WHY THE GREEKS?
AN INQUIRY INTO THE CULTURAL CHARACTERISTICS CONTRIBUTING TO THE DEVELOPMENT OF SCIENCE IN ANCIENT GREECE

THESIS

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CHAPTER I

INTRODUCTION

The history of science is unique among historical fields in that the basic origins of its subject can be explored with at least some degree of confidence. The beginnings of such human constructs as politics, economics or religion are lost in the midst of time and the study of them properly belongs to the field of anthropology. By contrast, science emerged at a time within human history and, as such, is fertile ground for historians who seek to know the circumstances and causes of its genesis.

It is the belief of this historian that science began in Greece, between roughly 600 and 400 B.C.E. Although the notion that science began in ancient Greece is a belief held by many historians, it has been and will continue to be extremely controversial in the history of science. The argument, however, is largely semantic and depends on how one chooses to define *science*. It is therefore necessary, before embarking on any study of the history of science, to attempt to give a definition of precisely what ones means by the term *science*.

In our society, there seems to be a general consensus as to what a person means when he or she uses the term *science*. It brings to mind researchers in laboratories mixing chemicals with one another, or astronomers on remote mountain peaks peering through telescopes. Still, providing a precise definition of the word is a difficult challenge and one that has confounded historians and philosophers of science for a very long time.

Historian of science G.E.R. Lloyd, in the preface to his work *Early Greek Science*, states:

> Science is a modern category, not an ancient one: there is no one term that is exactly equivalent to our 'science' in Greek. The terms *philophia* (love of wisdom, philosophy), *episteme* (knowledge), *theoria* (contemplation, speculation) and *peri physeos historia* (inquiry concerning nature) are each used in particular contexts where the translation 'science' is natural and not too misleading. But although these terms may be used to refer to certain intellectual disciplines which we should think of as scientific, each of them *means* something quite different from our own term 'science.'[1]

According to Lloyd, then, the Greeks did science without truly realizing it, because they had no concept of science in the modern sense. This leads us to the obvious question of what, exactly, is our modern conception of science. The great historian of science George Sarton (who emphatically rejected the contention that science began with the Greeks) attempted to explain his use of the word *science* in his monumental *History of Science*:

> What is science? May we not say that whenever the attempt to solve a problem is made methodically, according to a predetermined order or plan, we are witnessing a scientific procedure, we are witnessing the very growth of science? To be sure, early methods seem childish and weak as compared to ours, but will the scientists of the year 5000 think as favorably of our methods as we do ourselves?[2]

Despite his well deserved reputation as one of the giants of the history of science, Sarton's definition of science simply seems too broad to be workable. Solving a problem with a predetermined plan is a description that can be given to virtually any kind of human activity. When a high school boy concocts a scheme to convince a girl to attend a dance with him, he can hardly be considered as being engaged in science, even if he approaches the problem methodically and with a predetermined plan. Science, as it is generally understood by our society, must be narrowed to a more specific field.

Furthermore, the phrase "solve a problem" in Sarton's description is, this historian believes, somewhat confusing. Science does not directly involve *solving problems*, but *studying phenomena*. Fundamentally, science could exist even if it were never put to any practical use. An astronomer studying the planet Mars is engaged in science, while an engineer designing a spacecraft to travel to Mars is not. Knowledge provided by science is obviously needed for the construction of the spacecraft and the spacecraft will certainly be used to further the cause of science, but since it does not *directly* involve the studying of phenomena, the construction of the spacecraft is not, in and of itself, a scientific exercise.

Having decided that science involves the study of phenomena, what sort of phenomena does it study? Stated briefly, the area which comes under the view of science is that which humanity refers to as *nature*. Unfortunately, this term presents almost as much semantic difficulty as the term *science*. In order to achieve brevity and not become hopelessly muddled in a metaphysical trap, *nature* will be defined as everything which exists in the material world and is, therefore, subject to empirical study. The circulatory system of a human being is part of nature because it can be studied in an empirical sense; Plato's metaphysics is not part of nature since, being an abstract concept generated by a human mind, there is no way to study it empirically.

The empirically-based essence of science is important in differentiating it from other fields of study (or activities claiming to be fields of study) that claim the mantel of science but are not, strictly speaking, scientific. These are often termed *pseudosciences*, and include such things as astrology, creationism, and the belief in "psychic" powers. These items cannot fall into the category of science, as they claim to involve non-empirical processes, such as planets exerting magical forces or messages being miraculously transmitted from one human mind to another. While these activities are important to the history of science (astronomy and chemistry were largely derived, respectively, from astrology and alchemy), it cannot be stressed enough that, in and of themselves, they are not scientific.

The question of finding a definition of science is complicated by the misleading term *social science*. Without intending to insult such worthy fields of study, it must be made clear that so-called social sciences, such as history or political science, cannot be considered scientific under the definition we are approaching, because of their subjective nature. History, for example, is a largely subjective field; beyond using historiographical methods in an effort to accurately reconstruct a series of past events, the job of the historian is to interpret what those events mean, an endeavor which can hardly be described as scientific.

For example, to a certain extent, it is possible to objectively reconstruct the events involving the War of 1812. However, it is impossible to objectively state whether it was the United States or Great Britain that actually won the War of 1812, because that would be a subjective statement. One historian might claim that Great Britain won because it had captured and burned the American capital, while another historian might claim the United States won because it was the victor in the last major engagement, and a third might simply claim that neither side actually won. All of these arguments might be somewhat valid to historians, but neither makes any sense in scientific terms. All such conclusions in the so-called social sciences involve subjective value judgments, and there can be no room in any scientific undertaking for such things.

It must be admitted that certain fields, such as psychology or anthropology, seem to fall into a gray area between the social sciences and the field of science, which is the subject of this thesis. After all, psychology and anthropology study human beings, and human beings exist in the material world. To provide a more specific example, why is it considered scientific for zoologists to study chimpanzees but not for anthropologists to study humans? Some might consider these fields to be scientific, while others might reject such an idea (a few might even smugly suggest that the practitioners of those fields possess "science envy"). These are important questions and have not been adequately addressed in the academic world, but to attempt to address such questions here would take us far beyond the purview of this paper.

We have thus determined that science involves the study of nature, but this still seems insufficient when describing the modern endeavor we recognize as science. Science asks deeper questions, which seek to *explain* nature as well as simply *describe* nature. For example, a bird-watcher is obviously studying nature, but this does not necessarily make him a scientist. True science involves a search for *causes and effects* in nature. It is not enough to simply say, "The bird is red." Science must explain *why* the bird is red and the *consequences* of the bird's redness.

Science, therefore, is fundamentally the study of natural phenomena, seeking to answer questions without recourse to non-empirical explanations, the objective being the determination of causes and effects. Furthermore, science is also distinguished from other fields of human thought by the particular methods of attaining knowledge and coming to conclusions. Just as science seeks understand empirical phenomena, its techniques are based on the use of empirical means to discover and study those phenomena.

Professor of physics and philosopher of science Alan Cromer (who wholeheartedly accepts the notion that science originated with the Greeks) put it this way:

> All nonscientific systems of thought accept intuition, or personal insight, as a valid source of ultimate knowledge. Indeed . . . the egocentric belief that we can have direct, intuitive knowledge of the external world is inherent in the human condition. Science, on the other hand, is the rejection of this belief, and its replacement with the idea that knowledge of the external world can come only from objective investigation- that is, by methods accessible to all.[3]

From this idea comes the fact that science relies on such objective methods as direct observation and experiment. Theories such as Einstein's theory of relativity might be created purely by intuition, but they must be able to be tested by empirical methods to be considered scientific. Ideas in theology and metaphysics, on the other hand, cannot be tested empirically and are often determined to be valid by their protagonists based simply on the authority of the person putting forward the idea. Empirical study is yet another aspect of science that separates it from theology, metaphysics, and countless other fields.

Sir Karl Popper, one of the giant figures in the philosophy of science, argued that scientific theories are distinct from nonscientific theories by virtue of being *testable*; that is, having the possibility of being proved false. He states:

> A theory which is not refutable by any conceivable event is nonscientific. Irrefutability is not a virtue of a theory (as people often think) but a vice. . . Every genuine *test* of a theory is an attempt to falsify it, or to refute it. . . Confirming evidence should not count *except when it is the result of a genuine test of the theory*; and this means that it can be presented as a serious but unsuccessful attempt to falsify the theory.[4]

Sir Popper's point is science is not merely an inductive process, seeking evidence which supports a particular theory, but also a deductive process, seeking evidence which would prove a particular theory false. For any theory to be scientific, there must be some hypothetical way of proving it false. For example, if the positions of the stars had not been displaced by the sun's gravity during the celebrated solar eclipse of 1919, as Einstein's theory of relativity had predicted they would be, then Einstein's theory would have been proven false (they were displaced, thus helping confirm Einstein's theory). It is through such observations and experiments that the scientific method works.

Taking all of this into account, we can arrive at a general definition of science. *Science is the study of natural phenomena, answering questions through means of observation and/or experiment, without recourse to non-empirical explanations, the objective being the determination of causes and effects.*

Having arrived at this definition, it can be stated with some degree of confidence that this form of thinking did indeed arise in ancient Greece. As already stated, this contention is highly controversial among historians of science. Historian David Pingree, in an 1992 article printed in *Isis*, bitterly denounced the idea of a Greek invention of science, essentially accusing those who accept the idea as being guilty of ethnocentrism, if not racism. Pingree claims the idea that the Greeks invented science "distorts the history of science in two ways: passively, it limits the phenomena that the historian is willing or able to examine; actively, it perverts understanding both of Western sciences, from the Greeks till now, and non-Western science."[5]

Pingree is incorrect is his analysis because he commits the same error Sarton does in attempting to establish a definition of science: his definition of science is simply too broad. He says, "[T]he sciences I study are those related to the stars, and they include not only various astronomies and the different mathematical theories they employ, but also astral omens, astrology, magic, medicine, and law . . . All of these subjects, I would argue, were or are sciences within the contexts of the cultures in which they once flourished or are now practiced."[6]

However, under the definition of science which we have established, Pingree's inclusion of "astral omens, astrology [and] magic" under the heading of science is plainly absurd. Science requires that its questions and conclusions be firmly rooted in the empirical world, ignoring anything which is (or, at least, claims to be) somehow separate from the empirical realm. For example, no assertion made by the pseudoscience of astrology can be tested by scientific methods; therefore, it is a gross error to refer to it as a science.

Pingree attempts to qualify his definition by stating that different fields of study can be scientific "within the context of the cultures." This, too, is untenable. How could something be scientific in America but not in Japan? While all cultures have qualities which set them apart, they are also linked by ties that bond them together as members of the human family. Science is one such tie and it is unreasonable to maintain that something could be scientific in one culture but not in another.

But Pingree makes no apologies. He says, "I refuse to allow modern scientists who know little of history to define for me the bounds of what in the past- or in the present- I am allowed to consider to be science. It pains me to hear some scientists, who have not seriously considered the subject, denounce astrology as "unscientific" when all that they mean is that it does not adhere to their concept of a correct methodology."[7] As a person who knows more than a little about history and who has seriously considered the subject, this historian feels compelled to point out that the very concept of science is determined by its methodology. If an activity traditionally violates a fundamental tenant of scientific methodology (such as including non-empirical forces in its process, as astrology does), it cannot be considered science.

Furthermore, Pingree errs by referring to mathematics as a science, specifically calling Euclidean geometry the "pride of Greek science."[8] Again, under the definition we have arrived at, mathematics cannot be considered a science. Obviously, modern science could scarcely exist without the logical tools of mathematics, but mathematics is not, in and of itself, a science, because it deals with abstract concepts rather than empirical natural phenomena. It is logically obvious that two plus two equals four, but there is no way to prove this empirically through the means of the modern scientific method.

Still, the historian who claims that the Greeks were the first people to develop science are confronted by the enormous achievement of other civilizations in terms of their observing the heavens, a point which Pingree makes again and again throughout his article. It cannot be denied that virtually every ancient civilization, the Egyptians, the Babylonians, the Indians, the Chinese and the great civilizations of Mesoamerica, meticulously observed the night sky and charted the movements of the heavenly bodies. Indeed, throughout the world we find assemblies of stone monoliths erected by prehistoric peoples, the clear intention of which was to create calendars of some sort. Can it truly be argued that these endeavors were not scientific?

Again, the conclusion one must reach depends on the definition of science one uses. If one subscribes to the definition of science as given in this thesis, none of these non-Greek endeavors, however laudatory, was truly scientific. Each was undertaken for purely religious, astrological or agricultural purposes, rather than being scientific investigations into nature. While nearly all civilizations charted the movements of the planets and the stars, many with remarkable accuracy, only the Greeks ever bothered to ask *what* the planets and stars were or *why* they moved the way they did.

The non-Greek sky-watchers, for all the incredible work they did in charting the movements of the heavens, were not scientists. They did not undertake their activities with a view to explaining nature, nor did they seek to understand the specific causes and effects of the natural phenomena they witnessed. Furthermore, it did not occur to them to discount non-empirical factors in their work. Finally, and perhaps most importantly, they did not advance their ideas about what they were studying in formats that could be described as testable theories.

Of all the ancient civilizations, only the Greeks approached astronomy and other studies of nature with the methods of science, as they have been outlined in this introduction. They asked scientific questions, seeking to understand the basic causes and effects underlying nature. They relied on empirical and naturalistic explanations, not accepting divine intervention or magical powers as being factors in what they were studying. The ideas they put forward, even though they themselves may have been largely unaware of it, were formulated in such ways as to provide theories which could be subjected to empirical testing. While rudimentary and, from a modern perspective, perhaps even amateurish, the Greeks were undertaking scientific studies of the universe in which they lived, and they were the first human beings to do so.

But if we agree that science originated with the ancient Greeks, we come face-to-face with the central question of this thesis: why the Greeks? What was it about the Greeks that caused or allowed them to develop science while so many other civilizations did not?

It is the contention of this thesis that the rise of science in ancient Greece was due to a complicated set of cultural characteristics which were unique to Greek civilization and to be found nowhere else. To explore this question, this paper will first attempt to provide a general survey of the early development of Greek science by briefly examining the scientific achievements of the five most important Greek scientists between the years 600 and 400 B.C. This thesis shall then closely examine certain aspects of Greek culture, concerning their economics, their politics, and their religious and philosophical worldview, which separated the Greeks from other civilizations.

As is the case with most excursions into ancient history, the sources at the disposal of the historian are secondary rather than primary. No writings by the ancient scientists themselves have survived. However, the writings of Plato and Aristotle, as well as the historians Herodotus and Plutarch, contain numerous references to these five Greek scientists. The historian Diogenes Laertius provided an invaluable account with his *Lives and Opinions of Eminent Philosophers*, although nothing is known of the author beyond the fact that he wrote sometime during the early centuries of the Christian era. Hippolytus, writing around the turn of the third century C.E., provides a wealth of information with his *Refutation of All Heresies*, which describe the beliefs of the Ionian scientists in great detail.

