

## FRAGMENTARY KNOWLEDGE

*Was the Antikythera Mechanism the world's first computer?*

BY JOHN SEABROOK

In October, 2005, a truck pulled up outside the National Archeological Museum in Athens, and workers began unloading an eight-ton X-ray machine that its designer, X-Tek Systems of Great Britain, had dubbed the Bladerunner. Standing just inside the National Museum's basement was Tony Freeth, a sixty-year-old British mathematician and filmmaker, watching as workers in white T-shirts wrestled the Range Rover-size machine through the door and up the ramp into the museum. Freeth was a member of the Antikythera Mechanism Research Project—a multidisciplinary investigation into some fragments of an ancient mechanical device that were found at the turn of the last century after two thousand years in the Aegean Sea, and have long been one of the great mysteries of science.

Freeth, a tall, taciturn man with a deep, rumbling voice, had been a mathematician at Bristol University, taking a Ph.D. in set theory, a branch of mathematical logic. He had drifted away from the academy, however, and spent most of his career making films, many of them with scientific themes. The Antikythera Mechanism, which he had first heard about some five years earlier, had rekindled his undergraduate love of math and logic and problem-solving, and he had all but abandoned his film career in the course of investigating it. He was the latest in a long line of men who have made solving the mystery of the Mechanism their life's work. Another British researcher, Michael Wright, who has studied the Mechanism for more than twenty years, was coincidentally due to arrive in Athens before the Bladerunner had finished its work. But Wright wasn't part of the research project, and his arrival was anticipated with some trepidation.

It had been Freeth's idea to contact X-Tek in the hope of finding a high-resolution, three-dimensional X-ray tech-

nology to see inside the fragments of the Mechanism. As it happened, the company was working on a prototype of a CAT-scan machine that would use computer tomography to make 3-D X-rays of the blades inside airplane turbines, for safety inspections. Roger Hadland, X-Tek's owner and chief engineer, was interested in Freeth's proposal, and he and his staff de-

veloped new technology for the project. After the lead-lined machine was installed inside the museum, technicians spent another day attaching the peripheral equipment. At last, everything was ready. The first piece to be examined, Fragment D, was placed on the Bladerunner's turntable. It was only about an inch and a half around—much smaller than Fragment A, the largest piece, which measures about six and a half inches across—and it looked like just a small greenish rock, or possibly a

lump of coral. It was heavily corroded and calcified—the parts of the Mechanism almost indistinguishable from the petrified sea slime that surrounded them. Conservationists couldn't clean off any more of the corroded material without damaging the artifact, and it was hoped that the latest in modern technology would reveal the ancient technology inside.

The Bladerunner began to whirr. As the turntable rotated, an electron gun fired at a tungsten target, which emitted an X-ray beam that passed through the fragment, so that an image was recorded every time the turntable moved a tenth of a degree. A complete three-hundred-and-sixty-degree rotation, resulting in three thousand images or so, required



*The main part of the Mechanism, found after two thousand years under water.*

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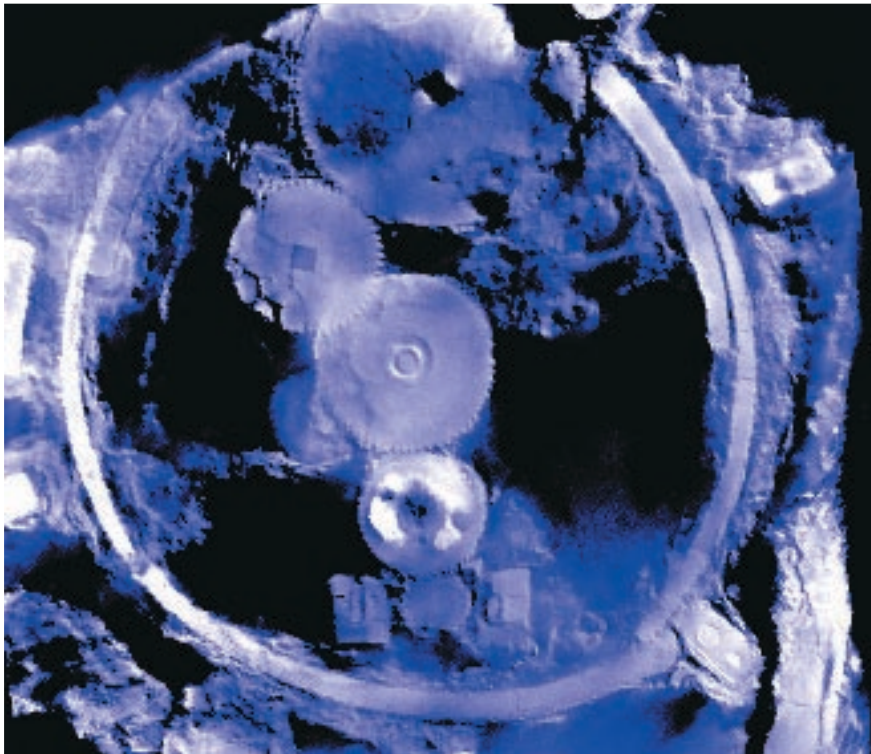
As Freeth waited impatiently for the first images to appear on the Bladerunner's monitor, he was trying not to hope for too much, and to place his trust in the skills of the group of academics and technicians who were there with him. Among them, waiting with equal anticipation, were John Seiradakis, a professor of astronomy at the Aristotle Uni-

