director and independently Dr. Agamemnon Tselikas dated them to 1780 AD.

# Greek Automata

The ancient Greeks developed an impressive tradition of automata, as evidenced by Homer’s description of the self-navigating ships, which moved without mechanical intervention (still used today). Greek engineers and philosophers designed automatic doors, hydraulic clocks, alarm mechanisms, and other mechanical innovations, demonstrating their deep appreciation and capabilities for technology. Archytas constructed the first known flying machine, a compressed air-propelled pigeon, mentioned by Pliny the Elder and Favorinus. These inventions highlight that Greek technology was central to the development of ancient science and Mediterranean dominance.

Numerous statuettes were found in the Antikythera shipwreck, including one that rotates. It is possible that the Antikythera Mechanism featured statuettes, similar to those seen in medieval astronomical clocks. If such statuettes were present, they may have been part of an automaton, performing movements such as indicating the time (as in Ctesibius’ water clocks) or producing sound by striking a rattle or another object.

Noteworthy is the renowned golden throne room of the Byzantine palace in Constantinople in the 9th century, constructed by the great philosopher Leo the Mathematician. This extraordinary work relied on hydraulic and pneumatic systems operated by water, compressed air, weights, and counterweights, which activated various automata through cords. Mechanized gilded lions would rise and roar upon the entrance of distinguished visitors to the throne room, while the emperor himself would ascend amid clouds. Meanwhile, mechanical birds perched on a gilded plane tree sang (like the clock of Archimedes), an automatic golden angel sounded trumpets, and automated cupbearers offered wine.

The Greek tradition of automata and clocks was continued by the Arabs and Europeans, with knowledge transferred through Greek (Byzantine) timepieces, especially after the fall of Constantinople in 1204. Medieval European astronomical clocks maintain strong connections to the Antikythera Mechanism and Byzantine technology. Remarkable descriptions of mechanical planetariums survive in works such as Huygens’ Descriptio Automati Planetarii (1703), which includes detailed mathematical analyses. The use of automata, such as statues striking bells, had already been established in antiquity. Ctesibius, Hero, and Archimedes developed hydraulic and mechanical clocks featuring complex automations, including moving statues and mechanisms that dropped small spheres every hour. Arabic sources preserve descriptions of Archimedes’ clock, which operated with floats, wheels, and gears, similar to later astronomical clocks. The technological achievements of ancient and Byzantine engineers laid the foundations for European horology and mechanical engineering.

# The Mechanism as an Educational Tool

The Mechanism has immense educational value, significantly aiding the understanding of nature across all age groups. It highlights the power of human intellect and demonstrates that the study of nature is based on modeling and the existence of universal physical laws, which can only be accurately expressed through mathematics.

From Pythagoras to Galileo and today, all scientists apply excact mathematical methods to physics andtechnology. The principle that "the language of nature is mathematics" remains fundamental in science, whether in astrophysics or engineering. The Mechanism, as an embodiment of this principle, proves that natural phenomena follow immutable laws and that predicting events such as eclipses is possible through mathematics and physics.

Furthermore, it teaches Philosophey. reflects the Pythagorean philosophical tradition, which recognized that physical laws are universal and eternal. Some philosophers foresaw that the laws of physics can be influenced by environmental conditions, an idea confirmed by modern science. The Mechanism teaches that studying nature or creating advanced technology rely on mathematical reasoning, permitting to the creation of a Mechanical World.

# Secrets of the Mechanism:

## Automation Valves

Archaeologist[[4]](#footnote-4) continue to discover significant archaeological artifacts at Antikythera shipwreck. Among them, a rectangular carved stone object (28×20×5 cm) was retrieved, featuring a hollow rectangular section (15×9×3 cm) with 12 parallel conical perforations in three rows. Each perforation has a truncated conical shape with a diameter of 2 cm inside and 10-13 mm at the base. These perforations resemble automation valves similar to those described in Heron’s inventions. In such systems, the release of liquid or solid materials (such as sand or lead spheres) activates a mechanism through applied torque. Each of the 12 perforations may have triggered a distinct function at regular intervals, akin to the valves of Hero automata and processes in the clock of Gaza or Damascus. The hollow section of the stone is filled with fine-grained material (fine sand?), within which small cut wires were discovered, some with a spiral shape. These "springs" may have been part of an ancient automaton, suggesting advanced mechanical engineering in the mechanism’s operation.

## The spheres for the planets?

The word sphaerion (little sphere) appears three times in the manual of the Mechanism, possibly referring to the indicators of the Sun, Moon, and planets. The names of all planets are written in the manual of the Mechanism. The Moon's indicator is known to be spherical at its tip, suggesting a similar design for the others. In the manual it is written “little golden sphere”, probably the pointer of the Sun. In ancient clocks, the Sun’s indicator was often a circular disk with rays.

In the shipwreck six small spheres made of precious stones have been discovered, each with a flattened base, possibly designed to be affixed to a metal pointer as part of the mechanism. It is plausible that they represent planets. Similar descriptions appear in ancient texts discussing such devices. The prevailing view identifies them as gaming pieces. These spheres exhibit various colors—deep blue, green, and yellow hues—matching descriptions of planetary colors in ancient sources on planetaria.

## Little Spheres for Automations

Ancient Greek texts, including Arabic sources describing Archimedes’ clock, Heron’s automata, and the Damascus clock, mention mechanisms that operated through spheres triggering automations to indicate time etc. Similar mechanisms may have existed in other ancient timekeeping devices, such as the Greek clock of Gaza or Damascus.

An examination of the Antikythera Mechanism’s fragments reveals a curved piece, possibly a broken part of a sphere or a curved cover or a float. It might have belonged to a celestial sphere or functioned as a float moving the mechanism through a regulated water inflow, a technique also documented in Archimedes' clock.