Sir Thomas Heath's account of ancient astronomy, *Aristarchus of Samos: The Ancient Copernicus* (which, despite its title, is a general account of Greek astronomy rather than a biography of Aristarchus) was published in 1913 and remains a valuable work. Benjamin Farrington published *Greek Science* in 1944, and his analysis is first-rate. George Sarton, one of the great historians of science, produced his *History of Science: Ancient Science Through the Golden Age of Greece* in 1952; it contains a wealth of useful information and analysis, although Sarton occasionally assumes too much. More recently, D. R. Dicks produced *Early Greek Astronomy to Aristotle*, and G. E. R. Lloyd wrote *Early Greek Science: Thales to Aristotle*, both of which were published in 1970. Of the other historical research which has been done on this subject, much of it (such as Otto Neugebauer's *History of Ancient Mathematical Astronomy*) is too technical to be used for the purposes of this paper.

G. S. Kirk, J. E. Raven, and M. Schofield, all of Cambridge University, authored *The Presocratic Philosophers: A Critical History with a Selection of Texts*, which, while focusing on philosophical rather than scientific aspects of early Greek thinkers, is not only a highly useful source in and of itself, but an excellent guide to ancient sources that discuss these men. It also provides references from classical writers that are otherwise not easily available.

Regarding the individual fields of Greek culture, a number of outstanding works are available. In surveying the economic world of the Greeks, this historian made tremendous use of H. Michell's landmark study, *The Economics of Ancient Greece*, published in 1940, which should stand as the definitive single-volume work on the subject. Furthermore, the exceptional writings on Lionel Casson provided a highly-detailed (and highly entertaining) glimpse into the world of ancient maritime commerce and all aspects of ancient seafaring and ship-building.

In looking over the world of Greek politics, one cannot do better than the contemporary historian Thucydides, whose *History of the Peloponnesian War* provides a clear account of the power politics of his day and the nature of the Greek *polis* system in general. Furthermore, this historian made use of the excellent work, *The Greek State*, by Victor Ehrenberg. Kathleen Freeman's work, *Greek City-States*, while intended as much for a popular audience as a scholarly one, provides unique insights as well.

This historian relied heavily on *Greek Religion*, an outstanding single-volume work by Walter Burkert, to provide an overview of the religious systems of the ancient Greeks. Furthermore, *A History of Western Philosophy*, by the philosopher Bertrand Russel, was of great value in providing certain insights into the Greek religious and philosophical mindset.

Finally, in gaining a clear understanding of science in general, this historian credits countless hours reading innumerable works by such science writers as Isaac Asimov, Arthur C. Clarke, Richard Dawkins and, above all, Carl Sagan.

[1]G.E.R. Lloyd, *Early Greek Science: Thales to Aristotle*. (New York: W. W. Norton & Company, 1970), preface
[2]George Sarton, *A History of Science: Ancient Science Through the Golden Age of Greece*. (Cambridge. Harvard University Press, 1952), 48-49
[3]Alan Cromer, *Uncommon Sense: The Heretical Nature of Science*. (New York: Oxford University Press, 1993), 21
[4]Sir Karl Popper, *Conjectures and Refutations: The Growth of Scientific Knowledge*. (New York: Basic Books, Inc., 1963), 36
[5]David Pingree, "Hellenophilia verses History of Science," *Isis* 83, no. 4 (1992): 557

[6]Ibid. 554
[7]Ibid. 559
[8]Ibid. 558

CHAPTER II

THE IONIAN SCIENTISTS

The purpose of this chapter is to provide a glimpse of the birth of Greek science by briefly surveying the accomplishments of five remarkable thinkers: Thales, Anaximander, Anaximenes, Anaxagoras and Democritus, some of the intellectuals who are often referred to as "Presocratic philosophers." In the opinion of this historian, these five individuals can be seen as the founders of Greek science.

Some might object to calling these men "scientists" at all, for their work was rudimentary by modern standards. But it must be remembered that they lived in the sixth and fifth centuries B.C.E. As the earliest practitioners of empirical science, they cannot be expected to have achieved results comparable to what has been achieved since their time. To criticize their failures would be similar to criticizing the Wright Brothers for not inventing a modern airliner.

The greatness of the early Greek scientists lies not necessarily in arriving at the right answers, which they seldom did, but in asking the right kinds of questions and using something akin to the modern scientific method in an attempt to answer those questions. They were the first people who intellectually pursued an understanding of the natural world through the use of reason, by means of experiment and direct observation, without recourse to superstition or religion. In other words, they quite accidentally stumbled upon the method of acquiring knowledge which we associate with the term *science*, as defined in the introduction. As such, they justly deserve the title of the first scientists, even though it is likely that these men saw themselves as no different from the nonscientific philosophers who were their contemporaries. These men represent the beginning of the scientific endeavor, from which would eventually spring the foundation of our modern civilization.

From roughly 600 to 400 B.C.E., the Greek world saw an intellectual flowering unprecedented in human history, bringing forth great achievements in literature and philosophy. Despite the fact that the scientists discussed in this chapter are often referred to as "Presocratic philosophers," this survey will remain focused strictly on the subject of science. The achievements of such great thinkers of the time as Zeno and Pythagoras will not be discussed, nor will the philosophical speculations of the scientists themselves (such as the philosophy of mind pursued by Anaxagoras), except whereas they relate to science.

It was the land of Ionia, amid the salt-encrusted rocks and gentle sea breezes of the eastern Aegean Sea, that gave to the world the early Greek scientists. Ionia was one of the dynamic centers of the ancient world, where Greek and Near Eastern cultures came into contact with one another. The people themselves were Greek, having first migrated from the Greek mainland during the early centuries of the Iron Age.[1] But they were far from the center of the Greek world and were geographically tied to such peoples as the Lydians and the Persians than they were to their fellow countrymen.

The Ionian Greeks were a merchant people, particularly skilled in the arts of navigation and seamanship. Because of their location, they lay across some of the most profitable trade routes of the time. All the commerce flowing between Asia and Greece and between the Mediterranean and the Black Seas passed through Ionia, bringing great wealth to the inhabitants. In a certain sense, the Ionians were the Dutch of the ancient world.

Farrington describes social conditions in Ionia at the time of the Ionian Awakening:

> Political power was in the hands of a mercantile aristocracy and this mercantile aristocracy was actively engaged in promoting the rapid development of techniques on which their prosperity depended. The institution of slavery had not yet developed to a point at which the ruling class regarded techniques with contempt. Wisdom was still practical and fruitful.[2]

Of all the great port cities of Ionia, none was more famous or more prosperous than the city of Miletus. Lionel Casson, the great historian of ancient seamanship, said of Miletus:

> [B]eginning with the eighth century B.C. and long thereafter, it was a great commercial center. Its merchants sent their ships southeast to Phoenicia, south to Egypt, and west to Italy, and enticed to their warehouses caravans bearing products from the Asia Minor hinterland and beyond. Its sheep breeders developed a prized quality of wool than commanded a market everywhere and its cabinet-makers were known for the fine furniture they turned out. The city, mingling its native Greek culture with the rich foreign influences that rode in on its far-flung trade, acquired a reputation for intellectual distinction as well.[3]

He goes on to say:

> [T]he Black Sea was almost a Milesian lake: the tons of wheat and fish shipped out annually were financed by the traders and bankers, and hauled by the skippers, of Miletus and its colonies. To make things perfect, its ships did not have to return in ballast. They arrived loaded with Greek pottery and bronze manufactures, which had a ready sale among the natives, as well as with wine and olive oil for the Greek colonists of the northern shore, who never acquired a taste for the local beverages or learned to cook with the local butter and were eager customers for these reminders of life in the old country.[4]

Clearly, Miletus was no ordinary city; its influence was incredibly widespread and its wealth was doubtless the envy of the world. But the city was far more than a simple center of commerce, for if any single place on Earth deserves to be considered the birthplace of science, it is Miletus. It was the home of the first three people in history who can truly be considered scientists, the "Milesian Trinity."

The first of the ancient Greek scientists was Thales, who lived in Miletus sometime around late 7th and early 6th centuries, B.C.E. Sarton states that Thales lived from *c.* 624 to 548 or 545, but he neglects to cite a source for these dates.[5] Herodotus tells us that Thales was of mixed Greek and Phoenician ancestry[6], and considering the cosmopolitan nature of his city, this does not seem implausible, although we have no reason for believing it except that Herodotus says so.

By the time of Plato and Aristotle, Thales was already a semi-legenday figure who was fading into the mists of history. Hard information on his life is virtually nonexistent and much of what we have is almost certainly not true. Still, if even a fraction of what was said about him has any basis in fact, it seems perfectly clear that he was a man whose intellectual powers were far beyond those of ordinary people.

Anecdotes told of Thales by later Greek writers reveal differing images. In *Theaetetus*, Plato has Socrates tell a story with Thales in the role of the stereotypical absent-minded professor. One day, a Thracian servant-girl was watching Thales as he walked past. He was gazing up into the sky, and so intent was he on the stars that he failed to notice a well in his path. He fell in, doubtless falling with a yelp of surprise and hitting the water with a resounding splash. The Thracian girl thought this was hilarious, declaring that Thales "was wild to know about what was up in the sky but failed to see what was in front of him and under his feet."[7] This has been an observation made of many a scientist since the time of Thales.

Aristotle, however, told a story about Thales that showed him in an entirely different light, as a practical and even devious man. After some people had made fun of him for being poor, implying that his intellectual pursuits were useless, Thales decided to adjust accounts. Through his scientific studies, he somehow deduced that the coming olive crop would be particularly good. He proceeded to raise a little money and cornered the local market on olive presses, being able to do so because no one else was bidding against him at such an early date. When the olive crop turned out exactly as he had predicted, he controlled the means by which to turn the olives into olive oil, and as a result, he made a fortune. Aristotle added, somewhat smugly, that Thales showed "that it is easy for philosophers to be rich, if they wish, but that it is not in this that they are interested."[8]

Thales apparently never married. According to Diogenes Laertius, "The story is told that, when his mother tried to force him to marry, he replied that it was too soon, and when she pressed him again later in life, he replied that it was too late."[9] Perhaps Thales simply was too focused on his scientific studies to devote the time and energy to raising a family.

Sarton repeatedly compares Thales to Benjamin Franklin. "Both were living in a stimulating environment, and both responded to it with open mind and natural genius. Both were inquisitive, quick to learn, ready to apply their knowledge to practical aims. Thales' journey to Egypt is like Franklin's to England; both observed eagerly what was done in the Old World and brought back the notions that they deemed useful. Franklin brought back a knowledge of electricity [sic] and Thales that of astronomy. That is not a slight achievement at all."[10] Following Sarton's analogy, Greece was the New World in ancient times and Thales was one of the chief proponents of its virtues.

In addition to his scientific talents, Thales apparently possessed great gifts as a statesman. According to Herodotus, Thales proposed that all the Ionian Greek create a unified government in order to oppose the growing Persian threat.[11] This adds to Sarton's comparison of Thales to Benjamin Franklin, as this plan is not all that dissimilar to Franklin's Albany Plan, by which all the American colonies were to unite to combat the threat of the French and their Indian allies. Unfortunately, the Ionians decided not to take his advice, with very adverse consequences.

Thales was a legend even to the ancient Greek and Romans, being considered as the quintessential genius in much the same way modern Western society sees Albert Einstein. Plato refers to Thales as being one of the Seven Sages of Greece.[12] Somewhat more crude, if rather more informative, is a portrait of Thales found in a bathroom in the Roman city of Ostia, under which is written, "Thales advises the constipated to push hard."[13]

As a scientist, Thales' greatest claim to fame is the fact that he was the first individual in history of the world who is said to have predicted an eclipse. Dramatically, it happened in Asia Minor in the midst of a battle between the Medes and the Lydians. According to Herodotus, "[A]fter five years of indecisive warfare, a battle took place in which the armies had already engaged when day was suddenly turned into night. This change from daylight to darkness had been foretold to the Ionians by Thales of Miletus, who fixed the date for it in the year in which it did, in fact, take place."[14]

The quote from Herodotus is vague and somewhat confusing. Firstly, when he refers to the "date for it in the year," does Herodotus mean that Thales predicted the exact date or only the year? If the latter is the case, the achievement of predicting an eclipse is somewhat less grand, since it might have simply been a lucky guess. On the other hand, why would Herodotus have deemed it worthy of comment unless Thales had been extremely accurate in his prediction?

Secondly, the question must be asked as to whether the prediction of the eclipse was the work of Thales himself or simply information he had obtained from elsewhere. According to two ancient writers, Aetius and Proclus, Thales had spent a considerable amount of time in Egypt.[15] As Thales was a Milesian and Milesians were a well-traveled people, this seems perfectly reasonable; indeed, Miletus had established a colony in Egypt called Naucratis.[16] It is also likely that the knowledge of Babylonian sky-watchers had permeated into Ionia and, if so, Thales could hardly have been unaware of it. Babylonian priests had been studying solar eclipses since 721 B.C.E. (for religious as opposed to scientific purposes) and had developed the ability to predict certain times when an eclipse was likely to take place.[17]

Thus, Herodotus' statement that Thales predicted an eclipse within a specified year would seem to indicate a possibility that the Greek scientist obtained his information from Babylonian sources rather than done the work himself. Still, the fact that Thales could study and understand what the Babylonian priests had done is an impressive achievement in itself, especially considering that he had no Greek antecedents.

The precise date of the eclipse has fascinated astronomers for centuries. The commonly accepted date is May 28, 585 B.C.E., the only day during the general time period when a total solar eclipse would have been visible in Asia Minor.[18] If this is the correct date, the unnamed battle may be the first event in the history of the world for which we can provide an exact date. The Lydians and Medes, interestingly enough, were said to have been so overawed by the spectacle that they immediately made peace. As odd as it sounds, the coincidental positioning of the Earth, sun and moon in the sixth century B.C.E. undoubtedly saved many lives.

In addition to his study of astronomy, Thales speculated as to the nature of the Earth itself. According to Aristotle, Thales believed that the Earth rested upon water, not unlike a log floating in a pond.[19] We have no record that Thales ever considered what the water itself was resting on; perhaps it simply never occurred to him to ask.