versity of Thessaloniki; Xenophon Moussas, the director of the Astrophysics Laboratory at the University of Athens; and Yanis Bitsakis, a Ph.D. student in physics. (Mike Edmunds, an astrophysicist at Cardiff University, who was the academic leader of the research project, remained in Wales.) “I was just focussed on my relief that this was happening at all, with all the delays of the past four years,” Freeth told me. “Honestly, there were times when I thought it would never happen.”

One day in the spring of 1900, a party of Greek sponge divers returning from North Africa was forced by a storm to take shelter in the lee of the small island of Antikythera, which

an abyss fell away into total darkness. Looking around, Stadiatis saw the remains of an ancient shipwreck. Then he had a terrible shock. There were piles of bodies, all in pieces, covering the ledge. He grabbed one of the pieces before surfacing in order to have proof of what he had seen. It turned out to be a bronze arm.

The following autumn, the sponge divers, now working for the Greek government, returned to the site, and over the next ten months they brought up many more pieces of sculpture, both marble and bronze, from the wreck, all of which were taken to the National Museum to be cleaned and reassembled. It was the world’s first large-scale underwater archeological excavation.



*X-ray imaging has made many gears and inscriptions newly visible.*

lies between Crete and Kythera. After the storm passed, one of the divers, Elias Stadiatis, put on a weighted suit and an airtight helmet that was connected by an air hose to a compressor on the boat, and went looking for giant clams, with which to make a feast that evening.

The bottom of the sea dropped sharply, and the diver followed the underwater cliff to a shelf that was about a hundred and forty feet below the surface. On the other side of the shelf,

Evidence derived from coins, amphorae, and other items of the cargo eventually allowed researchers to fix a date for the shipwreck: around the first half of the first century B.C., a time when the glorious civilization of ancient Greece was on the wane, following the Roman conquest of the Greek cities. Coins from Pergamum, a Hellenistic city in what is now Turkey, indicated that the ship had made port nearby. The style of the amphorae strongly suggested that the ship had called at the is-

land of Rhodes, also on the eastern edge of the Hellenistic world, and known for its wealth and its industry. Given the reputed corruption of officials in the provinces of the Roman Empire, it is possible that the ship's cargo had been plundered from Greek temples and villas, and was on its way to adorn the houses of aristocrats in Rome. The sheer weight of the cargo probably contributed to the ship's destruction.

Most of the marble pieces were blackened and pitted from their long immersion in the salt water, but the bronze sculptures, though badly corroded, were salvageable. Although bronze sculptures were common in ancient Greece, only a tiny number have survived (the bronze was often sold as scrap, melted down, and recast, possibly as weaponry), and most of those have been recovered from shipwrecks. Among the works of art that emerged from the waters near Antikythera are the bronze portrait of a bearded philosopher, and the so-called Antikythera Youth, a larger-than-life-size naked young man: a rare specimen of a bronze masterwork, believed to be from the fourth century B.C.

Other artifacts included bronze fittings for wooden furniture, pottery, an oil lamp, and item 15087—a shoebox-size lump of bronze, which appeared to have a wooden exterior. Inside were what seemed to be fused metal pieces, but the bronze was so encrusted with barnacles and calcium that it was difficult to tell what it was. With so much early excitement focussed on the sculptures, the artifact didn't receive much attention at first. But one day in May, 1902, a Greek archeologist named Spyridon Stais noticed that the wooden exterior had split open, probably as a result of exposure to the air, and that the artifact inside had fallen into several pieces. Looking closely, Stais saw some inscriptions, in ancient Greek, about two millimetres high, engraved on what looked like a bronze dial. Researchers also noticed precisely cut triangular gear teeth of different sizes. The thing looked like some sort of mechanical clock. But this was impossible, because scientifically precise gearing wasn't believed to have been widely used until the fourteenth century—fourteen hundred years after the ship went down.

The first analyses of what became known as the Antikythera Mechanism followed two main approaches. The archeologists, led by J. N. Svoronos, of the National Museum, thought that the artifact must have been "a kind of astrolabe." A Hellenistic invention, an astrolabe was an astronomical device that was widely known in the Islamic world by the eighth century and in Europe by the early twelfth century. Astrolabes were used to tell the time, and could also determine latitude with reference to the position of the stars; Muslim sailors often used them, in addition, to calculate prayer times and find the direction of Mecca.

