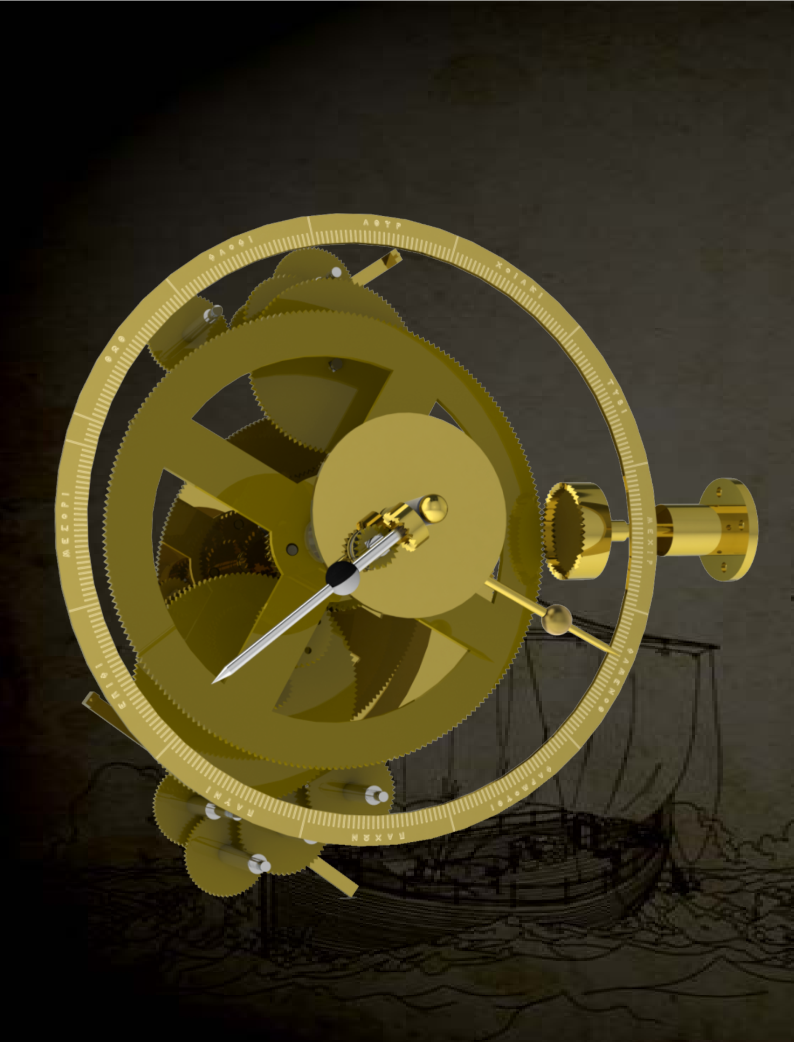
The Antikythera Mechanism

Historical Mechanical Engineering Landmark

Athens, National Archaeological Museum

The American Society of Mechanical Engineers

ASME SETTING THE STANDARD



Athens, National Archaeological Museum

The story behind the mystery

Recovered in 1901 from a first-century BC shipwreck, the Antikythera Mechanism is the oldest extant complex geared device. It is essentially an analog computer, an inscribed astronomical and calendrical device, designed to predict astronomical phenomena such as lunar and solar eclipses, to maintain calendar accuracy and to predict the dates of Panhellenic Games. The mechanism's miniature scale, the elaborate gear trains, the use of differential and epicyclic gears, and the employment of pin-and-slot couplings demonstrate that the Greek mechanicians of the Hellenistic period had become far more fluent in designing geared devices than the surviving written sources infer. Geared devices matching the complexity of the Antikythera mechanism would not appear again in Europe until the mechanical clocks of the thirteenth century.

2nd c. BC

Construction of the Antikythera Mechanism

The 82 fragments of the Antikythera Mechanism (NAM Inv. No. X 15087) are exhibited in the permanent exhibition of the Collection of Metalworks of the National Archaeological Museum in Athens (Gallery 38), accompanied by explicative texts, models and audiovisual material. The Antikythera Mechanism consisted of at least 30 gear wheels with teeth, as well as dials, axles and pointers, made of at least three different alloys of copper, tin and lead. The astronomical inscriptions on the interior surface of the Mechanism referred to astronomical and daily calculations, while those on the front and back plates convey information and instructions for the Device's use. The Greek inscriptions are carved by the same hand and date the device in the 2nd c. BC. Housed in a rectangular frame the device shows data on both sides. The Mechanism was probably constructed on the Greek Island of Rhodes, but we cannot be sure about the place or the manufacturer. In the period it was likely constructed, one of the greatest astronomers of antiquity, Hipparchus, lived on Rhodes.