This idea of the world is, of course, completely wrong. But the genius of Thales must be measured by his methods and ideas, rather than the incomplete fruits of those methods and ideas. In this regard, what is important about Thales conception of the world was that it was rooted in the empirical world, as opposed to the world of the supernatural. In his *Greek Science*, Farrington said,

> The name of the Babylonian creator was Marduk In one of the Babylonian legends it says: 'All the lands were sea . . . Marduk bound a rusk mat upon the face of the waters, he made dirt and piled it beside the rush mat.' What Thales did was to leave Marduk out. He, too, said that everything was once water. But he thought that earth and everything else had formed out of water by a natural process, like the silting up of the delta of the Nile.[20]

Historian of science G. E. R. Lloyd provides another such example in his *Early Greek Science*, when he discusses Thales' explanation for earthquakes:

> Thales apparently imagined that the earth is held up by water and that earthquakes are caused when the earth is rocked by wave-tremors in the water on which it floats. The idea that the earth floats on water is one that occurs in several Babylonian and Egyptian myths, and we have no need to go beyond Greece itself

> for a mythical precursor to Thales' theory, for the idea that Poseidon, the god of the sea, is responsible for earthquakes was a common Greek belief. Simple as Thales' theory of earthquakes is, it is a naturalistic explanation, making no reference to Poseidon or any other deity.[21]

We noted in the introduction, citing the words of Sir Karl Popper, that scientific ideas must be formulated in theories which are somehow testable. Thales, of course, could not have thought in such specific terms, but both his concept of the earth and his explanation of earthquakes can be considered theories that can be subjected to empirical tests. We have since discovered that the earth does not rest on water, so both of his theories were completely wrong. Still, the fact that Thales naturally gravitated towards a testable and theoretical approach to studying nature is a vitally important point to make.

The explanation of natural phenomena through empirical means, formulated into something similar to a testable theory, was one of the key intellectual developments that led to the birth of science. Because of this rationalistic quality, the work of Thales, so completely wrought with errors and misconceptions, is significant in and of itself, in that it represented the beginning of the scientific enterprise.

Thales was the first scientist, but others followed in his wake. The successor to Thales was a remarkable man named Anaximander, who likewise was a resident of the city of Miletus. According to Diogenes Laertius, he was sixty-four years old in the mid-540s[22], which would obviously place his birth sometime around 610. Thus, he was somewhat younger than Thales.

The ancient geographers Agathemerus and Strabo refer to Thales as being Anaximander's friend and mentor.[23] Sarton says of their relationship, "[T]heir particular views were different, yet they had in common . . . a deep curiosity and strong desire to explain the nature of things. In that sense. . . it is true that [Anaximander] continued Thales' work."[24] As every worthy pupil does, Anaximander was to surpass his teacher in a number of ways. His scientific speculations would range across the fields later recognized as astronomy, geography, meteorology and biology.

Some of Anaximander's most important work was done through the use of a crude device called a gnomon, which simply is a stick planted vertically in the ground.[25] By observing the shadow cast by the sun over a period of many months, one could discover a great deal. Sarton says, "[T]he gnomon enabled the astronomer to determine the lengths of the year and the day, the cardinal points, the meridians, real noon, the solstices, and later, the equinoxes and the length of the seasons. A relatively large amount of precise information could thus be obtained with the simplest kind of tool."[26]

According to a quote from Suda, Anaximander "discovered the equinox and solstices and hour-indicators, and that the earth lies in the center."[27] Despite the incorrectness of the final statement (for which we cannot blame Anaximander), it is clear that he did substantial work in astronomy. With a stretch of the imagination, Anaximander puzzling over the shadows cast by his gnomon can be seen as the distant ancestor of the modern astronomers studying images beamed down from the Hubble Space Telescope.

Anaximander envisioned the Earth as drum-shaped, with a height about one-third the diameter of the circular surface.[28] Whereas Thales believed the world to rest on water, Anaximander did not believe it rested on anything. Since, as he asserted, the Earth lay in the center of the cosmos, there was no more reason for it to move in one direction as opposed to another.

According to Aristotle, "[T]here are some, Anaximander, for instance, among the ancients, who say that the earth keeps its place because of its indifference. Motion upward and downward and sideways were all, they thought, equally inappropriate to that which is set at the center and indifferently related to every extreme points; and to move in contrary directions at the same time was impossible: so it must needs remain still."[29]

This concept is beautiful and brilliant. Strictly speaking, Anaximander's premise was completely wrong; asking why the Earth is stationary is a meaningless question because, as we now know, the Earth is not stationary. Nevertheless, by introducing the concept of lack of movement without being acted upon by an external force, Anaximander knocked on the door of Newton's First Law of Motion ("An object in motion tends to stay in motion; an object out of motion tends to stay out of motion"). This is a feat of scientific thought not to be underrated.

Anaximander's conception of the heavenly bodies is highly unusual. Rather than seeing them as separate objects, he envisioned a series of tubes running around the Earth, all of them filled with fire. According to Anaximander, the 'objects' we see are merely holes in the tubes through which the fire is visible. He believed that eclipses occurred when these holes were somehow stopped up.[30] While quite odd and completely wrong, this idea constitutes a scientific theory in that it is firmly rooted in the empirical world and has testable features. More importantly, this theory represents the first attempt in human history to construct a theoretical model of the cosmos.

According to some accounts, Anaximander was the first person who attempted to create a map of the world (or at least as much of it as was known to the Greeks). Diogenes Laertius says, "He was the first to draw on a map the outline of land and sea, and he constructed a globe as well."[31] The statement concerning the globe raises questions, since it doesn't seem possible for Anaximander to have created a globe if he subscribed to a model in which the Earth was flat. Perhaps a mistranslation occurred at some point during the transmission of the work of Diogenes Laertius, or perhaps Diogenes Laertius himself was simply confused.

Anaximander's contribution to biology are even more impressive than the rest of his work. Two and a half millennia before Charles Darwin, Anaximander seems to have grasped the fact that human beings have evolved from simpler animals.

If we can believe Plutarch, Anaximander came to this conclusion from the fact that, while most animals are self-supporting immediately after birth, humans go through a long period of helplessness, during which they are cared for by their parents. Obviously, no human infant could survive on its own. Therefore, humans could not have survived if they had been originally created in their present form.[32] Clearly, human beings had to have evolved from something else.

This argument is clearly incomplete, since whatever man had evolved from would have had to have been self-sufficient as well, and this logically leads to a never-ending process which must have a beginnıng at something that is not self-sufficient. Still, as far removed as it is from the modern theory of evolution by natural selection, is deeply intriguing and reflects well on the mental power of Anaximander. It also represents the first known attempt to explain the origin of the human race without recourse to divine intervention. Once again, we find a Greek thinker who seems to instinctively gravitate towards the scientific method.

The third and final member of the "Melisian Trinity" was Anaximenes, about whom we have even less information than we do for his two predecessors. According to Diogenes Laertius, he was a student of Anaximander.[33] If this is true and the previously-supposed connection between Thales and Anaximander is also true, there is a direct line continuity from Thales to Anaximenes. Indeed, it is similar to the famous line from Socrates to Plato to Aristotle. But however tempting it may be to believe this, we have only the word of Diogenes Laertius on which to base such a claim, and thus it must be treated with skepticism.

Anaximenes was fascinated by air, which he saw as the key to the cosmos. Aristotle says, "Anaximenes [makes] air prior to water, and the most primary of the simple bodies."[34] Diogenes Laertius says that Anaximenes "took for his first principle air or that which is unlimited."[35]

Anaximenes believed that everything that existed was air in some form or another. Liquids and solids were simply more air compressed together in a smaller place.[36] According to the historian G. L. Huxley, "At its finest air becomes fire, and then, in increasing degrees of density, wind, then cloud, then water, then earth, then stones. From these constituents all other things come into being."[37] By making these arguments, Anaximenes was on the verge of forming a coherent theory of matter, and these steps would be taken much farther by Democritus.

Sarton gives an account of Anaximenes' theory on air temperature and its consequences:

> Air is the primary substance but it may take all kinds of appearances by condensation or thickening or by rarefaction or thinning. Anaximenes associated these qualitative changes with changes in temperature. He had persuaded himself

> with a crude experiment that rarefaction increased the temperature while compression decreased it: when we blow with open mouth, the air that we breathe out is warm; when we blow with the lips almost closed, the air is cool. His assimilation of air with the breath of life was the occasion of his comparing the whole world with a single living organism, say a man. Breath is to the latter what wind is to the former.[38]

Anaximenes, like his two predecessors, believed that the Earth was flat. Where Thales thought it rested on water and Anaximander did not believe it rested on anything, Anaximenes was of the opinion that it rested on air. According to Aristotle, Anaximenes' theory was that the Earth "does not cut, but covers like a lid, the air beneath it."[39] Thus, the air is prevented from moving and holds the Earth up.

Anaximenes was the last of the "Milesian Trinity." Following him was another early scientist named Anaxagoras, who came from the Ionian town of Clazomenae, which was near the great city of Smyrna.[40] According to Diogenes Laertius, he was twenty years old when the army of Xerxes invaded Greece, and this would have placed his birth around 500 B.C.E.[41] A listing of the fundamental discoveries Anaxagoras made in astronomy quickly reveals the power of his intellect.

Much of Anaxagoras' most important work involved his studies of the moon. He was apparently the first person who understood that the moon does not shine by its own light, but merely reflects light from the sun. Plato speaks of Anaxagoras' theory "about the moon deriving its light from the sun."[42] Later, Hippolytus wrote of Anaxagoras's belief that the "moon has a light which is not its own, but comes from the sun."[43] How Anaxagoras came to this conclusion is unknown, but it likely involved his noticing that the illuminated side of the moon was always facing the sun.

From his understanding that the moon shines by reflected light, Anaxagoras was able to deduce the cause of the phases of the moon and of eclipses, being the first person to do so. According to Plutarch, "Anaxagoras . . . held that the moon's obscurations month by month were due to its following the course of the sun by which it is illuminated, and that the eclipses of the moon were caused by its falling within the shadow of the earth, which then comes between the sun and the moon, while the eclipses of the sun were due to the interposition of the moon."[44]

He also speculated that the moon was made of ordinary matter, the same material the Earth was made from. According to Hippolytus, he believed "the moon was made of earth, and had plains and ravines on it."[45] If Diogenes Laertius is to be trusted, Anaxagoras also believed that the moon was inhabited.[46] If this is true, Anaxagoras may have been the first person to speculate about the existence of extraterrestrial life. The importance of these observations is that Anaxagoras saw the moon for what is was: a world of its own. The proof of this would have to wait until the coming of Galileo, nearly two thousand years later.

Anaxagoras believed the sun "to be a mass of red-hot metal and to be larger than the Peloponnese."[47] Although his estimate of the size of the sun was a serious understatement, the idea that the sun was a flaming object is generally correct, and certainly was a great leap forward from the view that the sun was a god on a chariot.

Diogenes Laertius, frankly, seems a little overeager to sing the praises of Anaxagoras. He claims that the scientist predicted the fall of a meteorite, but that can be dismissed as absurd. Also easily set aside is a statement by Diogenes Laertius that Anaxagoras once predicted that it would rain, since predicting rain does not necessarily make one a genius. Nevertheless, when surveying all the astronomical accomplishments of Anaxagoras, it is quite clear that his theories were a vast improvement on those of the Milesian Trinity. He was the first of the ancient Greek scientists whose observations and theories were generally correct. Diogenes Laertius clearly described the mind of a true scientist when he said, "Being asked to what end he had been born, [Anaxagoras] replied, 'To study sun and moon and heavens.'"[48]

Anaxagoras has another important place in the history of science, in that he was the first scientist in history to have been punished for a religious crime. Anaxagoras lived much of his life in Athens, where, according to Plutarch, he was close friends with the great statesman Pericles.[49] But the demagogue Cleon, who was a political enemy of Pericles, indicted Anaxagoras on charges of impiety, for holding that the sun is a red-hot stone as opposed to the god Apollo, riding across the sky in his chariot. As a result of this attack, Anaxagoras was forced to flee the city of Athens.[50]

Cleon's motivation in bringing charges against Anaxagoras was probably to strike indirectly at Pericles. After all, a good way to discredit a popular political opponent is to attack his friends. Almost certainly, it had nothing to do with religion, in and of itself. Still, this was the first historical occurrence of a scientific theory being denounced as somehow irreligious, and it began a tradition which would occur repeatedly throughout the history of science.

The fifth and final scientist to be discussed in this chapter is Democritus. He came from the city of Abdera, which lay on the northern coast of the Aegean Sea. Although not actually in Ionia, the town had been settled by Ionian Greeks, who had been driven from their homes by the Persians.[51] Thus, it is perfectly reasonable to include Democritus among the ranks of the Ionians.

Diogenes Laertius tells us that Democritus was forty years younger than Anaxagoras, whom he had the opportunity to meet (for some reason, they did not seem to get along very well).[52] From this, we can extrapolate that Democritus was born in the mid-5th Century B.C.E. Democritus was alleged to have been quite a traveler, wandering through Egypt, Ethiopia, Babylon, Persia and perhaps as far as India.[53] While this may sound implausible, other Greeks did venture out to such distant locations, so there is nothing impossible about these claims. Even if he did not actually get as far as India, Democritus probably traveled a great deal and saw much of the known world. The knowledge gained on these travels must have been extensive, and perhaps the psychological impact of seeing strange and alien people and places transformed his mind into one which could easily consider radical new ideas (an idea to which we will return).

In Democritus' time, one such radical idea was being expounded by a philosopher named Leucippus. In response to a philosophical problem laid out by the influential Parmenides of Elea, who proclaimed that nothing which actually existed could ever change, Leucippus developed a counter argument. It stated, rather oddly, that not everything which existed actually existed and that some things which did not exist actually did. In other words, nonexistence was real, and the universe was made up of bits of existence and nonexistence. Change could therefore take place because the cosmos was in a state of flux between existence and nonexistence.

Democritus was influenced by the ideas of Leucippus, but elaborated extensively on them and brought them into a more scientific format. Where Leucippus had talked about existence and nonexistence, Democritus put forward the more concrete concepts of matter and empty space. As Democritus explained it, all matter was made of small, indestructible particles called atoms; empty space was simply the absence of atoms.

According to Aristotle, "Leucippus and his associate Democritus say that the full and the empty are the elements, calling the one being and the other non-being- the full and solid being, the empty non-being (that is why they say that what is is no more than what is not, because body no more is than the void); and they make these the material causes of things."[54] In other words, everything that ever took place in the cosmos was simply the interaction between being and non-being, or, putting it another way, between matter and empty space.

The historian of science G. E. R. Lloyd provides an excellent general description of the atomic theory of Democritus.

