The Antikythera Mechanism

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The Story Behind the Genius of the Greek Computer and its Demise

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Front cover painting of the Antikythera Mechanism by Evi Sarantea
Painting of the Antikythera Mechanism by the Greek artist Evi Sarantea. The painting is a panorama of the artist's vision of what the Antikythera Mechanism was at the time of its creation in the second century BCE and what it became in the twenty-first century: an emblem in a galactic temple decorated by a Renaissance clock and, on the left side, surrounded by the Wheel of the Sun god Helios depicting the Cosmos of the Sun, the Moon, and the planets, all bathed in stars and constellations, including the interlocking gears below the Cosmos. The right side of the painting depicts two interconnected spirals, the upper one showing a nineteen-year calendar and the lower depicting the eclipse-predicting eighteen-year calendar. Below them there's a painted representation of fragment A, Wheel of the Sun. And at the center lower section, one sees hanging flames representing the unknown scientists who created the Greek computer of genius. Courtesy Evi Sarantea.

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For Mark Andreas, Corinna Lia, Ellis (Herakles),
Katya (Athena) and Argo

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Preface

Suppose you could travel back 2,300 years in time to visit Alexandria, the capital city of the Greek kingdom of Egypt. This was the most enlightened, wealthy, and powerful of all the Greek states that flourished after the death of Alexander the Great.

Alexandria was famous for its Mouseion (University-Institute of Advanced Studies) and the great library, which held the collected science, philosophy, and literature of the Greek and Mediterranean world. The great library was rather like merging the Library of Congress with all the resources of Stanford, Harvard, and MIT. Its collections included the epics of Homer; the books of early natural philosophers like Anaximander; the plays of Aeschylus, Sophocles, Euripides, and Aristophanes; the atomic theory of Leucippus and Democritus; the engineering of Ktesibios, Archimedes, Philon of Byzantium, and Heron of Alexandria; the history of Herodotus and Thucydides; the medical knowledge of Hippocrates and Galen; the philosophy of Plato; the philosophy and science of Aristotle; the scholarship and geography of Eratosthenes and Ptolemaios; the astronomy of Eudoxos, Aristarchos of Samos, Hipparchos, and Ptolemaios; and the mathematics of Eudoxos, Euclid, Archimedes, and Apollonius of Perga. Homer and this small sample of scientist-philosophers defined Greek civilization.

However, if you were to revisit Alexandria 800 years later, you would find no trace of the great Library of Alexandria, or of its Mouseion University. These had been destroyed and wiped from the map by Christian fanatics.

In 415 of our era, a mob of Christian monks set out to expunge all traces of "pagan" Greece from history. To make their point, they murdered the mathematician Hypatia and tore her limb from limb in the public marketplace;

she was the head of a prestigious school of philosophy in Alexandria, but to the monks she was "anathema."

When the Christian faith was finally established as the official religion of the Roman Empire in the fourth century, an all-out Holy War was launched against the pagan unbelievers and all aspects of their culture. In the sixth century, Justinian, the Emperor of the Eastern Roman Empire, suppressed and destroyed the Platonic Academy in Athens, which had flourished as a university for about 900 years. This war against the science and culture of ancient Greece unleashed a wave of darkness and ignorance for both East and West. Christian fanaticism plunged Europe into the Dark Ages for almost a thousand years.

These imperially sanctioned attacks on Greek culture gave Christian monks tremendous power. They physically destroyed priceless texts of science by scraping the very ink from the parchments. Then they over-wrote the empty parchments with religious texts.

In 1998, an American paid $2 million for a 769-year-old Christian prayer book, known as a "palimpsest" (a manuscript from which the original text had been scraped off, enabling the blank parchment to be overwritten again). Christian prayer-texts were written over the erased scripts of some of the books of Archimedes.

This philanthropist was willing to pay such a vast sum of money for the "ghost" of a vanished book because of the slim hope that the content of Archimedes's original manuscript might be resurrected from oblivion.

In 2005, seven years after the Archimedes palimpsest surfaced in New York, an even greater drama was unfolding in the National Archaeological Museum in Athens.

A team of international scientists and engineers were struggling to "decode" the secrets of an ancient mechanical computer: the Antikythera Mechanism. In 1900, sponge divers had found this artifact among the broken amphorae and statues of an ancient shipwreck, on the seabed of the tiny Aegean island of Antikythera.