75 – 50 BC

The Roman shipwreck

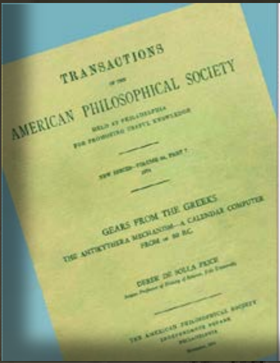
A Roman ship wrecked in the 1st century BC yielded numerous statues, vases, coins, and other artifacts, some dating back to the 4th century BC. Among them, were the severely corroded fragments of the world's oldest known analog computer, the Antikythera Mechanism. The ancient works of art, including parts of the ship itself, are now displayed at the National Archaeological Museum in Athens.

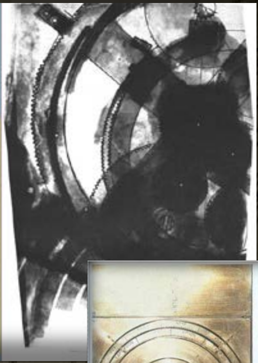
1900– 1901

The discovery and the excavation

In the spring of 1900, two sponge fishing boats from the Greek island of Symi came to the east coast of Antikythera Island, where diver Ilias Stadiatis discovered the wreck at depths between 40 and 50 m. In November of 1900, sponge boat captain Dimitrios Kontos alerted the authorities in Athens to the discovery. Instantly the Hellenic Royal Navy vessel "Mykali" was dispatched to the island to support the excavation, followed soon by the civilian steam ship "Syros" and later the Navy torpedo boat "Aigialeia". It was the first coordinated underwater excavation in history. In 1976 an excavation of the shipwreck was undertaken by the Ephorate of Underwater Antiquities in collaboration with Jacques Yves Cousteau and his oceanographic ship "Calypso". The underwater investigation continued under the supervision of the Archaeological Service in 2010s'. In 2012 the National Archaeological Museum organized a temporary exhibition dedicated to the "Antikythera Shipwreck". Almost all the finds were presented in their context for the first time (see N. Kaltsas, El. Vlachogianni, P. Bouyia (eds.), *The Antikythera Shipwreck, the ship, the treasures, the mechanism, April 2012 – April 2013, National Archaeological Museum,* Athens 2012).

Karakalos' X-rays and Price's Book





Many researchers studied the Mechanism from 1902 until 1970. Beginning in 1970, Derek J. de Solla Price of Yale University and nuclear physicist Charalampos Karakalos used gamma-rays and x-rays to see inside the corroded fragments. The images they secured showed several gears, along with dials and plates, some covered with inscriptions. Using these data, Robert J. Deroski, under the supervision of Price, constructed two models.

1998

The first computer simulation

Based on Derek J. de Solla Price's book ("Gears from the Greeks"), Professor Manos Roumeliotis (University of Macedonia in Thessaloniki) designed the first simulation of the Antikythera Mechanism and provided access to everyone! For the first time since the Antikythera Mechanism had been "rediscovered", anyone could download an interactive simulation and "explore" the Mechanism by rotating, zooming, and even changing the speed of the gears' rotation.

1990 - 2005

M. Wright's model

In 1990, A.G. Bromley collaborated with M. Wright, using X-Rays to determine the exact position of the gears inside the Mechanism, but their research didn't give the expected results. After Bromley's sudden death, Wright continued the research on his own, suggesting and constructing in 2005, a model with pointers not only for the Moon and the Sun, but also for the five planets known in antiquity.

2005

The "Blade Runner” and the "PTM Dome"

2005 was one of the most important years for Antikythera Mechanism research. Two world-class high technology companies, Hewlett Packard and X-Tek Systems, applied two new technologies to unravel the mystery of the Mechanism: the "PTM-Dome" and the "Blade Runner" respectively. PTM-Dome was a device that made it much easier to read the letters on the surface of the fragments by using a digital imaging technique. Blade Runner was an eight-ton x-ray tomograph that could "read" the inside of the Mechanism. Both techniques revealed a huge amount of previously unknown data, and for the first time the Mechanism was completely unlocked! The next step was to interpret all this data. A new chapter for the Antikythera Mechanism had just begun!