> The atoms are infinite in number and dispersed through an infinite void. They are, moreover, in continuous motion, and their movement give rise to constant collisions between them. The effects of such collisions are two-fold. Either the atoms rebound from one another, or if the colliding atoms are hooked or barbed or their shapes otherwise correspond to one another, they cohere and thus form compound bodies. Change of all sorts is accordingly interpreted in terms of the combination and separation of atoms. The compounds thus formed possess various sensible qualities, such as colour, taste, temperature and so on, but the atoms themselves remain unaltered in substance.[55]

This image of atoms is generally correct. Atoms do collide to form larger bodies, which we call molecules, although their "hooking" together is due to electrochemical forces rather than any actual shape of the atom. Furthermore, the various compounds thus created do have various different qualities. Indeed, the different combinations of atoms formed into molecules is precisely why the chemical elements are the way they are.

The atomic theory was devised in response to a philosophical argument, but the end result was one of the greatest scientific achievements of the ancient world. But historians must be cautious about taking Democritus' accomplishment too far. He was working entirely on intuition, and brilliant as his insights were, it is probably improper to consider them in the light of modern day atomic physics. Obviously, Democritus would have found quantum mechanics and super-string theory utterly incomprehensible. Like all the other Greek scientists, we must see Democritus for what he was: the man who took the first step. Today, we know that Democritus' general idea is largely correct, but the scientific investigation into the nature of matter is far from complete and, in all likelihood, will never be truly finished.

Before the time of the Ionian Awakening, no one had tried to understand the natural world through empirical methods. All events, from thunderstorms to the changing of the seasons, were ascribed to the gods. It cannot be said that the Ionian scientists understood much more about the natural world; their theories are so riddled with error as to be laughed at by uncharitable modern scientists. But these men were the ones who first began to study the natural world from a naturalistic point of view, to attempt to explain natural phenomena through the use of empirical study. For that, every scientist that has lived since their time is in their debt.

Farrington describes the mindset of the Ionian scientists:

> Everything we know about them confirms the impression that the range of ideas and modes of thought they applied to speculation on the nature of things in general were those which they derived from their active interest in practical affairs. They were not recluses engaged in pondering upon abstract questions, they were not 'observers of nature' in an academic sense, but active practical men the novelty of whose philosophy consisted in the fact that, when they turned their minds to wondering how things worked, they did so in the light of everyday

> experience without regard to ancient myths. Their freedom from dependence on mythological explanations was due to the fact that the comparatively simple political structure of their rising towns did not impose upon them the necessity of governing by superstition, as in older empires.[56]

Thales, Anaximander, Anaximenes, Anaxagoras and Democritus were the earliest pioneers of scientific thought. Their work represents the beginning of the scientific endeavor. Having provided a general survey to their speculations, we must ask the fundamental question of this thesis: what was it about the Greeks that allowed them to develop science? To answer this question, we must examine the unique aspects of Greek culture as they existed in the time of these five men. This will be the goal of the next several chapters.

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[2]Benjamin Farrington, *Greek Science*. (Baltimore, Penguin Books, 1944), 35
[3]Lionel Casson, *The Ancient Mariners: Seafarers and Sea Fighters of the Mediterranean in Ancient Times*. (Princeton University Press, 1991), 70
[4]Casson, *The Ancient Mariners*, 71
[5]George Sarton, *A History of Science: Ancient Science through the Golden Age of Greece*. (Cambridge. Harvard University Press, 1952), 169
[6]Herodotus, *The Histories*, 1.170
[7]Plato, *Theaetetus*, 174.a
[8]Aristotle, *Politics*, 1259.a.6-19
[9]Diogenes Laertius, I.24-27
[10]Sarton, *History of Science*, 171
[11]Herodotus, 1.170
[12]Plato, *Protagoras*, 343.a
[13]Lionel Casson, *Travel in the Ancient World*. (Baltimore, Johns Hopkins University Press, 1994), 217-218
[14]Herodotus, 1.74
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[16]Huxley, *The Early Ionians*, 72
[17]Kirk et al., *The Presocratic Philosophers*, 82
[18]F. Richard Stephenson and Louay J. Fatoohi, "Thales's Prediction of a Solar Eclipse," *Journal for the History of Astronomy* 28 (1997): 279-282
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[21]G. E. R. Lloyd, *Early Greek Science*: Thales to Aristotle. (New York: W. W. Norton & Company, 1970), 9
[22]Diogenes Laertius, II.1-2
[23]Kirk et al., *The Presocratic Philosophers*, 104
[24]Sarton, *History of Science*, 173
[25]Sarton, *History of Science*, 174
[26]Sarton, *History of Science*, 174
[27]Kirk et al., *The Presocratic Philosophers*, 101
[28]Sir Thomas Heath. *Aristarchus of Samos: The Ancient Copernicus*. (New York, Dover Publications, 1981), 25
[29]Aristotle, *On the Heavens*, 296.b.10-15
[30]Kirk et al., *The Presocratic Philosophers*, 135
[31]Diogenes Laertius, II.1
[32]Kirk et al., *The Presocratic Philosophers*, 141
[33]Diogenes Laertius, II.2-4
[34]Aristotle, *Metaphysics*, 984a.5-6
[35]Diogenes Laertius, II.2-4
[36]Kirk et al., *The Presocratic Philosophers*, 145-145
[37]Huxley, *The Early Ionians*, 102
[38]Sarton, *History of Science*, 177
[39]Aristotle, *On the Heavens*, 294.b.15-16
[40]Heath, *Aristarchus of Samos*, 78
[41]Diogenes Laertius, II.6-9
[42]Plato, *Cratylus*, 409.a
[43]Heath, *Aristarchus of Samos*, 79
[44]Heath, *Aristarchus of Samos*, 79
[45]Kirk et al., *The Presocratic Philosophers*, 381
[46]Diogenes Laertius, II.6-9
[47]Diogenes Laertius, II.6-9
[48]Diogenes Laertius, II.10-12
[49]Plutarch, *Pericles*, 185
[50]Diogenes Laertius, II.10-12
[51]Huxley, *The Early Ionians*, 120
[52]Diogenes Laertius, IX.34-36
[53]Diogenes Laertius, IX.34-36
[54]Aristotle, *Metaphysics*, 985.b.5-10
[55]Lloyd, *Early Greek Science*, 46
[56]Farrington, *Greek Science*, 35-36

CHAPTER III

GREEK ECONOMICS

Having provided a general survey of the rise of Greek science, the remainder of this paper will address the particular aspects of Greek culture which contributed to that development. As the rise of science was a gradual and complicated process, it can't be looked upon as the result of any single factor. Therefore, it is fallacious to say that Greek science had a particular "cause." The development of science was the result of a multitude of cultural factors that interacted with one another in complex ways and which occurred only in Greek civilization.

The first cultural characteristic this paper shall address is the Greek economic system, which is the focus of this chapter. Firstly, it is important to appreciate the fact that Greek economics, compared to the economic complexities of the modern world, were relatively simple. Unlike the case with the more recent economic theories of mercantilism or capitalism, in which the goal is the accumulation of wealth, or socialism, in which the ostensible goal is the achievement of equality, the economies of Greek civilization were based entirely on necessity and, in the final equation, survival.

The key economic problem facing the ancient Greeks was access to the grain it needed in order to feed its population. Greece was not a country possessing much agricultural potential, for the rugged nature of the terrain resulted in there being few areas in Greece with enough space for large-scale planting. Furthermore, the high amount of limestone in the soil of Greece made the region generally infertile.[1] The only area in Greece that grew substantial amounts of grain was Thessaly, an abnormally large region with decent agricultural land.[2] While other regions also produced a small amount of grain, it is quite clear from the evidence that Greece itself could not produce enough foodstuffs to feed its growing population.

As a result, the Greek city-states were forced to import grain from overseas. The grain came from many areas of the Mediterranean, including Sicily and Egypt, but the most important source of supply for the Greeks existed in what is now the Ukraine.[3] Indeed, Athens considered the trade route from the Ukraine to the Aegean so vital that, during the darkest days of the Peloponnesian War, it was willing to risk its entire fleet to ensure the passage of grain freighters through the Dardanelles.[4]

The need to ensure a continuous supply of grain forced the city-states of Greece to maintain a sizable fleet of merchant vessels. This, in turn, created another vital commodity in the Greek economy: timber. Without timber, of course, they could not build the ships they needed in order to bring in the grain. As Greece is a land practically devoid of forests, the Greeks were forced to depend on overseas supplies of timber just as they were forced to depend on overseas supplies of grain.

H. Michell, in *The Economics of Ancient Greece*, stressed the importance of the timber trade to the Greeks.

> To Greece, whose forests had early disappeared, the supply of ship's timbers was a matter of the gravest concern. There were three articles of prime necessity in which the Greeks were not self-sufficient, slaves, grain and timber; and while we may suppose that the food supply was the most important of the three, yet we can see that adequate supplies of shipbuilding materials, especially timber, pitch, flaw and wax, were vital to their existence, and that much of the

> strategy in war was directed towards securing these necessities and keeping open the trade routes along which they moved.[5]

Thus, the economic situation of ancient Greece is fairly simple. They needed grain in order to survive and they needed timber in order to have access to the grain. They could not produce these commodities themselves and were forced to seek them from overseas sources. Obviously, the people who lived in the localities where such commodities were to be found were not going to simply give them away, so the Greeks had to develop their own commodities in order to trade for them. Greek goods such as pottery, works of bronze, olive oil and wine filled this need. The finding of Greek pottery in archeological sites all across the Mediterranean and Black Seas is a testament to the extent of Greek trade.

Another vital consequence of this system of international trade was the remarkable program of colonization the Greeks collectively undertook, lasting roughly from 750 to 550 B.C.E.[6] They ventured far from home to establish their settlements. Eventually, Greek colonies were to be found on the north and east shores of the Aegean Sea, all around the rim of the Black Sea, on the island of Cyprus, Sicily and southern Italy, and along the Mediterranean coasts of Italy, Gaul and the Iberian Peninsula.[7] Some of these Greek colonies grew to become great cities; Istanbul was originally the Greek colony of Byzantium, Marseilles the Greek colony of Massalia and Taranto the Greek colony of Tarentum.

Eventually, the bulk of Greek trade would be conducted with Greek colonies rather than with non-Greeks.[8] It should not be surprising, therefore, that many of the Greek colonies were situated in positions designed to maximize their commercial potential. The colony of Byzantium, for instance, was founded on the Bosporus, in a perfect position to take advantage of the trade route between the Black and Aegean Seas (which, as we have already seen, was a vital matter for the Greeks). Syracuse, on the eastern coast of Sicily, took over one of the finest natural harbors in the Mediterranean and was placed to take advantage of the rich trade between Sicily and the Greek homeland. The northern coast of the Black Sea, the richest source of grain, was doted with Greek settlements.

On the other hand, commerce seems to have played little or not part in the foundation of some Greek colonies. As Lionel Casson points out in *The Ancient Mariners*, many colonists were simply people who wanted to leave Greece and start their lives over in a new world, not unlike the Europeans who traveled to the Americas in the 18th and 19th centuries. "Many of the little colonies that lined the sole and instep of the book of Italy were agricultural communities purely and simply; the founders had left the old country because of hard times, to build homes in a new territory that was a land of milk and honey by comparison."[9] Population pressures in Greece, made worse by constant threat of famine if the grain trade was interrupted, doubtless contributed to the outward migration of Greeks from the homeland.

Casson summarizes the achievement of Greek colonization by saying:

> [The Greeks] founded in the neighborhood of 250 colonies, a number of which have had a continuous existence ever since. In a way, it was like administering injections of Greek culture into the body of barbarism at 250 different points. Most of them took, whether the recipients were Scyths on the shores of southern Russia, Italians in southern Italy, or Gauls at the mouth of the Rhone. In a very real sense, the boatloads of Greeks that crossed the sea in those two centuries were the advance guard of Western civilization.[10]

The result was the creation of the "Greek world," which spread far beyond Greece itself. Whereas other major civilizations, such as Egypt and Persia, were essentially land-based, Greek civilization was almost unique in that it took to the sea. Maritime commerce was far more important to the Greeks than it was to Egypt and Persia. This fact would have tremendous significance in the development of science among the Greeks, for it contributed to the intellectual growth of Greece in both direct and indirect ways.

First, and most obviously, was the fact that a maritime economy requires a highly-developed understanding of navigation, which in turns requires an understanding of astronomy. Astronomy thus served an important and practical purpose to the Greeks and it is reasonable to postulate that economic factors, rather than idle curiosity, motivated Greek thinkers to study the stars. If this is true, it is not surprising that the earliest Greek scientists came from Miletus, which was the center of Greek seaborne commerce during the time period in which science first developed among the Greeks. The astronomical work of Thales, Anaximander and Anaximenes could have begun simply out of a desire to help the sailors of the city navigate their ships.

Another direct benefit the Greek economy had on Greek science stems from the simple economic fact that the Greeks strove to develop better and better ships. Obviously, whichever city-state had possession of the fastest or safest ships, or the ships with the largest carrying capacity, would have an enormous economic advantage over all the others. As a result, shipbuilding in the Greek world continually worked with various ship designs, launching a trial-and-error process of experimentation.

Lionel Casson points out that the vessels described in Homer's poems had no decks (similar to the vessels built by the Vikings), whereas the artistic depictions of sailing ships in later centuries did have decks and fighting platforms, as well as improved prows and an overall sleeker and less wasteful design.[11] Granted, this refers to warships as opposed to merchantmen, but there is no reason to believe that the same experimentation was not being undertaken with commercial vessels. Furthermore, the same knowledge gained from experimentation with warships could easily be applied to merchantmen.

Relatively few shipwrecks from before the 4th century B.C.E. have survived, leaving us uncertain as to the precise design of merchantmen in the days of the early Greek scientists. However, judging by the progressive changes and improvements seen in wrecks dating from the 4th century to the 1st century, it seems quite clear that shipbuilders were also great experimenters. Different hull designs were used, different techniques were applied towards the fusing together of the ship planks and some shipbuilders apparently alternated between building the skeleton first and the hull second and vice versa.[12]

This experimentation with various ship designs involved innumerable trial-and-error processes stretched out over a period of centuries. It is clearly very similar to the modern scientific method and almost certainly had tremendous influence in inculcating a scientific outlook in the Greek mindset.

The Greek economic system also influenced the development of science is more subtle and less direct ways, for the Greek vessels plying their trade throughout the Mediterranean were the blood vessels of Greek civilization. But the Greeks did not establish this network of trading posts and colonies in a void; they were faced with the competition of the Phoenicians, who were probably the finest seamen in the ancient world. From their homeland on the eastern seaboard of the Mediterranean, the Phoenicians spread outward across the sea, establishing colonies in Sicily and North Africa. One of their settlements, Carthage, would eventually become one of the major powers of the ancient world, eclipsing its Phoenician founders.