To the divers, it just looked like a lump of shell-encrusted bronze and it was impossible to see what it really was. In fact, the technology needed to reveal the innermost workings of this apparent lump of concrete did not even exist in 1900. This went hand in hand with the prejudices of most scientists, who believed they had a monopoly on science and technology. Only after decades of technological advances and the appearance in the early 1970s of a virtuous

scientist interested in the origins of the mechanical device was science able to penetrate this complex metal artifact and illuminate its innermost secrets.

Later still, scientists used MRI scanners and X-rays to probe this object. They were shocked to discover an interior mechanism of astonishing complexity: finely meshed cogs and toothed wheels. The scans revealed an instrument of mathematical exactitude, fabricated by advanced engineering. Inscriptions on the face and back of the computer indicate it was manufactured 2,200 years ago.

It is instructive to ask what most of the world was like 2,200 years ago. America, from the Andes to Alaska, was inhabited by Stone Age tribal cultures, to whom metalworking was largely unknown. Writing existed only as the stone-carved glyphs of the Maya, or the painted hieroglyphs of the Aztecs. With the possible exception of Rome, Europe was much the same: warrior tribes of sheep and cattle herders mingled with settled agriculturalists, while mountainous regions were still populated by hunter-gatherers. Writing only existed as stone-carved images or runes. Literacy did not exist; there were no books, no sciences, no architecture, no physics, no medical science, no engineering, no history, and no political theory.

Metalworking was limited to bronze swords and axe-heads, sickles and farm implements; war chariots represented the pinnacle of engineering.

Yet astonishingly, in that very same era, Greece had produced architects, artists, scientists, and engineers who built the Parthenon, great amphitheaters, harbors, and bridges. Mathematicians such as Eratosthenes had used geometry to estimate the circumference of the Earth. Democritus had produced the atomic theory of matter. Aristarchos of Samos invented the heliocentric theory of the Cosmos. The Sun rather than the Earth was at the center of the universe. Aristarchos also wrote a book on the measurement of the distances of the Sun and the Moon from the Earth, including measuring the sizes of the Sun and the Moon. The list of Archimedes's achievements is astonishing: he expounded the physics of levers and forces; laid the foundations of hydraulics and hydrostatics; calculated the value of Pi (Π), and invented calculus. In his work *On the Circle and the Sphere*, he derived the formula to calculate the surface area and volume of any sphere. In his book on *Parabolas*, he was the first to use the concept of "infinity." On a practical engineering level, he invented the Archimedes screw, used to raise water from rivers to irrigate fields, and in military technology he invented the "Claw of Archimedes"—a giant crane, which could grasp ships attacking a city, to destroy them. He also wrote a book on *Spheres*, now lost, in which he

described the construction of a mechanical universe. A model of the spherical mechanical universe of Archimedes survived until the first century BCE.

These thinkers link us to the sale of the Archimedes palimpsest and the X-ray investigation of the Antikythera device. These are parallel threads of the same narrative, which illuminate the fate of Greek science and civilization.

What happened to the advanced work of scientists like Eudoxos, Euclid, Aristarchos, Archimedes and Eratosthenes during the Dark Ages? How could the ancient Greeks have developed such a sophisticated science and technology more than 2,000 years ago, when most of the world was scientifically primitive? Is the Antikythera Mechanism the proof that other advanced technologies existed?

This book attempts to answer these questions.

My thesis contends that the ancient Greeks did indeed develop advanced science and engineering technologies, which enabled them to build the Antikythera astronomical computer and similar devices.

This is a crucial issue because many scholars and historians still believe that modern science is entirely the product of the fifteenth-century Renaissance and the eighteenth-century Enlightenment. Moreover, they cannot believe that the ancient Greeks ever developed advanced technologies.

So, who cares! Why should we be interested in the ancient Greeks, much less their technology? After all, modern science and technology has given us nuclear weapons and taken us to the Moon. How can the ancient Greeks possibly be compared to us?

"We are all Greeks." These were the heartfelt words of the English poet Percy Bysshe Shelley in 1821: "Our laws, our literature, our religion, our arts, have their roots in Greece."[1] Shelley was one of many philhellenes who fought alongside the Greeks during their War of Independence, in the heroic struggle to expel the Turkish occupiers of their homeland.