A circular bronze artifact, 8.5 cm in diameter, was discovered, featuring a relief of a bovine figure and small perforations for attachment. While its function remains uncertain, it could be linked to the Mechanism, serving either as a decorative element or as an astronomical reference, possibly representing a zodiacal sign.

# Modern science, and the Antikythera Mechanism

Modern science and technology trace their origins to the Antikythera Mechanism. From computers and space exploration to architecture, the influence of Greek scientific thought remains ever-present. Today's global civilization is, in essence, an extension of Greek culture, which shaped the philosophy and technology that define the modern world.

From Hephaestus and Prometheus to Thales, Leucippus, Plato, and Aristotle, Greek philosophers laid the foundations of science. The libraries, buildings, and mechanisms of today are the descendants of the Greek Miracle. As the god Apollo foretold through the Pythia, science is the means by which humanity will overcome disease and suffering.

# Acknowledgment

The study of the Antikythera Mechanism was funded by the John F. Kostopoulos Foundation to whom we express our gratitude. We are also grateful to the Leverhulme Trust for sponsoring the main and key phase of the study. Thanks to the Alexander S. Onassis Foundation for an exhibition grant at NASA at the JF Kennedy Space Center (USA), the Ogden Trust, The Institute of Physics (UK), the University of Birmingham (UK), the Technical Chamber of Greece (TEE), UNESCO in Paris, the University of Uppsala, the Toulouse Observatory, the Cosmonaut Training Center of Russia, the Russian Science Festival, the Athens Science Festival, the Mediterranean Science Festival, the Thessaloniki Science Festival, Drexel University, Stonehill College, Harvard-Smithsonian Center for Astrophysics, Tufts University, Lomonosov Moscow State University, University of Cyprus, European University of Cyprus, State Museum of Architecture Moscow, Attica Region,The Parthenon Museum Nashville, the Greek State Scholarship Foundation, three Grundtvig programs (EU) that contributed to the dissemination of the results of our study abroad.

Thanks also go out to Images First Ltd the technical aid of X-Tek Systems, now owned by Nikon Metrology, Hewlett Packard, Volume Graphics, MIET.

We express our gratitude to the National and Kapodistrian University of Athens, the Ministry of Culture, the then Deputy Minister of Culture Mr. Petros Tatoulis, the National Archaeological Museum, the National Archaeological Museum of Iceland, the Archaeological Museum Piraeus, the Archaeological Museum of Rhodes, the Archaeological Museum of Chania, the Archaeological Museum of Heraklion and their staff.

This study was carried out in collaboration with many friends and colleagues. I owe many thanks to the professors Mr. I. Seiradakis, Mr. M. Edmunds, Dr. Mr. T. Freeth, Mr. I. Bitsakis, Professor Manos Roumeliotis, Dr. E. Mangou, without whose encouragement I would not have begun the study of the Antikythera Mechanism, Ms. M. Zafeiropoulou, Mr. Roger Hadland, Mr. Andrew Ramsey, Mr. David Bate, Mr. Martin Allen, Mr. Alan Crawley, Mr. Peter Hockley, Mr. A. Ray, Dr. Tom Malzbender, Mr. Dan Gelb, Mr. Bill Ambrisco, Mr. C. Reinhart, Dr. Agamemnon Tselikas and his associates, Dr. Mr. Haris Kritzas, Mr. Dionysis Kriaris, Mr. Gerasimos Makris and associates, Ms. Antigoni and associates (Hellenic National Archaeological Museum) Dr. Magdalini Anastasiou, the late Elias Gourtsogiannis, Professor Kyriakos Efstathiou, the late Christos Lazos, the late Vangelis Spandagos, the lecturer Dr. Maria Pavlidou (University of Birmingham, now Galileo Voyage) for the 10 exhibitions and lectures we held in England, the lecturer Dr. Emilia Smyrlis for the talk and exhibition at the University of Central Lancashire, the late Mrs. Lisa Mandaliou-Stadiatis Lykopantis, Dr. Flora Vafea, Mrs. Angeliki Simosi and the collaborators of the Ephorate of Underwater Antiquities Greece and Aikaterini Laskaridis Foundation that supports them, the Suisse School of Archaeology in Greece, Professor Brendan Foley, Prof. A. Le Beuf, Dr. Leonid Gusev, Prof. Mary Blomberg, the late Professor Olga Zinovieva, Ms. Larisa Bakulina, Dr. Alessandro Massarotti, Ms. Nicole Giannopoulou, Mr. N. I. Georgakellos, the late Dion. Simopoulos, Professor Stratos Theodosiou, Professor Manos Danezis, Dr. Katerina Paliou, Dr. Minas Tsikritsis, Mr. P. Fildisis, the members of the Board of Directors of the Union of Greek Physicists.

Special thanks to Mrs. Evi Sarantea for the wonderful realistic portraits of the ancient philosophers that she created for the benefit of all of us and allows us to use in my exhibitions, lectures, films, and books.

I would like to thank the professor of the University of Athens Prof. Maro Papathanasiou for extensive critical discussions. Special thanks to Prof. Dr. G. Henriksson (University of Uppsala) for the calculations of the site of observation of eclipses mentioned in the Mechanism, and discussions about ancient solar Minoan calendars and the Octaeteris in Sweden.

Many thanks to my family for their encouragement, support and understanding for the countless hours I work at the University, or at home, due to constant studies and field research, the absences due to travel connected with the research, lectures and exhibitions of the Mechanism all over the world, constantly and positively promoting Greece.

Many thanks to Wikipedia and Wellcome collection for using several images in my books, films, and lectures.

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