However, other researchers, led by the German philologist Albert Rehm, thought that the Mechanism appeared much too complex to be an astrolabe. Rehm suggested that it might possibly be the legendary Sphere of Archimedes, which Cicero had described in the first century B.C. as a kind of mechanical planetarium, capable of reproducing the movement of the sun, the moon, and the five planets that could be seen from Earth without a telescope—Mercury, Venus, Mars, Jupiter, and Saturn. Still others, acknowledging the artifact's complexity, thought that it must have come from a much later shipwreck, which may have settled on top of the ancient ship (even though the Mechanism had plainly been crushed under the weight of the ship's other cargo). But, in the absence of any overwhelming evidence one way or the other, until the nineteen-fifties the astrolabe theory held sway.

Looking back over the first fifty years of research on the Mechanism, one is struck by the reluctance of modern investigators to credit the ancients with technological skill. The Greeks are thought to have possessed crude wooden gears, which were used

to lift heavy building materials, haul up water, and hoist anchors, but historians do not generally credit them with possessing scientifically precise gears—gears cut from metal and arranged into complex "gear trains" capable of carrying motion from one driveshaft to another. Paul Keyser, a software developer at I.B.M. and the author of "Greek Science of the Hellenistic Era," told me recently, "Those scholars who study the history of science tend to focus on science beginning with Copernicus and Galileo and Harvey, and often go so far as to assert that no such thing existed before." It's almost as if we wished to reserve advanced technological accomplishment exclusively for ourselves. Our civilization, while too late to make the fundamental discoveries that the Greeks made in the sciences—Euclidean geometry, trigonometry, and the law of the lever, to name a few—has excelled at using those discoveries to make machines. These are the product and proof of our unique genius, and we're reluctant to share our glory with previous civilizations.

In fact, there is evidence that earlier civilizations were much more technically adept than we imagine they were. As Peter James and Nick Thorpe point out in "Ancient Inventions," published in 1994, some ancient civilizations were aware of natural electric phenomena and the invisible powers of magnetism (though neither concept was understood). The Greeks had a tradition of great inventors, beginning with Archimedes of Syracuse (c. 287–212 B.C.), who, in addition to his famous planetarium, is believed to have invented a terrible clawed device made up of large hooks, submerged in the sea, and attached by a cable to a terrestrial hoist; the device was capable of lifting the bow of a fully loaded warship into the air and smashing it down on the water—the Greeks reportedly used the weapon during the Roman siege of Syracuse around 212 B.C. Philon of Byzantium (who lived around 200 B.C.) made a spring-driven catapult. Heron of Alexandria (who lived around the first century A.D.) was the most ingenious inventor of all. He described the basic principles of steam power, and is said to



have invented a steam-powered device in which escaping steam caused a sphere with two nozzles to rotate. He also made a mechanical slot machine, a water-powered organ, and machinery for temples and theatres, including automatic swinging doors. He is perhaps best remembered for his automatons—simulations of animals and men, cleverly engineered to sing, blow trumpets, and dance, among other lifelike actions.

Although a book by Heron, “Pneumatica,” detailing various of these inventions, has survived, some scholars have dismissed his descriptions as fantasy. They have pointed to the lack of evidence—no trace of any of these marvellous machines has been found. But, as other scholars have pointed out, the lack of archeological evidence isn’t really surprising. No doubt, the machines eventually broke down, and, as the know-how faded, there was no one around who could fix them, so they were sold as scrap and recycled. Very few technical drawings or writings remained, because, as Paul Keyser observes, “the texts that survive tend to be the more popular texts—i.e., those that were more often copied—and textbooks, not the research works or the advanced technical ones.” Eventually, following the dissolution of the Roman Empire, the technological knowledge possessed by the Greeks disappeared from the West completely.

But, if the Greeks did have greater technological sophistication than we think they did, why didn’t they apply it to making more useful things—time- and work-saving machines, for example—instead of elaborate singing automatons? Or is what we consider important about technology—which is, above all, that it is useful—different from what the Greeks considered worthwhile: amusement, enlightenment, delight for its own sake? According to one theory, the Greeks, because they owned slaves, had little incentive to invent labor-saving devices—indeed, they may have found the idea distasteful. Archimedes’ claws notwithstanding, there was, as Keyser notes, cultural resistance to making high-tech war machines, because “both the Greeks and the Romans valued individual bravery in war.” In any case,



in the absence of any obvious practical application for Greek technology, it is easy to believe that it never existed at all.