2008

First model of Aristotle’s University of Thessaloniki

The first attempt of Aristotle's University of Thessaloniki (Greece) to build a functional copy of the Mechanism was supervised by Professors K. Efstathiou (School of Mechanical Engineering) and J. H. Seiradakis (School of Physics). The model was based on a 2006 article in the journal “Nature”, but it turned out not to be functional. The problem was identified as being due to the gears‘ measured dimensions and axial distances, as reported in “Nature”. After more than 2000 years at the bottom of the sea, the Mechanism’s fragments had become fossilized, and all the components had been shifted. The data from “Nature” might have accurately reflected the position and dimensions of the gears in the recovered device, but the fragments had been so corrupted by several thousand years of corrosion that a functional model could not be built to those specifications.

2011

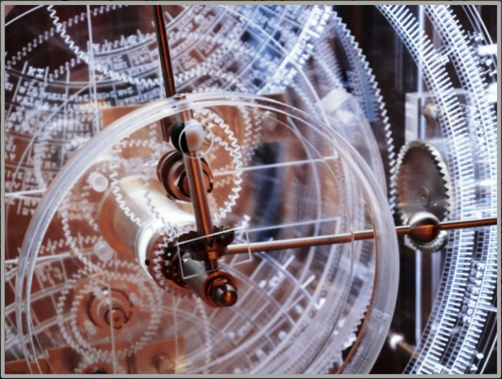
Second model of Aristotle's University of Thessaloniki

Right after the first, non-functional, model in 2008, Aristotle's University of Thessaloniki began a whole new research project, to determine all gears' diameters, the axial distances, and possible construction methods of the original Mechanism. The goal was to design all the mechanical parts from scratch (axial distances, position, and diameters of the gears), in order to construct a functional device as similar as possible to the tomographs. The result was a brand new functional model with more than 97% of the mechanical parts and their dimensions identical to the fragments! The goal had been completed!

2016

The latest most accurate models

Transparent functional model in 3:1 scale



Accurate functional model in real scale

After 7 years of research, the members of the Antikythera Mechanism Research Team of Thessaloniki, headed by A. Basiakoulis and Dr. M. Efstathiou, designed new models of the Mechanism. The new models were based on the second model of Aristotle's University, but certain mechanical parts had been improved and many letters had been added to the inscriptions. These are considered the most accurate models of the Mechanism ever built because they duplicate the original Mechanism better than previous models. In addition, the team designed a model three times larger than the model with transparent plates and lighting for exhibition purposes.

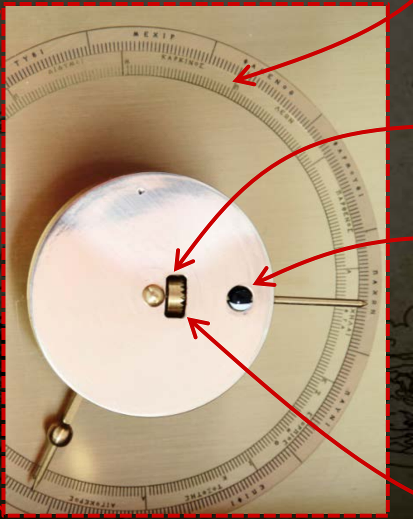
Athens, National Archaeological Museum

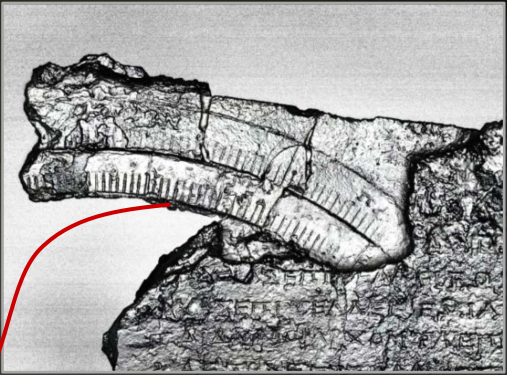
The indicators and the inscriptions

The Antikythera Mechanism was an analog computer used to calculate the position of the Sun and the Moon in the sky, determine the phases of the Moon, predict the eclipses of the Sun and the Moon, and indicate the celebration dates of the ancient Panhellenic games (e.g., the Olympic games). It had seven pointers which displayed the results on corresponding mathematical scales. Two of the indicator dials are on the front side of the Mechanism, and five are on the back side. The phases of the Moon were indicated by a rotating sphere, linked with a crown gear to the Moon's pointer. All these functions were incorporated in a portable, compact machine… Was it really just a computer, or the laptop of ancient times?