Jacob Burckhardt, the famous Swiss cultural historian, was grateful to the Greeks for laying the foundations of Western culture, enabling humans to become civilized. In 1872, he wrote that the Europeans see the world through the eyes of the Greeks and to abandon them would be to accept their own decline.[2]

[1] Percy Bysshe Shelley, *The Complete Poems* (New York: The Modern Library, 1994) 501.

[2] Jacob Burckhardt, *The Greeks and Greek Civilization*, tr. Sheila Stern, ed. Oswyn Murray (New York: St. Martin Press, 1998) 12.

Another European scholar from England, W. R. Inge, wrote in 1921 that there was no way the Europeans could go on without understanding the debt they owed to Greek civilization and culture. "Without what we call 'our debt to Greece'," he says, "we should have neither our religion nor our philosophy nor our science nor our literature nor our education nor our politics. We should be mere barbarians. Our civilization is a tree which has its roots in Greece ... [our civilization] is a river ... but its headwaters are Greek."[3]

In 1948, the English poet W. H. Auden suggested that the people of the West owe their very existence to the Greeks. He said the Greeks taught us to think about thinking, that is, to ask questions. Without the Greeks, he said, "We would never have become fully conscious, which is to say that we would never have become, for better or worse, fully human."[4]

In 1949, the famous British classical scholar Gilbert Highet added Greek logic and metaphysics to building reason among the people of the West.[5]

In 1951, another British scholar, H. D. F. Kitto, gave a brilliant and insightful perspective on the Greeks. The Greeks, he wrote, were "not very numerous, not very powerful, not very well organized." They had "a totally new conception of what human life was for and showed for the first time what the human mind was for." Comparing the historical chronicles of barbarians to the work of Thucydides, he said, is "the difference between a child and a man who cannot only understand, but also make his understanding available to others. Epic poetry, history and drama; philosophy in all its branches, from metaphysics to economics; mathematics and many of the natural sciences—all these begin with the Greeks."[6]

In the late 1950s, E. J. Dijksterhuis, Dutch historian of mathematics and natural sciences, captured the Western scientific esteem of the work of the Greeks. He said that the origins of present-day knowledge, especially in mathematics and natural sciences, go straight to ancient Greece.[7]

[3] W. R. Inge, "Religion" in *The Legacy of Greece*, ed. Richard Livingstone (New York: Oxford University Press, 1969) 28.

[4] W. H. Auden, *Forewords and Afterwords*, ed. Edward Mendelson (New York: Random House, 1973) 32.

[5] Gilbert Highet, *The Classical Tradition: Greek and Roman Influences on Western Literature* (New York: Oxford University Press, 1949) 542.

[6] H. D. F. Kitto, *The Greeks* (Penguin Books, 1967) 7, 9.

[7] E. J. Dijksterhuis, "The Origins of Classical Mechanics from Aristotle to Newton" in *Critical Problems in the History of Science*, ed. Marshall Clagett (Madison, WI: University of Wisconsin Press, 1969) 164.

In 1993, the American historian of astronomy Anthony Aveni reported that theory, logic, and models are gifts of the Greeks: "Indelibly written on the faces of all our modern texts about the natural world. If we can clearly trace one branch of the taproot of modern science back to the ancient Greece, it is this habit of formulating practical, non-human-centered, mechanical models of how nature works," he wrote.[8]

In 1999, Charles Freeman, a classical scholar, summed up the Greek influence with the chromosome metaphor. The chromosome was one of the greatest discoveries in biology in the twentieth century: the genetic material in every living thing responsible for passing one generation's biological characteristics to the next. The Greeks, he said, "provided the chromosomes of Western civilization."[9] The chromosome is an idea and metaphor of science; knowledge of where the Greeks have had their greatest lasting influence on the West, the theme of this book.

First, this book is about the greatest technological achievement of ancient Greek civilization: the Antikythera computer. It describes the political, scientific, and technological revolutions that enabled the Greeks to build it. The book explains how and why they were able to manufacture the first astronomical computer in the world.

However, the book is more than a biography of a computer. Indeed, that biography occupies but one chapter in a study tracing the history of the Greeks from the seventh century BCE to the second century of our era. In addition, two chapters delve into the fortunes of Greek civilization after the triumph of Christianity. Second, this book goes beyond technology, to investigate the ethics, which went along with the scientific advances. The Greeks believed that science and technology had to be used for the good of society. Technology does not exist in a vacuum or for selfish advancement and profit; it must contribute to "the good."