In 1958, Derek de Solla Price, a fellow at the Institute for Advanced Study, in Princeton, went to Athens to examine the Mechanism. Price’s interests fell between traditionally defined disciplines. Born in Britain, he trained as a physicist but later switched fields and became the Avalon Professor of the History of Science at Yale; he is credited with founding Scientometrics, a method of measuring and analyzing the pursuit of science. The study of the Mechanism, which incorporates elements of archeology, astronomy, mathematics, philology, classical history, and mechanical engineering, was ideally suited to a polymath like Price, and it consumed the rest of his life.

Price believed that the Mechanism was an ancient “computer,” which could be used to calculate astronomical events in the near or distant future: the next full moon, for example. He realized that the inscriptions on the large dial were calendrical markings indicating months, days, and the signs of the zodiac, and postulated that there must have been pointers, now missing, that represented the sun and the moon and possibly the planets, and that these pointers moved around the dial, indicating the position of the heavenly bodies at different times.

Price set about proving these theories, basing his deductions on the fundamental properties of gearing. Gears

work by transmitting power through rotational motion, and by realizing mathematical relationships between toothed gear wheels. The Mechanism concentrates on the latter aspect. Price seems to have assumed that the largest gear in the artifact, which is clearly visible in Fragment A, was tied to the movement of the sun—one rotation equalled one solar year. If another gear, representing the moon, was driven by the solar gear, then the ratio of wheels in this gear train must have been designed to match the Greeks’ idea of the moon’s movements. By counting the number of teeth in each gear, you could calculate the gear ratios, and, by comparing those ratios to astronomical cycles, you can figure out which gears represented which movements.

However, because only a few of the gears appear at the surface of the Mechanism, and because many of the gear teeth are missing, Price had to develop methods for estimating total numbers from partial tooth counts. Finally, in 1971, he and a Greek radiographer, Dr. C. Karakalos, were permitted to make the first X-rays of the Mechanism, and these two-dimensional images showed almost all the remaining gear teeth. Price developed a schematic drawing of a hypothetical reconstruction of the internal workings of the Mechanism. In 1974, Price published his research in the form of a seventy-page monograph titled “Gears from the Greeks.” He had written, “Nothing like this instrument is preserved elsewhere. Nothing comparable to it is known from any ancient scientific text or literary allusion. On the contrary, from all

that we know of science and technology in the Hellenistic Age we should have felt that such a device could not exist.”

Price expected his work on the Mechanism to change the history of technology. The Mechanism “requires us to completely rethink our attitudes toward ancient Greek technology,” he wrote, and later added, “It must surely rank as one of the greatest mechanical inventions of all time.” Price also pointed out that the Mechanism cannot have been the only one of its kind; no technology this sophisticated could have appeared suddenly, fully realized. Not only did the Mechanism demonstrate that our concept of ancient technology was fundamentally incomplete; it also contradicted the neo-Darwinian concept of technical progress in general as a gradual evolution toward ever greater complexity (technological history being the last refuge of the nineteenth-century belief in progress)—an idea firmly embedded in A. P. Usher’s classic 1929 study, “A History of Mechanical Inventions.” As Price writes, it is “a bit frightening to know that just before the fall of their great civilization the ancient Greeks had come so close to our age, not only in their thought, but also in their scientific technology.”

But Price’s work, though widely reviewed in scholarly journals, did not change the way the history of the ancient world is written. Otto Neugebauer’s huge “A History of Ancient Mathematical Astronomy,” which came out the year after “Gears,” relegates the Mechanism to a single footnote. Scholars and historians may have been reluctant to rewrite the history of technology to include research that had lingering doubts attached to it. Also, Price’s book was published at the height of the popularity of “Chariots of the Gods,” a 1968 book by the Swiss writer Erich von Däniken, which argued that advanced aliens had seeded the earth with technology, and Price got associated with U.F.O.s and crop circles and other kinds of fringe thinking. Finally, as Paul Keyser told me, “Classical scholarship is very literary, and focusses on texts—such as the writing of Homer, Sophocles, Virgil, or Horace, or it is old-fashioned and historical, and focusses on leaders and battles, through the texts of Herodotus and Thucydides, or it is anthropological-archeological,

and focusses on population distributions and suchlike. So when an archeological discovery about ancient technology arrives, it does not fit, because it’s new, it’s scientific, and it’s not a text. Plus, there is only one such device, and unique items tend to worry scholars and scientists, who quite reasonably prefer patterns and larger collections of data.” Whatever the reason, as one scholar, Rob Rice, noted in a paper first presented in 1993, “It is neither facile nor uninformative to remark that the Antikythera mechanism dropped and sank—twice”—once in the sea and once in scholarship.