The prowess of the Phoenician sailors was demonstrated by a remarkable voyage in which a Phoenician fleet circumnavigated the continent of Africa. This story comes from Herodotus. According to his account, the Phoenicians sailed southward from the Red Sea, rounded the southern cape, sailed north until they reached the Pillars of Hercules, then sailed through the Mediterranean until they reached Egypt, landing on the coast every autumn in order to grow grain.[13] Ironically, the best evidence that the voyage actually took place was the very item that Herodotus refused to believe: as the Phoenicians sailed westward around the southern tip of Africa, the sun was to their north.[14]

The Phoenicians were probably superior to the Greeks in terms of their seamanship. They set a limit to how far the Greeks could expand in the Mediterranean. Through their base at Carthage, the Phoenicians essentially sealed off the Western Mediterranean to Greek colonization. With the exception of Massalia on what is now the southern coast of France, there were no important Greek settlements to the west of Italy. Casson notes, "The west was fully open- but to Phoenicians alone. Through a wide-flung network of stations, the trade in tin from the Atlantic coast and in silver and lead and iron from Spain was firmly in [Carthage's] hands."[15] Furthermore, the Carthaginians in western Sicily made the existence of the Greek settlements on the eastern part of the island always precarious.

Despite the limits of Greek expansion enforced by the Phoenician settlements, the expanse of Greek settlements that had been created by this age of colonization was quite impressive. It provided an extensive Greek-speaking world, in which a Greek of means could wander from place to place, meeting different people, seeing different sights and experiencing different things.

The Greek trading vessels carried not only trade goods but knowledge, functioning as the "Internet" of the ancient world. Because news and rumors traveled along trade routes, the average Greek was doubtless more aware of events on the other side of the Greek world than the average Egyptian was of events taking place elsewhere in Egypt. An Egyptian might have had little news beyond that of his own village and would have had essentially no knowledge, or even basic conception, of the world outside of Egypt. But because of information transmitted across maritime trade routes, Greeks would have been aware of the entire Mediterranean world, as well as points beyond. A Greek who lived in a colony on the northern coast of the Black Sea might have been fairly well informed of events which had taken place on the west coast of Italy.

Science can only exist in an environment where information is readily available and easily exchanged. To continue the example of the preceding paragraph, the average Egyptian would have no impetus to use science as he would never encounter information regarding anything outside his immediate area. A Greek, however, might hear stories about volcanoes from Sicily and Italy, mysterious peoples from southern Russia or unusual plants and animals from southern Gaul. This information served as ingredients in the stew of Greek thought.

The maritime economy also gave a substantial number of Greeks exposure to non-Greek civilizations. Although probably a small percentage of the total population, the proportion of Greeks who traveled overseas was certainly much larger than the number of people from other societies. A Greek was much more likely to have knowledge of Egypt than an Egyptian was to have knowledge of Greece.

As was discussed in the previous chapter, among the Ionian scientists, Thales is said to have traveled to Egypt and perhaps Babylon, and Democritus was also widely-traveled, perhaps going as far afield as India. Although there is no evidence, it is possible that the other Ionian scientists traveled overseas as well.

Thales, as we have seen, was largely responsible for the introduction of geometry to the Greek world. We know that Egypt and Mesopotamia had highly developed mathematical traditions. Considering the contact Thales probably had with these civilizations, it stands to reason that his mathematical knowledge was either learned directly from them or at least heavily influenced by them. This is an obvious example of direct knowledge gained from other civilizations which was useful to the Greeks in the development of science. Although none of the civilizations in question actually developed science as we have defined it, much of their knowledge was crucial in its development among the Greeks.

The Greek maritime experience also gave rise to sea voyages of exploration. While they may not match the Phoenician circumnavigation of Africa, which has already been discussed, they were still quite impressive in and of themselves. One Greek sailor, Pytheas of Massila, undertook an astonishing voyage to northern Europe. Slipping through the Pillars of Hercules, he skirted the coasts of Spain and France, passed through the English Channel, circumnavigated Britain and perhaps reached as far north as Norway or even Iceland.[16] Some historians have speculated that the legend of Jason and the Argonauts is based upon an actual exploratory voyage to the edges of the Black Sea, which predated the Age of Colonization.[17] While such expeditions were likely motivated more by a desire to find new trade routes than anything else (just as with the European explorers of the 15th and 16th centuries), the information brought back by such explorations was doubtless of interest to those Greeks who were engaged in a scientific examination of the world in which they lived.

The information brought into Greece, both through their own experiences in other lands and information directly gained through their contact with other peoples, almost certainly exerted a strong indirect impact on the development of Greek science. To develop a scientifically-inclined mind, it is necessary for one to be faced with ideas or images that are outside of one's normal experiences. Obviously, the point of science is to explain that which has not yet been explained; if a person was never faced with anything new, he would never ask any questions because there would be nothing to explain. Because of the information constantly flowing into and through the Greek world as a result of their far-flung commerce, they were forced to confront the unexplained. This, in turn, helped create a mindset in which it was necessary to seek explanations by asking questions and attempting to answer them.

Aside from giving the Greeks access to new information, their maritime economy also indirectly contributed to science by allowing easy communication between Greek settlements. This allowed aspiring scientists in many different Greek communities to be able to keep track of what other Greek experimenters were doing through means of the information transmitted by trade routes. In the case of Thales, Anaximander and Anaximenes, this factor is of limited importance due to the fact that they all came from the same city, Miletus. However, their work and their ideas were able to be transmitted to other Greek cities and doubtless inspired the work of such figures as Anaxagoras and Democritus. Without such an extensive system of maritime trade, the communication between Greek communities would have been substantial less developed than it was, and the development of Greek science would have suffered accordingly.

Another indirect benefit to the rise of science that was provided by the Greek economic system was the urbanization of Greek society. Because the Greek economy leaned more heavily on commerce as opposed to agriculture than did the economies of most other civilizations, a smaller proportion of Greeks lived in the fields and a larger proportion of them lived in towns and cities. The historian Sir Moses Finley, in the opening words of his essay *The Ancient City*, states, "The Graeco-Roman world . . . was a world of cities. Even the agrarian population, always a majority, most often lived in communities of some kind, hamlets, villages, towns, not in isolated farm homesteads."[18]

The effects of urbanization on the development of Greek science can, in essence, be seen as a miniaturization of the effects of the Greek economy that have already been discussed, namely, making information accessible to scientifically-inclined Greeks. If a Greek scientist labored alone in a small homestead, the scientific knowledge gained through his work might have been stored in his mind alone and would have been lost upon his death. The work of a Greek scientist who lived in a city or large town, however, might have been widely known among his fellow citizens, with whom he would have interacted in the daily course of urban life.

The obvious example of this is the city of Miletus, which, as was described in the previous chapter, can fairly be called the birthplace of science. The work of Thales was widely known among his fellow citizens of Miletus, and this, in turn, spurned on the work of Anaximander. Anaximander's work, continuing the cycle, contributed to the work of Anaximenes, and so on. However, if Thales had lived on an isolated farm instead of a city, all his scientific achievements might never have been known and he never would have been able to make any serious contribution to the development of science.

The importance of a maritime economy plays in the promotion of science within a society can be illustrated by other historical examples. The first stirrings of the Scientific Revolution were seen in Renaissance Italy in the 15th and 16th Centuries. In the work of Leonardo da Vinci, Giordano Bruno and, above all, Galileo Galilei, one can see Western Europe emerging from the scientific darkness of the Middle Ages and beginning to chart its course as the world's most scientifically-advanced civilization.

Up until the discovery of the New World, of course, the Italian city-states had been Europe's most seagoing communities. Venice, in particular, was probably the greatest naval power of the age. With the possible exception of the towns of northern Germany, the Italian city-states relied more on commerce to sustain their economy than did any other Western communities. In this, they were very similar to the city-states of ancient Greece.

Another obvious example of a society in which a maritime economy correlates with scientific excellence would be the Dutch Republic during the 17th Century. The astronomer Christiaan Huygens worked to perfect the telescope and used it to discover Titan, the moon of Saturn. Cornelis Drebbel invented the microscope and thermometer. Anthonie van Leeuwenhoek discovered the existence of microorganisms and made stunning contributions to botany and anatomy.[19] The fact that this great age of Dutch science occurred during a period when the Netherlands held a virtual monopoly on merchant shipping and when Dutch sea captains were circumnavigating the globe should not be ignored.

A final example would be that of Great Britain from the late 17th Century to the early 19th Century. At the beginning of this period, Isaac Newton, widely considered the most ingenious and influence scientist in all of history, made his fundamental contributions in astronomy, physics, optics and mathematics. A little over a century later, Charles Darwin revolutionized the science of biology with his theory of natural selection. Throughout the period, the great Royal Society organized the work of literally dozens of great scientists. All of this took place during a time when Great Britain supplanted the Netherlands at the dominant commercial nation and when British ships wandered across virtual every body of water on the planet. Within the confines of British history, the intellectual explosion known as the Scottish Enlightenment, which contributed greatly to the advance of science, occurred only after the Act of Union of 1707 opened up the English maritime economy to Scottish exploitation.

The idea that a maritime economy is a necessary step can be further reinforced by negative examples. There have been major civilizations throughout history which, despite great achievements in numerous fields, do not distinguish themselves scientifically.

The most obvious example of a major civilization undistinguished by science would probably be Russia. Before the Mongol invasions of the 13th Century, none of the Russian entities, despite great achievements in art and other fields, seem to have had the slightest notion of science. Even after the Mongol yoke was thrown off, science was nonexistent in Russia for centuries. The country, of course, was largely landlocked and cut off from the outside world. It wasn't until the reign of Peter the Great, who worked to develop Russian maritime trade and open contacts to the outside world, that Russian science began to prosper. Astronomy was not seriously studied in Russia until the opening of the School of Mathematical and Navigational Sciences in 1701.[20] Since that time, Russia has made great contributions to science.

Two other examples might be China and Japan. Again, both civilizations were highly advanced in numerous fields, and China itself was a land of wonderfully ingenious mechanical inventions. Neither country, however, developed science as we have defined it. Both, it should be pointed out, worked hard to isolate themselves from the outside world and neither had a reputation as a seagoing people, despite their easy access to the sea.

But if certain nations or societies seem to experience maritime commercial success and scientific achievement at the same time, and other nations or societies seem to lack such commerce and also lack science, there are certain examples where this rule doesn't seem to apply. The outstanding maritime accomplishments of the Phoenicians have already been discussed, yet there does not seem to have been any corresponding scientific enlightenment in their culture. Similarly, Spain and Portugal gained preeminence in the maritime world during the late 15th and 16th Centuries, yet neither nation was particularly advanced in scientific terms.

If one contends that the Greek maritime experience was a crucial factor in the rise of science within their culture, and other societies are described in which scientific achievement and a commercial maritime economy seem intertwined, how can we reconcile the fact that there are obviously maritime societies which do not develop science? The answer, this historian believes, lies in the fact that there were numerous other cultural factors involved in the rise of Greek science; having the equivalent of a maritime economy is necessary but not sufficient. These other cultural characteristics will be the subject of the next few chapters.

In conclusion, an overview of the Greek economic system provides strong indications that it was vital in the development of Greek science. The desire to perfect navigation caused the Greeks to see the study of astronomy as a practical undertaking. The need for better ships resulted in a trial-and-error process of experimentation with various ship designs, clearly pushing Greek minds into developing something very similar to the modern scientific method.

The extent of Greek commerce allowed for information from many different regions to flow into the Greek intellectual current, thus destroying mental complacency and stimulating Greek thought. Greeks themselves could travel widely in a Greek-speaking world, providing further intellectual stimulation. Commercial contact with other civilizations allowed Greeks to be exposed to advanced mathematics, which was of inestimable value to them. The trading vessels served as means of communication from one Greek community to another, allowing the work of the early Greek scientists to be widely known across the Greek world. The urbanization of Greek society provided a setting in which scientific work could be shared with other citizens, rather than be carried on in isolation, thus allowing it to survive the death of a scientist by imprinting itself in the memory of others.

The evidence seems overwhelming enough to firmly state that the Greek economic system, unique in the ancient world, is one of the keys to answering the question as to the origin of Greek science. Had Greece been a land of immense agricultural productivity, or one which was landlocked, it seems logical to conclude that the Greeks would not have developed their system of maritime trade, and hence, would not have developed science.

[1]H. Michell. *The Economics of Ancient Greece.* (New York: Barnes and Noble, Inc., 1940), 45
[2]Michell, *The Economics of Ancient Greece*, 47
[3]Michell, *The Economics of Ancient Greece*, 265
[4]Casson, *The Ancient Mariners*, 95
[5]Michell, *The Economics of Ancient Greece*, 278-279
[6]Casson, *The Ancient Mariners*, 67
[7]Michell, *The Economics of Ancient Greece*, 217-218
[8]Michell, *The Economics of Ancient Greece*, 217
[9]Casson, *The Ancient Mariners*, 67
[10]Casson, *The Ancient Mariners*, 67
[11]Casson, *The Ancient Mariners*, 76-77
[12]Lionel Casson, *Ships and Seafaring in Ancient Times*, (University of Texas Press, 1996), 106
[13]Herodotus, *The Histories*, 4.42
[14]Herodotus, 4.42
[15]Casson, *The Ancient Mariners*, 66
[16]Casson, *The Ancient Mariners*, 124-126
[17]Casson, *The Ancient Mariners*, 55-60
[18]Sir Moses Finley, *Economy and Society in Ancient Greece.* (New York: The Viking Press, 1982), 3
[19]Jonathan I. Israel. *The Dutch Republic: Its Rise, Greatness and Fall.* (Oxford, Clarendon Press, 1995), 903-906

[20]Nicholas V. Riasanovsky, *A History of Russia.* (New York: Oxford University Press, 1993), 287

CHAPTER IV

GREEK POLITICS

The second aspect of Greek culture to be explored by this paper is one even more unique to the Greeks than their economic system: their unparalleled blend of political institutions and their unprecedented manner of approaching political questions. As has been repeated countless times in countless history books, our basic concepts in modern political science derive from the Greek experience. Indeed, it can be fairly said that the Greeks invented politics as surely as they invented science.

The first aspect of Greek politics with which we must concern ourselves is that fact that, throughout classical history, the Greek people were never united under a single political system. Although the Greeks shared linguistic, religious and certain other cultural ties with one another, they were grouped into a number of different city-states, which were politically independent of one another. Far from being united, the various city-states of ancient Greece were in a perpetual state of cold war, when they were not engaged in actual military hostilities.

What caused this political disunity? As with the Greek economic system, the development of the Greek political system can be largely explained by an examination of Greek geography. The geographic nature of the Greek homeland resulted in the people living there to be largely isolated from one another. Victor Ehrenberg, in his work, *The Greek State*, states it quite clearly.