My research is founded upon the use of primary sources. I trace the history of science and technology from original texts. This helped me understand the thought and labor that went into the building of a scientific computer and calendar that synchronized the movements of the heavens and the works of human beings by advising farmers when to plant for a good harvest, and when

[8] Anthony F. Aveni, *Ancient Astronomers* (Washington, DC: Smithsonian Books, 1993) 53–54.
[9] Charles Freeman, *The Greek Achievement* (Penguin Books, 2000) 434.

to expect the Olympic games. I have linked Archimedes and the Antikythera device to science and culture in ways that have never been done before.

Third, this book illuminates the relevance of Greek thought and engineering to our own times, building a case for why we should care about the world's oldest computer, which the ancient Greeks called Tablet. This cosmological and Promethean computer of genius has a history full of insights for today's computer geeks, high-tech executives, and discerning readers interested in Greek and Western civilization. This book documents and explains this history—a cautionary tale of what serves and what hurts the public good. It's a warning: that in their rush to make money, developers of artificial intelligence, machine learning, and driverless cars are opening another Pandora's box of uncontrollable violence and possible extinction.

The lesson from the Greeks is this: If technology is not used for the public good, it undermines society, as we saw in the global financial crash of 2008, or in Volkswagen's lies about their cars' poisonous emissions, or the deleterious and plague-like consequences of industrialized farming. The harm from modern farmers is so widespread that their animal feeding operations have become sources for pestilence. Young mothers are finding pesticides in their breast milk. And even worse than that, the United States and Russia are on a hair-trigger alert in unleashing a catastrophic nuclear war.

Galen, the Greek medical genius of the second century, put it bluntly: "If wealth is valued above Virtue, it spoils and corrupts science and society."[10] In other words, if we ignore the good and the beautiful, we are doomed.

In marked contrast, the Antikythera computer—Tablet—was built to serve the public good. (In chapter 6, I will explain why "Tablet" is the name ancient Greeks gave astronomical devices like the Antikythera Mechanism.) The Antikythera Tablet brought the heavens within the reach of human understanding. It was an astronomical compendium of astonishing complexity and accuracy. It provided accurate tracking of the movement and position of the planets, the Sun, the Moon, the constellations, and prominent stars. It mechanized the predictions of scientific theories, including the eclipses of the Sun and the Moon, as well as the phases of the Moon. It was a celestial calendar, a moving map of the constellations, and a mirror of nature and the heavens.

[10] Galen, "The Best Doctor is also a Philosopher" 57–61, in *Selected Works*, tr. P. N. Singer (New York: Oxford University Press, 1997).

Finally, this book sets this ancient history against the modern drama of the resurrection of the vanished texts of Archimedes from the palimpsest, and the decoding of the secret interior of an ancient Antikythera computer. Science gave us satisfactory answers to these enigmas. Indeed, science is our greatest connection with the Greeks. We acknowledge their invention of democracy. We also celebrate their achievements in laying the foundations of mathematics, physics, biology, and astronomy, which eventually took us to the Moon. This is what should make their story so important to the modern reader.

That is why the discovery of a vandalized book of Archimedes is big news and the decoding of a 2,200-year-old mechanical computer is of extraordinary importance. This computer was at the cutting edge of an evolving technology, which revealed the heavens, and connected the Greeks to nature, to their athletic and religious festivals, and to the gods. This book relates the dramatic story of those who built the Tablet and those who, more than two millennia later, unearthed its secrets from within an encrusted lump of marine debris and deciphered the corroded inscriptions.

Introduction

Science and the Public Good

Science was the greatest Greek achievement and the Antikythera computer its most brilliant expression. Scientists and engineers translated natural philosophy, astronomy, mathematics, physics, and engineering into the bronze gears of the mechanical universe of the computer.

But behind this celestial gear machine, there was a great metaphysical virtue, just as fundamentally important as the gears: the promise that science would rarely, if ever, be separated from the public good and the beautiful. This restraint, inherent in Greek thinking about science and technology, kept the potential excesses of scientific knowledge in check.

The successors of Alexander the Great, especially the kings of Egypt, adopted Aristotle's model of science: lavishing it with money, a great library, a university, and other support.