The National Museum in Athens took no special pains in displaying the lumps of bronze. Item 15087 wasn’t much to look at. When the physicist Richard Feynman visited, in 1980, there was little information explaining what the Mechanism was. In a letter to his family, later published in the book “What Do You Care What Other People Think?,” the physicist wrote that he found the museum “slightly boring because we have seen so much of that stuff before. Except for one thing: among all those art objects there was one thing so entirely different and strange that it is nearly impossible. It was recovered from the sea in 1900 and is some kind of machine with gear trains, very much like the inside of a modern wind-up alarm clock.” When Feynman asked to know more about item 15087, the curators seemed a little disappointed. One said, “Of all the things in the museum, why does he pick out that particular item, what is so special about it?”

For the Greeks, as for other ancient civilizations, astronomy was a vital and practical form of knowledge. The sun and the moon were the basis for calendars by which people marked time. The solar cycle told farmers the best times for sowing and harvesting crops, while the lunar cycle was commonly used as the basis for civic obligations. And, of course, for mariners



the stars provided some means of navigating at night.

Xenophon Moussas, one of the two Greek astronomers who are part of the research project, is a compact, soft-spoken man. He grew up in Athens, and as a boy, visiting the museum, he often pondered the Mechanism; now as a professor of astrophysics, he uses it to connect with his undergraduate students, for whom ancient technology is often more compelling than ancient theory.

One evening in January, Moussas led me on a memorable walk around the archeological park in central Athens, which includes both the Greek and the Roman agoras. As a quarter moon shone in the clear night sky, illuminating the ruined temples and markets, Moussas narrated the story of how the ancients slowly learned to recognize patterns and serial events in the movements of the stars, and to use them to tell time and to predict future astronomical events. “It was a way of keeping track not of time as we think of it,” he told me, “but of the movement of the stars—a deeper time.”

For the Greeks, like the Babylonians before them, the year consisted of twelve “lunations,” or new-moon-to-new-moon cycles, each of which lasted an average of twenty-nine and a half days. The problem with a lunar calendar is that twelve lunar cycles takes about eleven days less than one solar cycle. That means that if you don’t make regular adjustments to the calendar the seasons soon slip out of synch with the months, and after eighteen years or so the summer solstice will occur in December. Finding a system that reconciled the lunar year with the solar year was the great challenge of calendar-making.

Most ancient societies readjusted their calendars by adding a thirteenth, “intercalary” month every three years or so, although methods of calculating the length of these months, and when they should be added, were never precise. Babylonian astronomers hit upon an improvement. They discovered that there are two hundred and thirty-five lunar months in nineteen years. In other words, if you observe a full moon on April 4th, there will be another full moon in that same place on April 4th

nineteen years later. This cycle, which eventually came to be known as the Metonic cycle, after the Greek astronomer Meton of Athens, was an extremely useful tool for keeping the lunar calendar and the solar calendar in synch. (The Metonic cycle is still used by the Christian Churches to calculate the correct day for celebrating Easter.) The Babylonians also established what would come to be known as the saros cycle, which is a way of predicting the likely occurrence of eclipses. Babylonian astronomers observed that eighteen years, eleven days, and eight hours after an eclipse a nearly identical eclipse will occur. Eclipses were believed by many ancient societies to be omens that, depending on how they were interpreted, could foretell the future of a monarch, for example, or the outcome of a military campaign.

The Greeks, in turn, discovered the Callippic cycle, which consisted of four Metonic cycles minus one day, and was an even more precise way to reconcile the cycles of the sun and the moon. But the Greeks' real genius was to work out theories to explain these cycles. In particular, they brought the concept of geometry to Babylonian astronomy. As Alexander Jones, a professor of classics at the University of Toronto, put it to me recently, "The Greeks saw the Babylonian formulas in terms of geometry—they saw all these circles all spinning around each other in the sky. And of course this fits in perfectly with the concept of gearworks—the gears are making little orbits." Some Greek inventor must have realized that it was possible to build a simulation of the movements in the heavens by reproducing the cycles with gears.

But who? Price called the inventor simply "some unknown ingenious mechanic." Others have speculated that the inventor was Hipparchus, the greatest of all ancient Greek astronomers. Hipparchus, who is also believed to have invented trigonometry, lived on the island of Rhodes from about 140 to 120 B.C. He detailed a theory to explain the anomalous movements of the moon, which appears to change speed during its orbit of the Earth. Hipparchus is also thought to have founded a school on Rhodes that was maintained after his death by Posidonius,

with whom Cicero studied in 79 B.C. In one of his letters, Cicero mentions a device "recently constructed by our friend Posidonius," which sounds very like the Mechanism, and "which at each revolution reproduces the same motions of the sun, the moon, and the five planets that take place in the heavens every day and night."

As Moussas and I headed uphill, toward the Acropolis, he pointed out the spot where Meton's astronomy school and solar observatory had been. On our way back down, we stopped at the famous Tower of the Winds, the now gutted shell of what was the great central clock of ancient Athens. Designed by the renowned astronomer Andronicus of Cyrrhus, it is thought to have been an elaborate water clock on the inside and a sundial on the outside. "But, in light of what we know about the Mechanism," Moussas said, "I am beginning to wonder whether this was a much more complicated clock than we think."