> The fact that land and sea were so broken up led. . . to the erection of innumerable barriers. The land was torn in pieces by the bays, gulfs, and arms of the sea, and not less by the mountains which belong to a number of systems, created by mighty geological convulsions. Thus the Greeks area displays an interlocked pattern of land and sea, mountains and mountainous districts, plains and valleys, islands and peninsulas, and the result is a wealth of small, sharply separated regions: nature sets an example of fragmentation that was followed and even surpassed by the political world.[1]

Greek settlements grew up in these small, isolated areas, and due to the isolation imposed upon them by the barriers of nature, it logically followed that each settlement would chart its own course. This multitude of Greek settlements eventually developed in the *polis* system, about which we will have more to say later.

The fact that Greece was a politically disunited civilization was not, strictly speaking, unique. Mesopotamia, for example, was similarly divided into numerous independent city-states. The same can be said for the Phoenicians, the major competitors of the Greeks in the field of maritime commerce. Indeed, of all the major civilizations that had close contact with the Greeks, only Egypt was politically united for the majority of its existence.

By the time science began to rise in Greece (roughly between 600 and 400 B.C.E.), however, things had begun to change. A series of empires had risen in the East, culminating in the gigantic and immensely powerful Persian Empire, which had swallowed up Mesopotamia, Phoenicia, and Egypt. Although the different cultures of the East more or less survived, they had come firmly under the political thumb of the Persians.

At a certain point, the Greek world was flanked to the west by Carthage and to the east by Persia (this was, of course, prior to the rise of Rome). Among the civilized societies in the Mediterranean world, Greece existed precariously as a culturally advanced but politically divided civilization. It was at this moment in history when Greece experienced its "Golden Age," achieving great heights in art, literature, philosophy and many other fields. It also happened to be the time in which science was born, and this was hardly a coincidence

Historians have often looked upon the political disunity of the Greeks as their great disadvantage in the geopolitical struggles of the ancient world. Although the city-states did come together in an unnatural alliance to repulse the threat of the Persian Empire, they were unable to repeat this feat when faced with new threats over the next few centuries. Historian and writer Kathleen Freeman states that Greek civilization "perished because they were unable to sink their differences and combine."[2] As a result, the Greeks were eventually conquered by outsiders, first by the Macedonians and later by the Romans.

Whatever impact Greek political disunity had in terms of the political and military events of the day, in their intellectual struggle to give birth to the idea of science, it was certainly no disadvantage. Indeed, the fact that the Greek city-states were politically fragmented was one of the key elements in the rise of science. Had the Greeks coalesced into a single state or empire, it may well be that the rise of science would never have taken place.

The most obvious factor the lack of political unity played in the development of science was that it prevented any single power from exerting a suppressive influence over Greek intellectual activity. Had a single king, emperor or group of aristocrats gained political control over all of Greece, they would have then been in a position to destroy scientific progress by simply decreeing that it should not take place. Science is often a destabilizing force in society and it can easily be viewed by those in power as a threat to their positions.

This may sound implausible, but a quick glance through history shows that such events have happened with grim regularity. An example from later Greek history can be seen in the person of the Byzantine Emperor Justinian, who inflicted a death blow to Greek philosophical inquiry by closing down the famed Academy of Athens, originally founded by Plato. Justinian opposed the Academy because of its pagan beliefs, which he saw as being anti-Christian. In more recent history, during the horrific series of events known as the Lysenko Affair, the Soviet Union brutally suppressed all genetic research in its country, contending that genetic biology violated Communist ideology. The science of biology was effectively destroyed in Russia and has yet to fully recover.

These two examples describe intentional governmental policies designed to suppress certain intellectual activities, but the political divisions in Greece prevented incidental anti-intellectual attitudes from limiting scientific achievement as well. Conditions in certain Greek communities seemed to be more advantageous to science than in others. Consider that science flourished in Miletus, but was effectively nonexistent in Sparta. The militaristic way of life in Sparta, leading to an incredible level of social discipline, resulted in Spartan culture being static and uncreative; Spartans made excellent soldiers, but shoddy thinkers. Had the Spartans gained control over Greece before the rise of science (as they later did afterward, albeit briefly), their influence might have smothered science in its cradle. Unlike the two examples cited above, this would likely have not been the result of any deliberate political policy, but simply the result of cultural evolution.

By maintaining a political climate of disunity, with no power in Greece achieving complete dominance over the civilization, the Greeks were able to avoid these obstacles on the road to the establishment of science. This was obviously not their actual intention (like Darwinian evolution, cultural evolution shouldn't be viewed as having any specific objective), but simply the end result of the historical and cultural events as they played out.

It should be pointed out that the political leadership of a state can often assist science by instituting pro-science policies. The governments of Great Britain, France and the United States, beginning in the 19th Century, provided financial incentives for scientific research leading to numerous technical innovations. Today, nations subsidize scientific research in a virtually every field of science, from decoding the human genome to flying robotic probes around distant planets. This derives not only from intellectual curiosity, but also from a desire to turn the products and discoveries of science towards useful social ends.

Still, this is a historical development which has evolved only in the last few centuries, after the power and potential of science had become obvious to all observers. In the time of the Greeks, when the very notion of science was just emerging, the political leadership of the various city-states would probably not have seen it as anything worth supporting, if they noticed it at all. Furthermore, they may have seen science as potentially threatening, as many other political entities did in subsequent centuries.

Political diversity was important to the rise of science in less obvious ways, in that it facilitated the rise of the *polis* system, which was the basic institution of Greek political structure. Often, the *polis* is simply described as a "city-state," indicating that it was an independent political entity which controlled the city itself and a small amount of surrounding territory. While true, this definition is overly simplistic and masks much of what made Greeks politics unique.

The essence of what made a *polis* different from a simple city-state was the nature of the relationship between the citizens and the government. There was effectively no distinction between the political entity of the *polis* and the body of the citizens themselves; they were one and the same. Whereas a peasant in a city-state of ancient Mesopotamia would have been looked upon as belonging to that city-state, the citizens of a *polis* would have been seen as a member of the community. The *polis* belonged to its citizens as much as its citizens belonged to it (the category of "citizen" did not, of course, include slaves or women).

Ehrenberg describes the essence of the *polis*:

> The Greeks took their idea of the state as a whole not from territory and not any more or less abstract concept (*res publica*), but from the free men who sustained the state. There were no subjects. Even under a tyrant the Polis knew of no subjects in the meaning of a real monarchy. The structure of the constitution was decided by the share the citizens took in the popular assembly, in the Council and the courts. The dangers of radicalism were at least restricted by the joint efforts of these institutions.[3]

The connection between a Greek citizen and his *polis* is part of what made Greeks unique in the ancient world. According to Herodotus, when Solon was asked why a certain man was the happiest man in the world, the first reason Solon provided was that "his city was prosperous."[4] This attitude of civic connectivity had its finest expression in the legendary funeral oration given by Pericles to the citizens of Athens at the end of the first year of the Peloponnesian War. "Here each individual is interested not only in his own affairs but in the affairs of the state as well: even those who are mostly occupied with their own business are extremely well-informed on general politics- this is a peculiarity of ours: we do not say that a man who takes no interest in politics is a man who minds his own business: we say that he has no business here at all."[5]

Pericles was speaking about Athens in particular, but the same spirit of civic pride was to be found in virtually every other Greek *polis*. An attitude very similar to the nationalism of the late nineteenth and twentieth centuries developed among the Greeks in classical times. Individual citizens felt that the destiny of their *polis* and their own personal destiny were inextricably tied together. This may explain, in part, the extraordinary dynamism exhibited by Greek civilization.

The institution of the *polis* is what allowed the Greeks to develop their unique political structure. Because Greek civilization was not united under a single government, there were literally hundreds of different *poleis* scattered throughout the Greek world. Each developed on its own, with various forms of government and constitutions, and this inevitably resulted in a diverse collection of political structures. Some *poleis* were democracies, others were tyrannies (which was not necessarily considered negative), while others were ruled by aristocracies.

It might be tempting, particularly for Westerners, to assume that those Greek city-states that were democracies were the most scientifically-advanced *poleis*, but the facts do not bear this out. Miletus, the *de facto* birthplace of science, was torn by political power struggles between various factions. These conflicts lasted for two generations, and eventually the Milesians were forced to call in arbiters from the city of Paros, who apparently decided that the answer was an aristocratic government made up of the wealthiest landowners.[6] It was in this environment, rather than in a democracy, that Thales and his successors gave birth to science. Contrast that with the supposedly democratic government of Athens, which persecuted Anaxagoras for his scientific theories and forced him to flee the city.

Another misconception one might have would be to believe that science was more likely to develop and flourish in a community that had a measure of stability. It could be argued that, without the unnecessary distractions caused by political and economic troubles, people might be able to devote their attention to scientific questions. However, the opposite appears to have been the case. As described above, Miletus was a hotbed of social unrest and political upheaval, coupled with the pressures caused by rapid economic expansion. How could science have developed in such an environment? The answer lies in the fact that science apparently did not develop *in spite* of societal stress, but precisely *because of* societal stress.

To answer the question of how might societal stress contributed to the rise of science requires a careful examination of how the Greek political institutions influenced the Greek mind. Because of the unique characteristics of *poleis*, in addition to their relatively small size, individual Greeks would have been far more interested and involved in political matters than people who lived in other societies. The average peasant in Egypt would have been completely unaware of the policy matters being discussed in the court of the pharaoh; even if he was informed of them, he couldn't have done anything to influence events. In short, Greek citizens experienced the problems of their societies more directly than did those people of other civilizations.

The effect this must have had on the mind of the Greek citizen can hardly be exaggerated. The political and military struggles among the Greeks, combined with the unique aspect of civic participation in the affairs of the *polis*, presented Greeks with difficult problems and the urgent need to devise solutions for them. Ordinary citizens often found themselves directly involved in making the society function.

Greeks were so used to living with conflict and instability in their society that the very idea of prolonged peace and calm seems, to them, to have been highly unusual, perhaps even boring. A demonstration of this can be seen in the writings of Herodotus, describing the history of Gyges, King of Lydia. "Once established in power, Gyges sent a military expedition . . . and captured the citadel of Colophon. That, however, being his only act of any importance during a reign of thirty-eight years, I will pass on without further comment. . ."[7] One of the greatest historians produced by ancient Greece considered a peaceful reign of nearly four decades to have been completely irrelevant. This example helps illustrate how much Greek politics revolved around conflict and constant change.

The fact that the Greeks were surrounded by transforming events and saw themselves as direct participants in them shook their mental complacency and provided a spark which helped ignite the scientific mindset. Had Greek society resembled Asian or Egyptian societies, where little changed over long periods of time, this probably would not have taken place. Carl Sagan, the great populizer of science during the late 20th Century, expressed this view in his book, *The Demon-Haunted World.* "In those cultures lacking unfamiliar challenges, external or internal, where fundamental change is unneeded, novel ideas need not be encouraged. Indeed, heresies can be declared dangerous; thinking can be rigidified; and sanctions against impermissible ideas can be enforced- all without much harm."[8]

In examining the relationship between Greek science and Greek politics, Thales provides an interesting case study, despite how little we know about him. We can extrapolate from Aristotle's story of the olive presses, related in the first chapter of this thesis, that Thales might have been a businessman of some sort, but was certainly not wealthy (at least, not until he cornered the market on the olive presses). But in addition to being a scientist and businessman, Thales also seems to have been a politician. According to Herodotus, Thales proposed that the Ionian Greeks form a federation of city-states, thus combining their resources to combat the growing menace of the Persian Empire.[9] Unfortunately, this proposal was rejected and the Ionians were, in fact, conquered. In addition to Thales, we can see that Anaxagoras was a friend of Pericles and involved himself in the politics of Athens, which caused him a good deal of trouble.

Can it be a coincidence that two of the greatest scientists of ancient Greece also found themselves involved in politics? This historians does not think so. In ancient Greece, the necessary mindset the Greeks developed to solve their political problems was very similar to the same mindset needed for exploring scientific questions, so it shouldn't be surprising that a Greek might be both a scientist and a politician.

The essence of the scientific method is that one is faced with a particular question, examines the available evidence through observation and/or experiment, contemplates the various possibilities and through these means arrives at the most probable answer to the original question. Such a way of thinking did not develop in a void, and did not originally develop among the Greeks for scientific purposes. It was to solve the political troubles which constantly surrounded them that the Greeks developed their unique approach towards solving problems. These political troubles and the participation of Greek citizens in dealing with them stem directly from the fact that Greece was a disunited country of various political entities. Had Greece been a unified autocracy, as their neighbors were, such a mindset could hardly have developed.

In terms of how it relates to the rise of science, perhaps the most important aspect of the Greek mindset, molded by their unique political circumstances, was the belief that all problems had to be discussed and debated. In the Homeric epics or the histories of Herodotus or Thucydides, the authors spend as much time describing details of political debates and discussions as they do providing details on military engagements. From these windows into the Greek world, it becomes obvious that, among the Greeks, the ability to persuade others to one's point of view was as admirable and desirable a characteristic as being a skillful warrior.

In the *Iliad*, Phoinix, the tutor of Akhilleus, says to his student, "Still a boy, you knew nothing of war that levels men to the same testing, nothing of assembly where men become illustrious. That is why [your father] sent me, to instruct you in these matters, to be a man of eloquence and action."[10] It must be remembered that the *Iliad* was to the Greeks what the Bible was to the Christians. All Greek men were expected to look upon Akhilleus as the ideal figure to emulate. The two primary virtues Homer identified as being worthy of emulation were the ability to fight and the ability to debate. Through this Homeric lens, it can easily be seen how important the ability to discuss and debate ideas was to the ancient Greeks.

The cultivation of the art of debate created another crucial institution in the Greek political system. This was the assembly, where men would gather to argue and discuss matters of importance to the *polis*. In a democratic *polis*, such as Athens, the assembly held the reins of political power.

Assemblies usually existed even in those in *poleis* that were not purely democratic. Sparta, for example, was governed by an oligarchy, but it nevertheless had an assembly of citizens known as the Apella, which was allowed to debate the issues even though it lacked the power to decide policy.[11] Aristotle describes some oligarchies as having assemblies which are "thrown open to all," but in which the rich had fines leveled against them if they declined to attend, whereas the poor were encouraged not to take part.[12]

In any *polis*, whether or not it was a democracy, it was necessary to learn the arts of rhetoric and debate if one wanted to advance. A citizen could not simply stand up in the assembly and say, "We should do such-and-such a thing." The other members of the assembly would have forced him to provide an explanation for *why* such-and-such a thing should be done. The political atmosphere of discussion and debate, carried out in the context of the assemblies of the *poleis*, helped cultivate a mindset necessary for scientific thinking. Arbitrary answers to difficult questions were looked upon with suspicion. If a person made a claim but failed to provide sufficient evidence to back it up, the claim was rejected. Although formulated largely for political questions, this skeptical and relentlessly questioning attitude is a fundamental aspect of the scientific method.