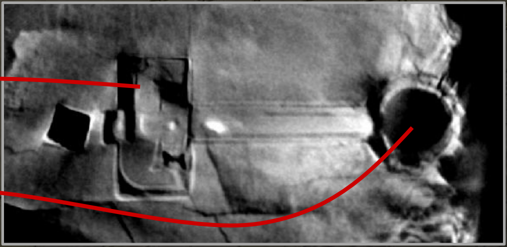
The front side

On the front side, there were two concentric circular scales. The outer scale had 365 subdivisions and the names of the 12 Egyptian months in Greek. The inner scale had 360 subdivisions and the names of the 12 zodiac constellations. The operator, by turning the shaft to which the moon's pointer is linked, moved the gears, which in turn rotated two pointers on the front side that indicated the position of the Sun and the Moon. Beneath the outer scale, which was removable, there were 365 holes. Every four years the operator could detach the scales and shift them by one hole, thus taking into account leap years. A rotating sphere, linked by a crown gear to the Moon's pointer, displayed the phases of the Moon.

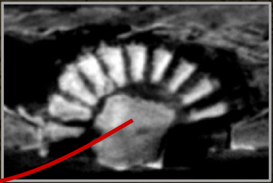




The two concentric dials



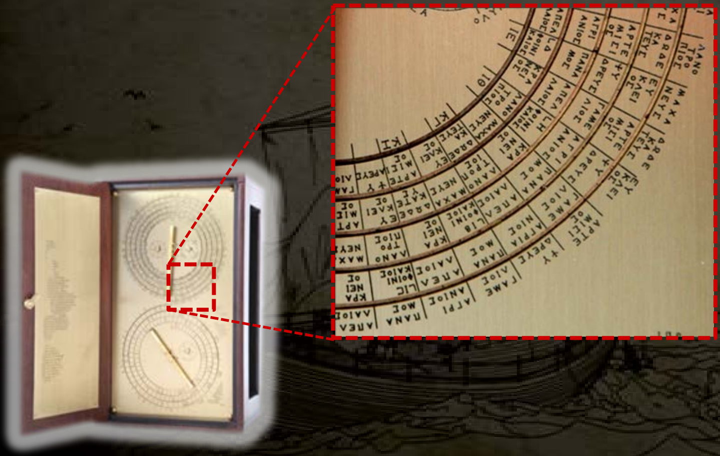
The Moon's pointer and its sphere



The Moon's pointer crown gear

The back side - An ancient calendar

On the back side of the Antikythera Mechanism, there were two main dials in the form of spirals. The upper back dial is a 19-year calendar, arranged as a five-turn spiral of 235 lunar months. This calendar is known as the Metonic cycle, named after the Greek astronomer Meton of Athens who lived in the 5th century BC and had observed that every 19 solar years the Moon returned to the same point in the sky with the same phase.



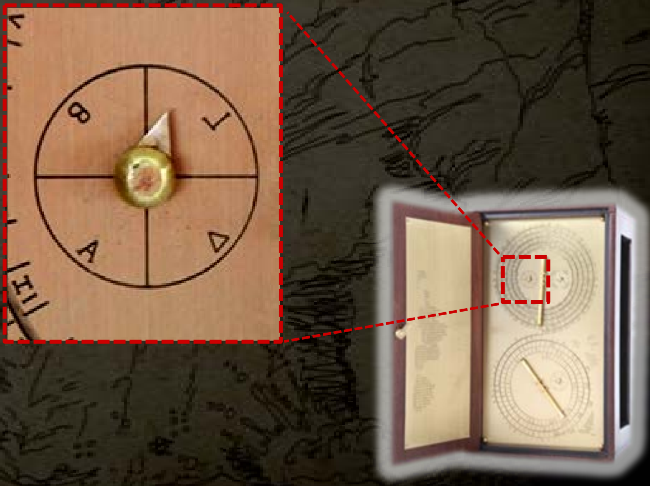
At the subdivisions of the spiral, the ancient names of 12 lunar months are artistically carved, repeated to form a period of 19 years. The names of the months are of Corinthian origin, reflecting those used by the Corinthian colonies of northwestern Greece.