When Derek Price died, of a heart attack, in 1983, his work on the Mechanism was unfinished. Although his fundamental insights about the device were sound, he hadn't figured out all the details, nor had he succeeded in producing a working model that was correct in all aspects.

That year, in London, a Lebanese man walked into the Science Museum, on Exhibition Road, with an ancient geared mechanism wrapped in a handkerchief in his pocket. Michael Wright, one of the curators of mechanical engineering, was summoned to examine the artifact, which was in four main fragments. The man said that he'd bought the artifact in a street market in Beirut several weeks earlier. The Science Museum eventually bought it from him, and Wright and a colleague, J. Field, showed that it was a geared sundial calendar that displayed the positions of the sun and the moon in the zodiac. Wright also built a reconstruction of the sundial. The style of lettering on the dial dated the device to the sixth century A.D., making it the second-oldest geared device ever found, after the Antikythera Mechanism.

In addition to his job as a curator, Wright helped to maintain the

old clocks exhibited in the museum. Among them was a replica of the oldest clock that we have a clear account of, constructed in the early fourteenth century by Richard of Wallingford, the Abbot of St. Albans. It was a fantastic astronomical device called the Albion ("All-by-One"). Another reconstruction was of a famous planetarium and clock built by Giovanni de' Dondi, of Padua, in the mid-fourteenth century, known as the Astrarium. Like many students of mechanical history, Wright had noted this odd upwelling of clockwork in Europe, appearing in several places at around the same time. He was familiar with the theory that many of the elements of clockwork were known to the ancients. With the decline of the West, goes this theory, technical expertise passed to the Islamic world, just as many of the Greek texts were translated into Arabic and therefore preserved from loss or destruction. In the ninth century, the Banu Musa brothers, in Baghdad, published the "Book of Ingenious Devices," which detailed many geared mechanical contrivances, and the tenth-century philosopher and astronomer al-Biruni (973-1048) describes a Box of the Moon—a mechanical lunisolar calendar that used eight gearwheels. The more Wright looked into these old Islamic texts, the more convinced he became that the ancient Greeks' knowledge of gearing had been kept alive in the Islamic world and reintroduced to the West, probably by Arabs in thirteenth-century Spain.

In the course of this research, Wright became intensely interested in the Antikythera Mechanism. Upon studying Price's account closely, he realized that Price had made several fundamental errors in the gearing. "I could see right away that Price's reconstruction doesn't explain what we can see," he told me. "The man who made the Mechanism made no mistakes. He went straight to what he wanted, in the simplest way possible." Wright resolved to complete Price's work, and to build a working model of the Mechanism.

Whereas Price worked mainly on an academic level, approaching the Mechanism from the perspective of mathematical and astronomical theory, Wright drew on his vast practical knowledge of arbors, crown wheels,

and other mechanical techniques used in gear-train design. His experience in repairing old grandfather clocks, many of which also have astronomical displays that show the phases of the moon, led him to one of his key insights into the engineering of the Mechanism. He posited that there must have been a revolving ball built in the front dial that indicated the phases of the moon—one hemisphere was black, the other white, and the ball rotated as the moon waxed or waned. Wright also showed how a pin-and-slot construction could be used to model the movement of the moon.

Wright, who is fifty-eight, has a British public-school demeanor, which is generally courteous and hearty and seemingly rational. But he is prey to dark moods, wild, impolitic outbursts, and overcomplicated personal entanglements—"muddles," he calls them. Although he told me, "I really hate confrontation, and antagonism of any kind, even competition," he consistently finds himself in disastrous confrontations with people who should be his allies. Whereas academic researchers are used to collaboration, and to sharing resources and insights, Wright is temperamentally more like a lone inventor, working away in secrecy and solitude until he has found the solution.

He did have a collaborator once—Allan Bromley, a lecturer in computer science at the University of Sydney and an expert on Charles Babbage, the nineteenth-century British mathematician who was the first to conceive of the programmable computer. Bromley used to come to the Science Museum to study Babbage's papers and drawings and Wright would often lunch with him. In 1990, the pair took new X-rays of the Mechanism, the first since Price's. But Bromley brought the data back to Sydney and would allow Wright to see only small portions of the material. (According to Wright, Bromley confessed "that he had it fixed in his mind that it would be his name, preferably alone, that would be attached to the 'solution.'")

