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Ancient Egypt to Plato

THE PRELITERATE BEGINNINGS

Natural philosophy began with no name to designate it, and in its embryonic phase it included just about anything relevant to nature. Until the time of Aristotle, who shaped the discipline of natural philosophy for the following two thousand years, the study of nature may be said to have embraced all inquiries and questions about the physical world. On what is such a claim based? Surely it is not based on anything said or recorded. But we may reasonably interpret the earliest form of natural philosophy as embracing "all inquiries about the physical world" because we have no reason not to do so. Natural philosophy may be said to have begun with the first efforts to understand the world by the earliest human beings in their fight for survival. Thus, it extends to preliterate societies, which, for thousands of years, amassed knowledge about the world, which they passed on to subsequent generations.

Members of preliterate societies learned by empirical methods about the habits of this or that animal, or this or that plant, or devised explanations, either magical or natural, about this or that individual natural phenomenon. They must have gleaned knowledge about nature from hunting and from the earliest kinds of agriculture in which they engaged. "But to have the idea of the nature of some particular object is not to have the general conception of a *domain of nature* encompassing all natural phenomena."[1] The idea of a "*domain of nature* encompassing all natural phenomena" was probably not arrived at, or invented, by the Greeks.[2] Nature was not invented. It was a given. The first humans must have been aware of nature, which was all around them and which was involved in everything they did. What the Greeks seem to have invented were instructive ways of talking about nature. They consciously pursued ways of studying and explaining the nature that surrounded them and in which they were immersed. But long before the Greeks, the ancient civilizations of Egypt and Mesopotamia learned much about nature and its actions.

[1] From G. E. R. Lloyd, "The Invention of Nature," in G. E. R. Lloyd, *Methods and Problems in Greek Science* (Cambridge: Cambridge University Press, 1991), 418.
[2] As Lloyd would have it in his article cited in the preceding note.

ANCIENT EGYPT AND MESOPOTAMIA

The first written evidence of anything that we might appropriately characterize as natural philosophy appears in the two great contemporaneous river-valley civilizations of Egypt and Mesopotamia, commencing sometime around 3500 to 3000 BC. Because each of the two civilizations developed their own form of writing – hieroglyphics for the Egyptians, who wrote on papyrus and on tomb walls and monuments, and cuneiform or wedge-shaped characters for the Mesopotamians, who wrote on clay – they left written records that modern scholars have deciphered. The surviving literature reveals a great emphasis on mythology and religion as the means of explaining the creation of the world and its operations. There is also a rather practical interest in the physical world that manifested itself primarily in the areas of astronomy, mathematics, and medicine.[3]

In his splendid multivolume work on Egyptian science, Marshall Clagett explains that what passed for natural philosophy among the ancient Egyptians was never distinct from religion and magic.[4] It is not surprising that in ancient Egypt and Mesopotamia, the initial interest in anything resembling a physical question was focused on how the world came to be. It is here where religion, myth, magic, and gross observation fused together to provide a variety of answers to perplexing questions. The idea of creation from nothing (*ex nihilo*) did not occur in the ancient world until the rise of Christianity. Before that, it was always assumed that the world came out of something. The Egyptians, for example, assumed that the world was created out of Nun, who was regarded as the primitive waters, or abyss, out of which things emerged. Out of Nun came a variety of creator gods, for example, the sun, or Ptah, or a cluster of gods called the primitive Eight (the Ogdoad). Before they could create anything, however, they had first to create themselves.[5]

A version of Babylonian creation myths appears in the *Enuma Elish*, which has striking similarities to the first two chapters of the Book of Genesis.[6] It

[3] Accounts of Egyptian and Mesopotamian science can be found in George Sarton, *A History of Science: Ancient Science through the Golden Age of Greece* (Cambridge, MA: Harvard University Press, 1952), chs. 2–3, 19–99; Marshall Clagett, *Greek Science in Antiquity* (London: Abelard-Schuman, 1957), ch. 1, 3–20. For a briefer presentation, see David C. Lindberg, *The Beginnings of Western Science: The European Scientific Tradition in Philosophical, Religious, and Institutional Context, 600 B.C. to A.D. 1450* (Chicago: University of Chicago Press 1997), ch. 1, 13–20.