However, the Christianization of Greece and the West in the fourth century led, first, to the near disappearance of science during several centuries of darkness, usually described as the Middle Ages (chapter 9). Then, starting with the Renaissance in the fifteenth century, science revived in the West primarily because Greek scholars in Padua, Venice, Florence, Rome, and other cities in Western Europe translated ancient Greek scientific and philosophical texts into Latin. Western scientists studied those texts and absorbed their science, triggering additional insights that became modern science. But without the virtues science had in its Greek origins and development, science in the West got into trouble. It had its numerous flashes of genius, but it almost lost its integrity, becoming by the twentieth and twenty-first centuries primarily a factory for

nuclear weapons, intercontinental missiles, nuclear power plants, satellites, pesticides, genetic engineering, high-tech computers, artificial intelligence, iPhones, pharmaceuticals, countless cars run on petroleum, and countless chemicals and machines.

This metamorphosis of science, among other things, explains why modern scientists took more than a hundred years to understand the science and purpose of the Antikythera computer. It did not meet their expectations. It was too much like the science they practiced, a reality that shocked them. They could not answer a question that arose immediately when they began to understand the complexity of the Greek computer: How could Greeks, 2,200 years ago, do things we do now? The Antikythera device challenged their understanding and metaphysics.

The contrast between ancient Greek science and modern science is necessary if only in helping us appreciate the enormous potential that the Greek science model presents for our science and civilization in the twenty-first century. In addition, people who understand the limitations of what science has become are likely to judge fairly and appreciate the Greek computer.

Even a cursory review of a few facts in the history of modern science might help place the ancient device in proper perspective. The Antikythera computer, after all, is more than an interesting if spectacular curiosity and a fantastic example of genius. It seamlessly weaves scientific technology and the Cosmos around a portable and small metal device that reveals the secrets of the heavens to farmers, priests, and astronomers. Benefiting all, as the Antikythera computer did, is not exactly an easy theoretical or practical achievement. For this reason, the Antikythera computer may well prove essential for our survival.

Here's why.

Science for the Greeks was *episteme (ἐπιστήμη)*, expert knowledge of something like archery and *techne (τέχνη)* or cunning craftsmanship, technology. Aristotle said that *episteme* comes with certain knowledge of a thing. When we are certain we know the cause behind a fact, we are doing science.[11]

[11] Aristotle, *Posterior Analytics* 71b8–12, ed. Richard McKeon, *The Basic Works of Aristotle* (New York: The Modern Library, 2001). In most of my citations of ancient Greek authors, I use the Greek texts of the Loeb Library or the Oxford Classical Texts. The English translations in the Loeb Library are for the most part obsolete. So, with some exceptions, all translations in this book are my own.

Knowledge for the Good of Society

Like technology and culture, *episteme* came to mean primarily knowledge for the good of society. This idea of the good, almost always connected with the beautiful, was pervasive in Greek thought and society.

For example, Xenophon, c. 428–354 BCE, an Athenian writer, student of Socrates, and military man, tells the story of Herakles's choice by Prodikos, a fifth-century BCE sophist. Young Herakles, the greatest hero of the Greeks, is reflecting on what he should be doing in life: What path should he follow? At that moment, two goddesses approach Herakles. One of them, Vice, offers Herakles a career full of pleasures. The other goddess, Virtue, tells Herakles that a life merely full of pleasures promised by Vice is meaningless and empty; she advises Herakles to work for a living, insisting that only honest labor makes life truly good and happy:

"The gods give nothing to man without effort and work," says the goddess of Virtue. "If you expect the favor of the gods, worship them: if you want your friends to respect you, be good to them: if you want a polis to honor you, help that polis: and if you are thinking of winning the admiration of all Hellas, you need to do things that benefit Hellas."[12]

For example, the founder of the Olympics deserved public recognition and honor all over Hellas. A legend has it that Herakles founded the Olympics.

Plato warned us about the misuse of knowledge.[13] Plato, 427–347 BCE, was a great philosopher (chapter 3). His original name was Aristokles. The epigram from his grave praises him to the heavens, calling him divine, and extolling his virtues of temperance, justice, and wisdom.[14] But Plato grew up in a country, Athens and Greece, torn apart by war. Plato witnessed Athens humbled by Sparta. He also lived through the wrongful death of his teacher Socrates by democratic Athens.

About 800 years after Plato, the Platonic philosopher Proklos, 412–485, denounced a group of philosophers calling themselves Skeptics who refused to accept that knowledge was possible. The Skeptics, Proklos said, "would do away

[12] Xenophon, *Memorabilia* 2.1.28.