Another consequence resulting from the Greek cultivation of debate and discussion was that it forced the Greeks to develop a certain level of tolerance for opposing viewpoints. Without a willingness to allow the voicing of differing opinions, the institution of the assembly could never have come into existence. While a Greek politician might bitterly denounce an opponent in debate, very often in quite personal and offensive ways, it does not seem to have been the practice of the Greeks to force silence upon people. It seems that this freedom of speech was not always precisely codified by law, but rather established by custom.[13]

This Greek trait has certain obvious exceptions, such as the already discussed case of Anaxagoras or the famous trial of Socrates. It also must be remembered that the ideal form of a democratic assembly was often subverted by the appearance of powerful demagogues. Still, by and large, the Greek political process allowed for various views to be voiced.

This, in turn, helped to develop another crucial aspect of the scientific method: the viewing of a problem from all possible angles and the prohibition against arbitrarily ruling in favor of any particular answer. Science cannot be undertaken in an atmosphere where only one point of view is permitted, for the heart of the scientific process is the extrapolation of theories from a body of evidence, with the theory that best fits the evidence eventually emerging triumphant. If only a single theory is allowed, the scientific process breaks down. The Greeks escaped this trap because they developed a mindset in which it was permissible to entertain opposing ideas without necessarily subscribing to them; this mindset would find its greatest expression in the dialectic constructs of Plato and Aristotle.

The ability and willingness to debate ideas was not a quality which endeared itself to the peoples of the eastern empires, had it even occurred to them. Lacking the *polis* system of the Greeks, the Eastern cultures were based on a more strictly hierarchical systems, dominated by absolute monarchies who expected the people to look upon them as gods. In such societies, one was not supposed to debate anything; one was simply supposed to do what he was told to do by his superior. Discussions and debates concerning matters of governmental or economic policy may have taken place among the king and his circle of advisors, but it certainly would never have permeated into the lives of ordinary Persians or Egyptians. This fact perhaps goes a long way toward explaining why the Greeks developed science while other civilizations did not.

To conclude, the political structure of the Greek world influenced the development of science in a multitude of ways. Their lack of political unity prevented any single power from subverting scientific work, which has taken place, intentionally and unintentionally, in other places and eras throughout history. More importantly, however, the unique institution of the *polis*, which created an enormous political diversity in the Greek world, generated a way of thinking among the Greeks that fostered the birth of scientific thought. The need and ability of Greek citizens to consider questions of political importance caused a need for them to develop critical thinking skills, which form the basis for the scientific method. Because an integral part of the *polis* was the assembly, Greeks had to develop both the skills of persuasive debate and a level of tolerance for opposing ideas, both of which constitute pillars of the scientific method.

In the previous chapter, we discussed how the Greek economic system gave the Greek world access to vast amounts of information. In this chapter, we discussed how the Greek political system, in effect, provided the mental structures of the Greek mind to allow them to properly make use of this information. In the next and final chapter, we shall see how certain aspects of the Greek worldview created an intellectual atmosphere in which scientific thought could both rise and flourish.

[1]Victor Ehrenberg. *The Greek State.* (London: Methuen & Co., Ltd., 1969), 4
[2]Kathleen Freeman. *Greek City-States.* (New York: Norton & Company, Inc., 1963), 18
[3]Ehrenberg, 88
[4]Herodotus. *The Histories.* 1.30
[5]Thucydides. *History of the Peloponnesian War.* 2.40.6-11
[6]Herodotus. 5.28-29
[7]Herodotus. 1.15
[8]Carl Sagan. *The Demon-Haunted World: Science as a Candle in the Dark.* (New York: Ballantine Books, 1996), 311
[9]Herodotus. 1.170-171
[10]Homer. *Iliad.* 9.34-39
[11]Ehrenberg, 54
[12]Aristotle, *Politics*, 1297a16-18
[13]Ehrenberg, 56

CHAPTER V

THE GREEK WORLDVIEW

Having discussed the influence of economics and politics on the development of Greek science, this thesis shall now address the third and final area of Greek culture which, this historian believes, was crucial to the development of science: the Greek worldview. In other words, this chapter will attempt to study how certain aspects of Greek religious beliefs, as well as some of the philosophical implications of those beliefs, influenced the Greek intellectual climate in such a way as to make it more open to the idea of scientific inquiry than were those of other ancient civilizations.

As is known to every schoolchild, the Greeks worshipped a large number of different divine beings: full-blown gods, demigods, spirits, nymphs and other such creatures. The de facto worship of mythical heroes such as Achilles and Agamemnon can also be included as part of the Greek religious tradition. The stories of these divine beings and heroes have been firmly planted in the Western lexicon over the course of history, but it would be a gross error to conclude that the essence of Greek religion consisted in nothing more than these myths. Indeed, Greek religion was highly complicated and possessed numerous aspects which must be understood in order to properly comprehend the role of Greek religion in shaping the rise of Greek science.

All religions obviously have traits which set them apart from one another, but Greek religion seems particularly unique among the religions of the ancient world. This dissimilarity is most clearly manifested in the area of the priesthood. Whereas many other civilizations had religious systems utterly dominated by priestly classes, Greek religion was different in that it was not controlled by priests. Although the religious practices of the Greeks involved a large number of highly complex rituals, it does not seem to have been the case that the presence of priests was vital to their being conducted.

Walter Burkert, a historian of Greek religion, described the role of Greek priests:

> Greek religion might almost be called a religion without priests: there is no priestly class as a closed group with fixed traditions, education, initiation, and hierarchy . . . The god in principle admits anyone, as long as he respects the *nomos*, that is, as long as he is willing to fit into the local community; for this reason, of course, role distinctions between strangers and citizens, slaves and freemen, children and adults, women and men, are all important at times. Herodotus records with amazement that the Persians must call on a Magus for every sacrifice; among the Greeks, sacrifice can be performed by anyone who is possessed of the desire and the means, including housewives and slaves. The tradition of rites and myths is easily learned through imitation and participation; much can even be acquired of the specialist arts of the seer simply through observation.[1]

Priests were certainly not irrelevant in Greek religion. The inner chambers of the highly influential Oracle at Delphi, for example, were off limits to everyone excepts the priests of Apollo.[2] But the role played in Greek society by the priestly class was utterly dwarfed by the role played by priests in other ancient civilizations, such as Egypt and Mesopotamia. For example, as historian Chester Starr pointed out when discussing the city-states of early Mesopotamia, "[T]he priests who clustered around [the] temples were so important that one may almost call an early Sumerian city-state a theocracy."[3] In Egypt, priests served as the Pharaoh's direct religious representatives to the people, which, considering that the Pharaoh was held up to be a god, gave them enormous political and social influence.[4]

The fact that Greek religion was not controlled by priests to the same extent as earlier religions had crucially important ramifications to the development of Greek science. History shows numerous examples of societies in which priestly classes gain such a level of control over a society that they are placed in a position from which they could hinder or halt various avenues of intellectual speculation. It has always been an unfortunate aspect of human nature for individuals or groups to jealously guard their own positions of power at the expense of other individuals or groups. Priestly classes in the ancient world felt it necessary to stifle various intellectual currents in order to maintain their positions

The most obvious example of this can be seen in the astronomical work of the priestly class of Babylon. Although they lacked the theoretical and empirical attitudes of the Greeks, Babylonian priests conducted brilliant work in the field of observational astronomy. But the obsessive need of the Babylonian priests to maintain their privileged positions insured that they would keep their astronomical knowledge a secret and not allow it to be transmitted to the society as a whole, thus strangling the seed of science in its cradle. As discussed earlier, one of the key aspects of Greek culture which benefited science was the free exchange of ideas across many levels of society. This was obviously not a characteristic of Babylonian culture, and this contributed to the failure of science to develop in Babylon. Had Thales and his successors held powerful positions in their society, the perpetuation of which required that they keep their scientific work secret, Greek science would undoubtedly have perished in its infancy as well. One wonders whether or not the scientific method might have taken root in ancient Babylon had the priests openly and eagerly shared their astronomical work with the rest of society.

The case of the Babylonian astronomers is one involving the priestly class of a society keeping proto-scientific ideas a secret because they relied on such knowledge to maintain their positions. Other priestly classes in other societies have effectively stifled scientific work altogether, because their positions of power depended on their particular theological beliefs being the anchor of the intellectual currents of their society. In such cases, a scientific attitude of skepticism and empiricism is dangerously threatening.

One obvious example of this type of social phenomena can be found in the civilization of medieval Christendom. In that civilization, the priestly classes not only dominated the intellectual areas of society, but also possessed enormous political and social power as well. During this time period, science found its importance diminished in the West, as the great intellects of the day turned their attention to theology and no longer considered empirical ways of thinking particularly useful. For centuries after the fall of the Roman Empire, there was not a single scientific discovery of any particular importance in Europe.

However, we must again guard against confusing causation with correlation. There were a number of factors aside from a powerful priesthood which might account for the decline of science in medieval Europe. One possibility was the general breakdown of the economic system caused by the rise of feudalism, which resulted in a degradation of transportation and communication throughout Europe.

As the intellectual stagnation of the early Middle Ages came to an end, it was largely the work of such brilliant Catholic thinkers as St. Thomas Aquinas and St. Francis of Assisi who rejuvenated intellectual pursuits. Even more telling is the fact that many of the early pioneers of the Scientific Revolution, such as Nicholas Copernicus and

Johannes Kepler, were either clergymen themselves or were trained in theological schools. If the decline of science in medieval Christendom can be even partially attributed to a powerful priestly class, the later Middle Ages provides an example of how the priestly class can reinvigorate scientific thought.

Another historical example of the relationship between science and religion can be found in the medieval Islamic world. Islam is clearly a religion in which the clergy have a comparatively smaller level of influence than is the case in Christianity. During the early Middle Ages, while Europe slumped into an intellectually stagnant period, science experienced a brief golden age among Muslim scholars, who translated much of the scientific work of the ancient Greeks into Arabic. Scientific thinking flourished in the great institutes of learning in Baghdad and Cordoba. This golden age did not last, however, for Islam gradually became more radicalized and Islamic science faded away into nothingness. Still, it is worth considering the possibility that Islamic science would not have experienced its brief flowering at all had it been dominated by a politically powerful clergy.

In the modern Western world, the gradual separation of religious and secular authority has allowed religion and science to flourish easily side-by-side. Today, this can be seen most clearly in the case of the United States, which is at the same time the most religious and the most scientifically advanced nation in the West. In the opinion of this historian, there is no necessary conflict between science and religion. It seems quite clear that, so long as religion does not infringe upon the intellectual fields of science, they can peacefully coexist. But if religion attempts to encroach upon science, as it did regarding the heliocentric and evolutionary theories during the Scientific Revolution, the effects will be harmful to both institutions.

These historical examples show persuasive if not entirely convincing evidence that religions which contain powerful and highly institutionalized priesthoods are liable to stifle scientific thinking. Cultural evolution gave the Greeks a religion in which the priests had comparatively little power and influence, and the Greeks thus avoided a cultural obstacle which could have seriously hindered the development of Greek science.

In an earlier chapter, we discussed a single example of religion and science coming into conflict in ancient Greece. It happened when Anaxagoras, contending that the sun was a red-hot stone and that the moon was made of rocky matter, was denounced by the Athenian politician Cleon for impiety. But it is a telling fact that no priest was involved in this affair. Cleon's motive in attacking Anaxagoras was almost certainly to strike at Pericles, who was Anaxagoras' friend and Cleon's enemy. The attack on Anaxagoras was cloaked in religion but actually had its roots in a political struggle. The religious denouncement of Anaxagoras was a highly unusual event and should be viewed as a cultural fluke rather than as an example of a general tension between scientific thinkers and the religious establishment.

Aside from the institutional particulars of Greek religion, the theological attitudes fostered by their particular beliefs also had a tremendous effect on the development of science. Indeed, it may well be that this cultural item was the crucial element in the Greek mindset that allowed them to cultivate a scientific mode of thinking, more important even than the economic and political factors which have been discussed in previous chapters.

In the great monotheistic religions of Judaism, Christianity and Islam, the object of worship is God (or, at least, some manifestation of God). In these religions, God is seen as being an all-powerful deity, the quintessential Supreme Being, utterly above and unlike human beings. This is the religious outlook that has largely shaped Western civilization for the last two thousand years, so it is sometimes difficult for Westerners to fully grasp the religious attitudes of the ancient Greeks, which were so completely different.

The gods of the ancient Greeks often seem hardly different from human beings, except that they are more powerful than humans and, if anything, are less inclined towards morality. Burkert points out this fact when describing the gods of the Homeric poems:

> The easy living gods are a foil to the mortals. As the first consequences of Achilles' wraith appear, there answers from Olympus the inextinguishable Homeric laughter of the blessed gods; as the battle around the Achaean camp nears its highest pitch, Hera decides to seduce the father of gods and men and send him to sleep; as Achilles takes fearful vengeance for Patroclus, the gods also join battle with one another, but this is no more than a harmless farce.[5]

To be sure, the Greeks worshipped their gods and hoped for divine assistance in life, but judging from the presentation of the gods in the works of Homer, they certainly did not view them with the same awestruck respect and devotion with which Jews, Christians and Muslims look upon their deity. The twentieth century philosopher Bertrand Russell, in *A History of Western Philosophy*, also notes this phenomena:

> It must be admitted that religion, in Homer, is not very religious. The gods are completely human, differing from men only in being immortal and possessing superhuman powers. Morally, there is nothing to be said for them, and it is difficult to see how they can have inspired much awe. In some passages . . . they are treated with Voltairean irreverence."[6]

But Russell also notes an important aspect of religion in Homer, which he goes on to describe:

> Such genuine religious feeling as is to be found in Homer is less concerned with the gods of Olympus than with more shadowy beings such as Fate or Necessity or Destiny, to whom even Zeus is subject. Fate exercised a great influence on all Greek thought, and perhaps was one of the sources from which science derived the belief in natural law."[7]

In regards to how Greek religion relates to Greek science, this is a vital point. Indeed, it may well be the decisive peculiarity of Greek culture that allowed them to develop a scientific mindset. In Greek religion, the gods were not omnipotent; there were things which even they could not do. Whatever governed the cosmos governed the immortals as surely as the mortals. Russell refers to this as "natural law," which is perhaps misleading, given the term's connection to political philosophy. A better way to express what Russell meant would be to refer to "laws of nature." In other words, by holding up such impersonal concepts as Fate and Destiny, the Greeks marked out their belief that the universe was governed by unvarying laws which could not be violated. This view of the universe is the iron anchor upon which scientific thought is based.