Meanwhile, Wright got into a muddle with his boss at the Science Museum, an "out-and-out bully" who would allow Wright to work on the Mechanism only

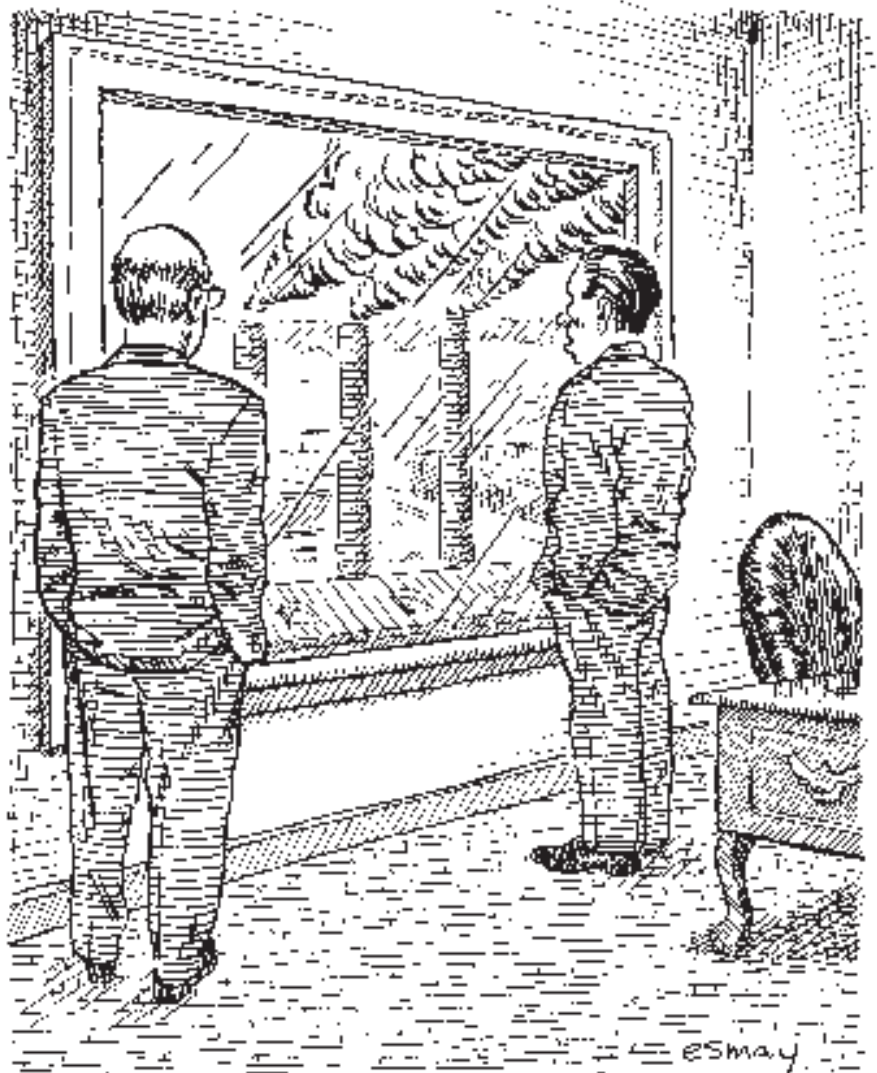
in his free time. ("We don't do the ancient world," Wright remembers another colleague saying.) This meant that while Wright's wife would go on holiday with their children, Wright would go to the museum in Athens. (Eventually, after years of this routine, he and his wife divorced.)

By the late nineteen-nineties, Bromley was dying of cancer. Wright went to see him in Sydney, and Bromley turned much of the data over to him. Just as Wright was finally able to work up their findings for publication, however, he learned of the research project and the effort to take a new set of X-rays of the Mechanism. Instead of viewing this new investigation as a potential boon, he saw it as an improper encroachment on his own turf. "There is a long-established unwritten law concerning the study of Greek antiquities,

which is that when one researcher has access to the material, any other researcher is denied access until the first has finished," he wrote to me. "In my case, this understanding was swept aside through the machinations of the group." So, when he arrived at the National Museum while the Bladerunner's X-rays were in progress, he was not excited, like the others; he was "angry, tired, and depressed."

The first images of Fragment D to appear on the Bladerunner's monitor were stunning—"so much better than we dared to hope," Freeth told me. "They took your breath away." Inside the corroded rock was what looked like a geared embryo—the incipient bud of an industrial age that remained unborn for a millennium.

Then the team spotted an odd-



*"Can't we just dye the smoke green?"*

looking inscription. Andrew Ramsey, X-Tek's computer-tomography specialist, who was operating the viewer, zoomed around inside the 3-D representation until he found the right slice. Written on the side of the gear were the letters "M" and "E"—"ME." Was this the maker's mark? Or could "ME" mean "Part 45"? ("ME" is the symbol for forty-five in ancient Greek.) Freeth joked that Mike Edmunds had scratched his initials on the fragment. Others suggested that this particular piece of the Mechanism could have been recycled, and that the "ME" was left over from some earlier device.