[4] Marshall Clagett, *Ancient Egyptian Science: A Source Book*, 3 vols. (Philadelphia: American Philosophical Society, 1989–1999), vol. 1, tome 1, ch. 2 ("The World and Its Creation: Cosmogony and Cosmology"), 263.

[5] See Clagett, *Ancient Egyptian Science*, vol. 1, tome 1, 264–265.

[6] On the Enuma Elish, I follow the translation and summary account in Alexander Heidel, *The Babylonian Genesis: The Story of Creation*, second edition (Chicago: University of Chicago Press, 1951).

tells of the relations between the gods before the creation of the world. It describes the time when only Apsû, the primeval sweet-water ocean, and Ti'âmat, the saltwater ocean, existed along with their son, Mummu, who seems to represent "the mist rising from the two bodies of water and hovering over them."[7] After an unknown time, the god Ea and the goddess Damki[na] produced a child, Marduk, who would eventually become "the wisest of the gods."[8] Indeed, so beloved was he that many of his fellow gods made him the supreme god in the pantheon. His rival was Ti'âmat, who was thought to be invincible. In an epic showdown battle, Marduk killed Ti'âmat and then split her immense body in two, using one-half of her corpse to fashion the sky, and used the other half to make the earth.[9] Thus was our world created.

Egyptians and Mesopotamians viewed the world as a place where magic was essential for survival. It was used to explain virtually all phenomena that we would regard as natural. This is nowhere better exemplified than in medicine, where the diagnosis and treatment of internal ailments relied heavily on magic. For obvious reasons, medicine is probably the first discipline to be developed by any people. But Egyptian medicine is the first to have left a written legacy in the form of seven or more papyri documents that convey a good idea of the level of their medical knowledge. Among these, the most important are the documents known as the Ebers and Smith papyri, which probably date from the seventeenth and sixteenth centuries BC but reflect knowledge and practices that were in use centuries earlier.[10] The Ebers papyrus, approximately five times larger than the Smith papyrus, was composed as a guide for physicians. The Egyptians believed that internal ailments were caused by the presence of demons in the body. To restore the body to health, it was essential to drive the demon from the body or to drive out the poisons it may have injected into the body. To do this, Egyptian physicians usually recited threatening spells and incantations against the demons and used amulets and other efficacious objects to protect the patient. They also used drugs and medicines, some of which proved helpful over time. It was, indeed, in the domain of drugs and medicines that Egyptian physicians acquired a reputation in the ancient world.

In the treatment of internal ailments, Mesopotamian medicine was similar to that of the Egyptians, relying on spells and incantations to cure the patient. But the Egyptians produced one medical text that far exceeds all the medical texts of Mesopotamia. The Edwin Smith Surgical Papyrus is an extraordinary medical treatise. It includes forty-eight cases, which are all about wounds to the body. Although incomplete, the forty-eight cases were organized from head to toe, but the last case extends only to the spinal column, where the

[7] Heidel, ibid., 3. [8] Ibid., 5. [9] Ibid., 8–9.

[10] For brief, but lucid, descriptions of the Ebers and Smith papyri, see Sarton, *A History of Science*, 44–48, and Clagett, *Greek Science in Antiquity*, 6–9.

treatise terminates. Each of the forty-eight cases is subdivided systematically into five parts as follows:

1. Title of case.
2. Examination.
3. Diagnosis and opinion.
4. Treatment.
5. Glosses to explain possible obscure terminology.