The back side - The Panhellenic “Crown Games” dial

A subsidiary dial within the upper back spiral of the Antikythera Mechanism displayed the celebration date of the important ancient Panhellenic “Crown Games”. On the circumference of the dial the words Olympia, Pythia, Isthmia, Nemea and Naa have been deciphered. Internally, in each quadrant, the four years of the Olympic cycle are indicated. In all these “Crown Games” the winners were being awarded with wreaths.

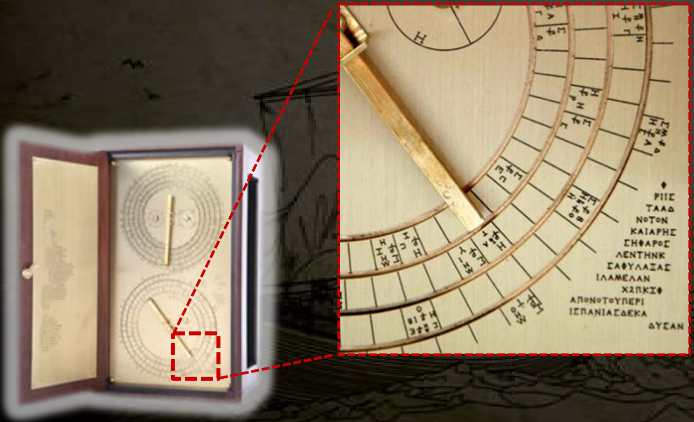
The back side - The “Callippic dial”

Calippos, a 4th century BC astronomer who lived after Meton, discovered that Meton had made a small mistake in his calendric system. Every 4 periods of Meton, i.e., every 76 years, one day needed to be removed. The Callippic pointer indicated when the correction must take place.



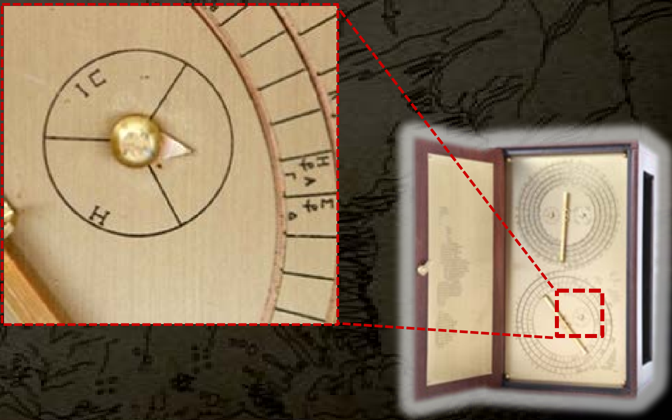
The back side - The spiral of Saros

The lower back dial is a Saros eclipse-prediction dial, arranged as a four-turn spiral of 223 lunar months, with glyphs indicating eclipse predictions.
Within each period of 223 lunar months, known as the Saros cycle, eclipses are repeated with the same intervals and characteristics.



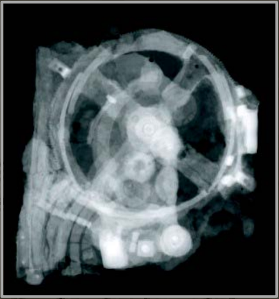
The back side - The “Exeligmos dial”

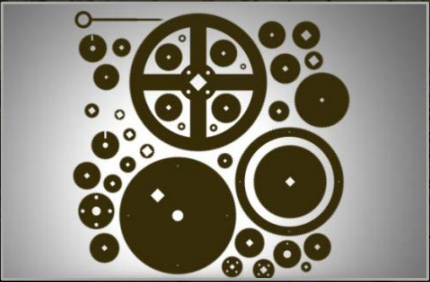
A subsidiary Exeligmos dial, within the Saros dial, extended the eclipse prediction capabilities to three Saros cycles, indicating that 8 and 16 hours should be added respectively in the second and third Saros cycles to the eclipse times indicated by the inscriptions.