By instinctively grasping the concept of laws of nature, the Greeks gained a tremendous advantage on the road to developing science. Clearly, if the people of a society did not comprehend that there were such laws governing the universe, there would obviously be no inclination to discover them. One would have simply concluded that he lived in a universe where anything was possible and nothing was predictable; why, then, try to predict anything? But this particular aspect of Greek religion gave the Greeks a mental concept of *impossibility*. In other words, the Greeks comprehended that they lived in a universe where certain events simply could not take place, because they were prohibited by the laws of nature. Because of this, the universe was permeable to human understanding.

It may be constructive to look at certain aspects of Eastern religions such as Confucianism, Jainism and Buddhism, although this historian admits to a slight deficiency of knowledge concerning them. In such religions, the object that is worthy of worship is not anything particularly divine, but instead is a certain code of ethics and behavior. Even Hinduism, despite its myths and its impressive pantheon of gods, seems mostly concerned with the concept of *dharma*, which can be translated roughly as "duty," "good conduct," or "decency."[8]

In essence, the followers of these religions do not seem overly concerned with whatever forces are controlling the universe. While this particularity may allow such societies to avoid potential conflicts between science and religion, it would also reduce the impetus for science, because the intellectual climates of such societies would be such that they would not fully comprehend the idea of laws of nature and would therefore not set out to discover them.

The Greeks understood the existence of laws of nature and believed them to be independent of divine intervention. With that comprehension, the Greeks could and did set out to discover what these laws were and to use them to explain the world they saw around them. No other civilization before them had attempted such a thing.

An example of this phenomena can be seen in the efforts of the Milesian scientists to discover what is was that held the Earth up. As we have already discussed, Thales believed the Earth was held up by water, Anaximander believed the Earth was stable at the center of the universe and thus did not need to be held up, while

Anaximenes believed the Earth was somehow held up by compressed air. But why should these Greek thinkers have thought that they needed to explain why the Earth was stable in the first place? No one else had ever bothered to ask such a question before. The likely answer is that they had observed that heavy objects had a tendency to fall and it therefore stood to reason, considering the existence of laws of nature, that the Earth should do likewise. Because it did not fall, they needed to explain why it did not, using their rudimentary understanding of the laws of nature to do so.

As in most other cases, the conclusions reached by the Greek thinkers in this case were completely wrong. Indeed, the question of why the Earth is stable is meaningless, as we now know the Earth is not stable but is always falling in the gravitational field of the Sun. The important conclusion to draw from such activities on the part of the Greek scientists is their instinctive grasp of the laws of nature, which largely seem to have derived from the peculiar religious beliefs of their people.

Beyond the scientists themselves, this train of thought was taken up by some of the most brilliant philosophical minds in the Greek world, chief among them being the great Heraclitus. Heraclitus was thought to have been active around 500 B.C.E.[9] This would have placed him within the time frame during which the Ionian scientists were thriving. As such, his philosophical ideas concerning the nature of the cosmos, which are brilliant if somewhat difficult to understand, are helpful in revealing certain aspects of the Greek worldview during this time.

Much of the thought of Heraclitus seems confusing and contradictory; it was not for nothing that the Greeks referred to him as "the obscure."[10] Aristotle seems to have grouped him together with the Ionian scientists, saying that he believed the fundamental substance of the universe was fire.[11] This is similar to the statement of Thales that the fundamental substance was water and the belief of Anaximenes that the fundamental substance was air. He also valued the knowledge gained through the empirical senses, saying, "Whatever comes from sight, hearing, learning from experience: this I prefer."[12] Furthermore, despite the fact that he criticized a great many other Greek thinkers, sometimes with intense bitterness, he never attacked any members of the Milesian school.[13]

Still, Heraclitus cannot be seen as a scientist in the same sense as the five Ionian thinkers discussed in the first chapter. There does not seem to be any evidence that he seriously investigated nature in anything resembling a systematic fashion, nor does he seem to have put forward any testable scientific theories. Despite his possible leanings towards empiricism, the majority of his thought seems to have been devoted to subjects more akin to metaphysics and theology than to science.

Nevertheless, some of the ideas of Heraclitus expressed aspects of the Greek worldview that are highly relevant to the development of science. One of the central fulcrums of his thinking was the belief that the cosmos was pervaded by some sort of universal source of understanding, which he termed the *logos*. Heraclitus described the *logos* by saying it was, "The ordering, the same for all, no god nor man has made, but it ever was and is and will be: fire everlasting, kindled in measures and in measure going out."[14]

It is difficult to understand exactly what Heraclitus meant by the term "fire everlasting." But it seems perfectly clear that he saw the *logos* as the governing force in the cosmos. For his personal religion, the *logos*, rather than the gods, was a concept worthy of being worshipped. Incidentally, if scientists hold the same attitude towards the laws of nature as Heraclitus did towards the *logos,* it might explain the modern social phenomena of scientists, as a class, being less religious than the population as a whole.

If one sees Heraclitus' concept of the *logos* as analogous to the idea of laws of nature, which does not seem to be a very large leap, the connection between science and that manifestation of the Greek worldview represented by Heraclitus is easily seen. The laws of nature represent the fundamental forces which govern the universe and science can be understood as a quest to discover those laws. Thus the philosophy of Heraclitus, while certainly not directly correlative to the scientific method, represents the philosophical justification for the scientific endeavor itself: there is a force governing the universe which we can discover through the use of our minds.

It is perhaps a stretch, but it might be said that Heraclitus' concept of the *logos* represents the earliest human perception of what has been termed the Unified Field Theory, a thus far undiscovered equation which would encompass all the elemental forces of the cosmos, combining gravity, electromagnetism and nuclear forces into a single basic force. The search for the Unified Field Theory is the "Holy Grail" of modern theoretical physics, often referred to by physicists, unjokingly, as the "Theory of Everything."

To sum up the arguments of this section of the thesis, the Greek religious and philosophical worldview influenced Greek civilization in such a way as to make it much more open to scientific ways of thinking. Greek religion evolved in such a way that, unlike the religions of most other civilizations, a strong priestly class never developed in Greece. Because of this unique quality, there existed no force in Greek society which had a vested interest in preventing new ways of thinking to develop or in keeping newly-developed knowledge in their own hands. Thus the Greeks were able to avoid some of the intellectual pitfalls which helped prevent science from becoming establishing in other societies.

More important, however, was the role the Greek religious and philosophical view of the world affected the Greek mindset. The Greek religious tradition viewed the universe not as being controlled by deities but as being governed by higher forces to which even the gods were subject. The idea of implacable and unchanging laws of nature allowed the Greek thinkers to visualize a cosmos which could be understood by human reason; one only needed to discover what the laws of nature were in order to figure out how the cosmos worked. The concept of the *logos*, as devised by Heraclitus, is the best reflection of this attitude. The realization that the universe is governed by laws of nature not only gave the Greeks a motivation to study nature, but the philosophical grounding with which to do so.

[1]Walter Burkert, *Greek Religion.* (Cambridge, Harvard University Press, 1985), 95
[2]P. E. Easterling and J. V. Muir, *Greek Religion and Society* (Cambridge, Cambridge University Press, 1985), 95
[3]Chester G. Starr, *A History of the Ancient World.* (New York, Oxford University Press, 1983), 38
[4]B. G. Trigger and others, *Ancient Egypt: A Social History* (Cambridge, Cambridge University Press, 1983), 303
[5]Burkert, 122
[6]Bertrand Russell. *A History of Western Philosophy.* (New York: Simon & Schuster, 1945; reprint, 1972), 11
[7]Ibid.
[8]John Keay, *India: A History.* (New York: Grove Press, 2000), 95
[9]Edward Hussey, "Heraclitus," in *The Cambridge Companion to Early Greek Philosophy*, ed. A. A. Long (Cambridge University Press, 1999), 88
[10]Hussey, 88
[11]Aristotle, *Metaphysics*, 984a6
[12]Charles H. Kahn, *The Art and Thought of Heraclitus: An Edition of the Fragments*

with Translation and Commentary. (Cambridge, Cambridge University Press, 1979), 35
[13]Hussey, 89
[14]Kahn, 45

CHAPTER VI

CONCLUSION

As our modern civilization is dominated by science, it stands to reason that the development of science is one of the most important events in all of human history. In the modern historical profession, the study of science as an impacting force on human society has been strangely overlooked. This thesis was an attempt to contribute to the rectification of that shortcoming.

The central point of this thesis was the idea that Greek civilization possessed a combination of cultural characteristics, unique in the history of the ancient world, which allowed it to develop science while so many other civilizations did not. A thesis on a subject of this magnitude can, at best, be a general overview. This historian has attempted to provide such an overview in this paper. This conclusion will provide a brief summary of the arguments put forward in this thesis.

The Greek economic system, due to the fact that the Greek homeland was not agriculturally self-sufficient, was forced to become an economy based on maritime trade and overseas colonization. This directly impacted Greek science by forcing them to study astronomy so as to understand nautical navigation. Furthermore, the trial-and-error process of developing better ships helped inculcate an experimental pattern of thinking, contributing towards making the Greek mind more open to the scientific method.

More indirectly, the Greek economy facilitated science by opening the world up to the Greeks, so that the Greeks became more knowledgeable about their world than were the peoples of other civilizations. The wide-ranging travels of the Greeks, including at least some of the early scientists themselves, brought a flood of information to the Greek homeland, forcing them to ask questions about their surroundings and further stimulating the Greek intellectual mind. The maritime connections among Greek communities also contributing to an ease of communication in the Greek world, which is a necessary prerequisite for any society undertaking scientific work. The Greeke economic system also contributed to the urbanization of Greek society, which facilitated science by bringing the scientific thinkers into closer proximity to one another.

The influence of economics on Greek science can be easily seen in the city where the earliest scientific work was done. Miletus, during the time of Thales, Anaximander and Anaximenes, was the preeminent economic power of the Greek world. Doubtless its people carefully studied the stars in order to navigate their ships and tinkered with various designs of vessels in order to gain an advantage over their commercial rivals. Its traders brought back information from the whole of the Mediterranean, stimulating the minds of its citizens. Its urbanized nature allowed Thales to influence Anaximander and perhaps Anaximander to influence Anaximenes. Had Miletus been an economic backwater, science could never have developed there.

The political aspects of Greek culture also exerted a powerful influence on the development of Greek science. The politically-disunited nature of the Greek world ensured that no single political entity would ever be in a position to stifle the intellectual progress of the Greeks, as has unfortunately happened to other societies throughout history. The unique nature of the *polis* allowed the Greeks to develop in an environment where the expression of differing points of view was encouraged, or at least not repressed to the extent that happened elsewhere.

The institution of the assembly contributed to the development of the Greek mind by encouraging the discussion of ideas and persuasion through means of argument. One of the great attributes of the ideal Greek man, as seen in the Homeric epics, was the ability to persuade others to one's own point of view. Tolerance for dissenting opinions and persuasion through rational debate are at the heart of the modern scientific method.

The Greek religion also contributed to the development of science. Because the Greeks lacked a politically-oriented priesthood, the Greeks scientists never faced an intellectual elite who had a vested interest in hampering their work. This stood in contrast to the societies of Egypt and Babylon, which were theocracies in which the priests had a stranglehold on intellectual thought.

Greek religion further assisted the rise of science through its influence on the Greek philosophical worldview. Because the religious tenets of the Greeks taught that the universe was governed by implacable and impersonal forces, the Greek mind was able to divine that the universe is controlled by laws of nature. Greek thinkers were thus motivated to discover what those laws were, and that quest is the very heart and soul of the scientific endeavor.

This combination of cultural qualities was unique to Greece. Other civilizations had one or more of these aspects of culture, but not a single other one shared them all. The Phoenicians shared with the Greeks many aspects of their economic system, but were politically and religious quite distinct. The Roman religion was very similar to that of the Greeks, but the Romans generally avoided maritime undertakings and the Roman political structure eventually consolidated into an autocratic empire. The peculiarity of Greek culture was to be found nowhere else but Greece.

The counterfactuals the mind conjures up concerning this remarkable period of history are immense and fascinating. If the amount of limestone in the soil of Greece had not been so high, perhaps Greece would have been agriculturally more productive and would have turned to maritime commerce to such a great extent. If one of the Greek city-states had achieved control over the rest of the country early in Greek history, perhaps the subsequent lack of political discourse would have stifled the development of rational debate. If Greece had evolved into a theocracy ruled by priests, perhaps the scientific knowledge would have been monopolized as a state secret. Any of these events would have destroyed Greek science. The development of science in Greece was an unlikely happening and could have been derailed at innumerable points in Greek history.

The development of science in ancient Greece was one of the most important events in all of human history. Thales, Anaximander, Anaximenes, Anaxagoras and Democritus were the first scientists, but they would not be the last. In the centuries which passed after these men had lived and worked, Aristotle brilliantly systematized all that was known about the natural world in his time, setting out ideas that would dominate Western thinking for two thousand years. Aristarchus of Samos correctly concluded that the Earth was a planet moving around the sun. Dozens of scientists worked for centuries in the legendary Library of Alexandria. Eratosthenes correctly calculated the size of the Earth, Euclid established the principles of geometry, Archimedes knocked on the very doors of calculus, and Heron developed steam engines. Perhaps most telling is the fact that when Alexander the Great, that powerful proselytizer of Greek culture, invaded Asia, he took with him what amounted to a mobile academy of scientists. According to Alexander's biographer Peter Green, "His team included architects and geographers, botanists, astronomers, mathematicians and zoologists. All scientific knowledge of the East, for centuries to come, depended, ultimately, on the accumulated information they brought back with them."[1]

If one is concerned only with the accuracy of the scientific work undertaken by the Greek thinkers, comparing the work of the later Greek scientists to the work of the early Ionians is like comparing a forest fire to a match flame. But every forest fire needs an initial spark, and that was the gift of the Ionian scientists to the Greek thinkers who came after them. Without Thales, Anaximander, Anaximenes, Anaxagoras and Democritus, the later Greek scientists would have had nothing with which to start.

Centuries after the golden age of Greek science, the work done by the ancient thinkers would greatly impact the Scientific Revolution of the 16th and 17th centuries. It was largely the rediscovery of Greek science which later launched Scientific Revolution, upon which our modern civilization is based. Hence, indirect though it was, the influence of the Ionian scientists upon the modern world is so profound as to defy easy calculation. Few can argue that, were it not for a few rather clever men wandering the waterfronts of Miletus and other Ionian towns, the world would today would be a completely different place, and if this historian may be forgiven by the reader for a moment of personal speculation, probably a world much for the worse.

[1]Peter Green, *Alexander of Macedon, 356-323 B.C.*, (Berkeley, University of California Press, 1991), 161

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