Altogether, the team salvaged about a thousand new letters and inscriptions from the Mechanism—doubling the number available to Price. Together with earlier imaging, the new inscriptions support theories that both Price and Wright had advanced. On Fragment E, for example, the group read "235 divisions on the spiral." "I was amazed," Freeth said. "This completely vindicated Price's idea of the Metonic cycle of two hundred and thirty-five lunar months on the upper back dial." They also read words explaining that on the extremity of "the pointer stands a little golden sphere," which probably refers to a representation of the sun on the sun pointer that went around the zodiac dial at the front of the Mechanism. Wright had proposed that the rings of the back dials were made in the form of spirals; the word *eliki*, meaning "spiral," can be seen on Fragment E. On Fragment 22, the number "223" has been observed, pointing to the use of the saros dial as an eclipse indicator.

It was, as Xenophon Moussas put it to me, as if "we had discovered the user's manual, right inside the machine." What had been regarded mainly as an archeological artifact took on a different sort of artifactual status, as an important astronomical text. Very few copies of original astronomical texts remain from the period; most of our knowledge about ancient astronomy comes from other, later astronomers. Little of Hipparchus' writing survives; we rely largely on Ptolemy of Alexandria, who some believe took much of Hipparchus' work and called it his own.

Many of the inscriptions took months to read. Yanis Bitsakis, the Ph.D. stu-

dent, collaborated with Freeth and the X-Tek team in rendering the X-ray data as computer images, while Agamemnon Tselikas, a leading Greek paleographer, did all the readings and most of the translations. As Bitsakis explained to me, "One of the difficulties in reading the texts was that in ancient Greek there were no spaces between the words, and there are many alternative readings. Also, in many cases the edges of the lines are missing, so we don't know what is continuous text." He and Tselikas would work on the readings through the night, frequently e-mailing and calling other members of the team about new discoveries. Moussas remembers this period, lasting until the spring of 2006, as "the most interesting time in my life." For example, finding the words "sphere" and "cosmos" was extremely moving, Moussas told me: "I felt as though I were communicating with an ancient colleague, through the Mechanism."

One day last month, I paid a visit to Michael Wright, in his book-and-clock-cluttered home, in West London. Wright was reading Xenophon, the Greek historian, in ancient Greek. He put the book down and brought out his model of the Mechanism from a cabinet underneath the stairs. In size, it is startlingly similar to a laptop computer, though a bit thicker. On the front dial, in addition to the pointers for the sun and the moon that Price posited, Wright added pointers for the planets and a separate pointer for the day of the year. On the back dial were two hundred and twenty-three divisions, marking months in the saros cycle; a similar dial above that showed months in the Metonic cycle. The gears were hidden inside a wooden casing, which had a large wooden knob on one side.

Wright was still a little upset about what he considered the sweeping claims that the research group had made when it published its findings, in the November 30, 2006, issue of *Nature*. He almost stayed home from the two-day conference on the Mechanism that the group put on, in early December. In the end, he decided to go, taking his wife, Anne, whom he married in 1998, "to stop me from lifting my knee in some chap's groin."

We went upstairs to Wright's workshop. It was filled with tools and pieces of metal, and the air held the pleasantly acrid scent of machine oil. Scattered across the tables and the floor were clever devices that Wright had fashioned out of gears—clocks, astrolabes, engines of various kinds. I recalled Price's description of the maker of the Mechanism—"some unknown ingenious mechanic"—and wondered if this mysterious maker might have been a bit like Wright, with a workshop similarly cluttered with machines.

Wright took his model apart and showed me how all the gears fitted together. I noticed some writing on a rectangular metal plate in the middle of the mechanism, and Wright told me that it was made of recycled bits of brass left over from some previous incarnation.

"So you think that the letters 'ME'—"

"Precisely," Wright interjected. "I think they must relate to whatever that bit of metal was used for before."

Then Wright put the machine back together and turned the hand knob that drives the solar gear. It engaged with the smaller gears, through the various gear trains, and the pointers began to spin around the dials. The day-of-the-year pointer moved forward at a regular pace, but the lunar and planetary pointers traced eccentric orbits, sometimes reversing course and going backward, just as the planets occasionally appear to do in the night sky. Meanwhile, the pointers on the back dials crept through the months in the saros and Metonic cycles; eclipses came and went. I noticed that as long as he kept turning the knob Wright himself seemed, for once, perfectly unaddled.

Until this moment, I had, like many others, continued to puzzle over why, if the Greeks were capable of building such a technically sophisticated device, they used that capacity to construct what is essentially a toy—an intellectual amusement. But as I beheld this whirring, whirling symphony of metal, a perfect simulation of a mechanistic and logical universe, I realized that my notions of practicality were foolish and shortsighted. This machine was much more than a toy; it embodied a whole world view, and it must have been, for the ancients, wonderfully reassuring to behold. ♦