Because the wounds were easily observable, the Smith papyrus had little recourse to magic, although it is not wholly devoid of it. The cases bore titles of the following kind:

Case 4: "Instructions concerning the gaping wound in his head, penetrating to the bone, and splitting his skull."
Case 6: "Instructions concerning a gaping wound in his head, penetrating to the bone, smashing his skull, and rending open the brain of his skull."[11]

In thirteen of the forty-eight cases – including Case 6 – the author warns that they are untreatable. Although there is no evidence that the Egyptian practice of mummification added anything to their knowledge of anatomy, the Smith papyrus reveals a high level of knowledge and understanding. The forty-eight cases range from the head to the spinal column. Most cases involve broken bones, each of which is systematically investigated. The Smith papyrus also includes mention of the pulse, as well as the first extant attempt to describe the brain. In thirteen of the forty-eight cases, physicians are advised not to treat the wounds because they are inevitably fatal.[12] The Smith papyrus, and to a lesser extent the Ebers papyrus, give us a very favorable idea of the medicine, anatomy, and physiology of the Egyptians, and of the scientific outlook they had obtained at least two thousand years before Hippocrates.[13]

If the ancient Egyptians showed a greater aptitude for medicine than did their Mesopotamian contemporaries, there is little doubt that the Mesopotamians were superior to their Egyptian contemporaries in astronomy and mathematics.

Great strides were made in astronomy. Although the Egyptians devised a solar calendar in which the year was divided into three parts of four months each, their most significant achievement was a civil calendar of exactly 365 days formulated sometime around 2900 BC. The civil calendar was not based on any astronomical phenomena; nor, indeed, did it have any

[11] Sarton, *A History of Science*, 46. For the English translation of Case 6, see Clagett, *Greek Science in Antiquity*, 8–9.
[12] Clagett, *Greek Science in Antiquity*, 7–8.
[13] Sarton, *A History of Science*, 47–48.

astronomical function. It consisted of twelve months of thirty days each, plus five festival days, to yield 365 days. The civil calendar was a great achievement because it played a significant economic, social, and scientific role. Because the civil calendar always began on the same day of the year, which was not true of the Egyptian lunar calendar, the precise day when debts fell due could be calculated easily for many years into the future. Similarly, the exact number of days intervening between different festivals was readily determined. But the civil calendar found its most enduring role in astronomy. From Claudius Ptolemy (fl. 150 AD) to Nicholas Copernicus (1473–1543), some astronomers (if not many) found it convenient to record astronomical observations in the Egyptian civil calendar, as it enabled them to determine the exact interval between any two observations of a celestial body.

It was, however, the Babylonians and Assyrians in Mesopotamia who brought astronomy to its greatest heights in the period to approximately 500 BC. Our great debt to them becomes evident when we realize that they applied their sexagesimal numerical system – that is, a number system based on sixty and its subdivisions – to the sky. Around 500 BC, the Babylonians introduced the concept of the ecliptic, which was the circle traced out by the Sun's apparent path around the earth. They assigned 360 degrees to the ecliptic and divided it into twelve divisions of thirty degrees. The twelve divisions formed the signs of the zodiac. The Babylonians were fine observers of the heavens and by 300 BC knew how to predict the length of a month – whether it was twenty-nine or thirty days. They could do this because they recorded their observations in tables that proved useful for their needs and also for the future of Greek astronomy.[14]

Babylonian, or Mesopotamian, astronomy reached a sophisticated level because it could utilize an exceptionally well-developed mathematics. Their flexible and powerful sexagesimal number system enabled them to express all numbers with only two symbols and to carry out all arithmetic operations with ease, a status the Egyptians never attained. They could use only two symbols because they arrived at the concept of place notation, whereby the value of a symbol depended on its place in the number. Thus they had the same kind of mathematical flexibility as we have with our decimal system. Sometime around 300 BC, the Babylonians introduced the idea of zero and used it in their astronomical calculations. Finally, the Babylonians carried out arithmetic operations on fractions in exactly the same manner as they did on their integers.