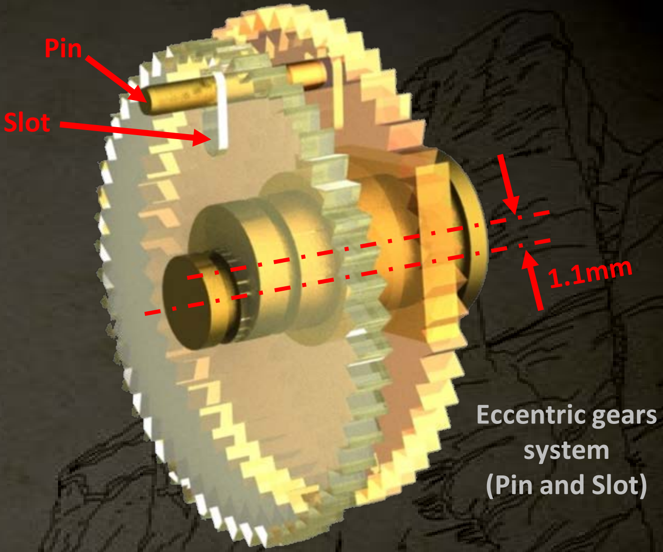
The gears

The gears found on the Antikythera Mechanism are the earliest known to resemble the shape and design of modern gears. Their triangular teeth were designed to transmit angular motion, not power. The Mechanism contained at least 39 interacting gears, among which were two crown gears. 30 of the gears were extant in the fragments of the Mechanism and others have been inferred, taking into account their probable use in calculating astronomical phenomena. The Mechanism included 7 pointers with 8 displays. The moon's pointer displayed two phenomena: the position of the moon in the sky and the phase of the moon. A rotating sphere, linked by a crown gear to the Moon's pointer, displayed the phases of the Moon.





The epicyclical motion of the moon



The movement of the Moon is not circular but elliptical. The Mechanism's display of this movement takes into account the anomaly caused by its eccentric orbit around the Earth by using two eccentric gears, the axes of which are separated by 1.1 mm. The lower gear has a pin that engages with a slot on the upper gear, forcing it to rotate elliptically. The epicyclical movement of the upper gear tracked the motion of the Moon in the sky with great accuracy.

The history and heritage program of ASME

Since the invention of the wheel, mechanical innovation has critically influenced the development of civilization and industry as well as public welfare, safety and comfort. Through its History and Heritage program, the American Society of Mechanical Engineers (ASME) encourages public understanding of mechanical engineering, fosters the preservation of this heritage and helps engineers become more involved in all aspects of history. In 1971 ASME formed a History and Heritage Committee composed of mechanical engineers and historians of technology. This Committee is charged with examining, recording and acknowledging mechanical engineering achievements of particular significance. For further information, please visit http://www.asme.org.

Landmark designations

There are many aspects of ASME's History and Heritage activities, one of which is the landmarks program. Since the History and Heritage Program began, 270 artifacts have been designated throughout the world as historic mechanical engineering landmarks, heritage collections or heritage sites. Each represents a progressive step in the evolution of mechanical engineering and its significance to society in general. The Landmarks Program illuminates our technological heritage and encourages the preservation of historically important works.

It provides an annotated roster for engineers, students, educators, historians and travelers. It also provides reminders of where we have been and where we are going along the divergent paths of discovery.

ASME helps the global engineering community develop solutions to real world challenges. ASME, founded in 1880, is a not-for-profit professional organization that enables collaboration, knowledge sharing and skill development across all engineering disciplines, while promoting the vital role of the engineer in society. ASME codes and standards, publications, conferences, continuing education and professional development programs provide a foundation for advancing technical knowledge and a safer world.

The research team of Thessaloniki

The Antikythera Mechanism Research Team of Aristotle's University of Thessaloniki (AUTH) and the University of Macedonia of Thessaloniki (UOM), has constructed accurate and functional copies of the Mechanism. These are entirely based on those portions of the research team's findings that have been accepted by the international scientific community through publications in reliable scientific journals. These models include all the latest revelations, but do not include anything that has not been scientifically proven. For that reason, the international scientific community recognizes these models as the most accurate and reliable constructed to date.

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