[13] Plato, *The Republic* 7.519a, ed. Ioannes Burnet (Platonis Opera, Oxford Classical Texts, Oxford: Oxford University Press, 1902, 1978). With some exceptions, all my citations of Plato come from the Oxford Classical Texts. The text edited by Burnet was revised by later editors.

[14] *The Greek Anthology*, 7.60, tr. W. R. Paton (Loeb, 1960–1968), 5 vols.

with all knowledge, like enemy troops destroying the crops of a foreign country, in this case a country that has produced philosophy [Hellas/Greece]."[15]

Despite these rare excesses, science served the public interest. First of all, science was not, strictly speaking, a technical process or enterprise. It was much more than using reason and experiment for understanding society, nature, and the universe. Science was asking questions. It was philosophy. It included the appreciation and understanding of the beauty and workings of nature and the Cosmos, which, in Greek, means an ordered universe that even the gods dare not interfere with.

In fact, according to fifth-century BCE historian Herodotus, c. 490–c. 425 BCE, the Greeks called their divinities gods because they believed those divinities had set all things in order and assigned a place to everything.[16] In other words, the gods opened the path of organized knowledge, order, and reflection. According to Aristotle, those cultivating reason and doing science were dear to the gods.[17] (I examine Aristotle and science in chapter 3.) The most outstanding example of that divine order was the Cosmos, which, in the vision of the Greeks, was also a world made beautiful, equitable, and just as well as having the appearance of an ornament. Greek science was the rigorous search for the truth in society, the natural world, and the Cosmos. No wonder the Cosmos found its place within and without the computer Greeks invented and manufactured in the second century BCE.

In the fifth century BCE, Hippocrates, c. 460–370 BCE, exemplified science and craftsmanship. An unknown commentator alleged Hippocrates was the son of *Phoibos* (Shining) Apollo. In addition, we learn Hippocrates was from Thessaly but was born in the Aegean island of Kos. The commentator hastened to explain that Hippocrates triumphed over many diseases not by accident but by the application of *techne*.[18]

Hippocrates expected the Greek physicians not to harm those seeking their help. Greek doctors took an oath to heal. In that sense, Hippocrates mirrored the main purpose of Greek science, which was to improve the human condition, not to injure men and women or nature. Aristotle searched for the truth in the natural world, human society, and the Cosmos.

[15] Proklos, *A Commentary on the First Book of Euclid's Elements* 199, tr. and ed., Glenn R. Morrow (Princeton, NJ: Princeton University Press, 1992).

[16] Herodotos, *The Histories* 2.52.

[17] Aristotle, *Nicomachean Ethics* 1177b31–1179a33.

[18] *The Greek Anthology* 7.135.

The biology of Aristotle (chapter 3) and the mathematical physics of Archimedes (chapter 4) remain the same to this day; in fact, they triggered "modern" science, the science we have today in the third decade of the twenty-first century. But they are different from our science in the sense they stood by their principles of the discovery of truth and the application of that knowledge for the protection of nature and the good of society, not its harm.

In the history of science, the technical component of science keeps becoming more complicated but science remains pretty much the same. What has become alienated in modern times is the purpose of science.

Who Invented Science?

The Greeks and the Babylonians were stargazers. The Greeks decoded the heavens because they sought to understand the working of the Cosmos, home of the gods. After all, Ouranos, the sky, was a god who hosted other gods, the stars.

According to Edward Rosen, distinguished professor of the history of modern science at the City University of New York, the Babylonians had no interest in "the inner workings of the cosmos. Their aim was to master those cosmic features which they believed controlled human destiny."[19] I will discuss the differences between Greek science and non-Greek science in chapter 8. But at this point I am suggesting that Greek science triggered Western science; and to some degree, Western science became a continuation of Greek science. This is true provided one also takes into consideration that modern times altered our relations with the ancient Greeks in a lasting fashion. To the invisible but real influence Christianity exercises over science, we must add the overwhelming power and influence nuclear bombs have been having on science and civilization.

Modern Science

This is not the place for a history, even a sketchy one, of modern science. I will, instead, summarize a few key developments that highlight the new nature of science and technology in the West. It's always important to know where we

[19] Edward Rosen, *Copernicus and the Scientific Revolution* (Malabar, FL: Krieger Publishing, 1984) 15.