With a powerful and sophisticated number system, the Babylonians made and utilized all manner of numerical tables. As a consequence, they attained

[14] For a detailed study of Mesopotamian mathematics and astronomy, see O. Neugebauer, *The Exact Sciences in Antiquity* (Princeton, NJ: Princeton University Press, 1952).

a high level of achievement in algebra, solving many kinds of quadratic equations.[15]

Because they were the first to leave written records of their achievements, there can be little doubt that scholars in ancient Egypt and Mesopotamia began the human process of understanding the operations of the natural world. They did so largely in the areas of medicine, astronomy, and mathematics, but also inevitably began to gather information about natural history. What they began and developed would become a legacy for the Greeks, who arrived on the scene long after their Egyptian and Mesopotamian predecessors.

EARLY GREEK NATURAL PHILOSOPHY AND MEDICINE

Although they made significant contributions toward a better understanding of nature, the Egyptians and Mesopotamians were heavily reliant on explanations rooted in magic, mythology, and the supernatural. Their role was nonetheless significant because they began the lengthy quest for understanding the workings of our world. The interplay between natural and supernatural explanations of observed effects in the physical world took a dramatic turn toward the natural around 600 BC, when the ancient Greeks appeared on the scene and left traces of their earliest speculations during the period between 600 and 400 BC, a period that laid the foundations of Greek science and natural philosophy for the next six hundred years.

The Pre-Socratic Natural Philosophers

Greek thought blossomed in the city-states that Greeks had founded along the coast of Asia Minor in the seventh and sixth centuries BC. Of these, the most important was the city of Miletus, which produced some of the most famous early thinkers, such as Thales, Anaximenes, and Anaximander, collectively known as Milesians.

The years from 600 to 400 BC usually are called the pre-Socratic period – the period of philosophical activity before the time that Socrates (469–399 BC), the teacher of Plato, lived – and the philosophers of whom we have any record are identified collectively as "Pre-Socratics." None of their works is known to have survived; only bits and pieces, mere fragments that were preserved by subsequent authors who quoted from their works. For example, Theophrastus, who succeeded Aristotle as head of the Lyceum, had before him the works of various Pre-Socratics and wrote a treatise titled *Opinions of the Physicists* in sixteen or eighteen books, of which only the last has survived, bearing the title *On Sensation*. In order to evaluate the

[15] For a brief, clear account of the Babylonian number system and Babylonian contributions in algebra, see Clagett, *Greek Science in Antiquity*, 16–19.

thought of pre-Socratic philosophers, Hermann Diels searched Greek literature for actual quotations from Pre-Socratic authors. In 1903, he published *The Fragments of the Pre-socratics* (*Die Fragmente der Vorsokratiker*). To aid in the interpretation of these fragmentary thoughts, scholars use the doxographic tradition that derives from Theophrastus' work and consists of opinions of later authors on pre-Socratic thinkers. To this, we must add Aristotle's important discussion of the Pre-Socratics in the first book of his *Metaphysics*. Aristotle regarded these early philosophers as his predecessors and thought it important to describe their views about the nature of the physical world.

To convey a flavor of the fragments that Diels published, it will be useful to cite a few from the translation by Kathleen Freeman. Although Anaximenes of Miletus is regarded as one of the most important pre-Socratic philosophers, and is known to have written one book, only one authentic sentence survives, in which he declares: "As our soul, being air, holds us together, so do breath and air surround the whole universe."[16] Among the more than three hundred fragments attributed to Democritus of Abdera (fl. 420 BC) is this important and somewhat lengthy one:

> 9. Sweet exists by convention, bitter by convention, colour by convention; atoms and Void (*alone*) exist in reality.... We know nothing accurately in reality, but (*only*) as it changes according to the bodily condition, and the constitution of those things that flow upon (*the body*) and impinge upon it.[17]

These two fragments are reasonably intelligible, but many others are little more than snippets, as, for example, when Democritus asserts that:

> 145. Speech is the shadow of action.
> 147. Pigs revel in mud.
> 151. In a shared fish, there are no bones.[18]

Despite the enormous difficulties of interpreting fragments that have no proper context, modern scholars have recognized their great, and even overwhelming, significance. These early Greek thinkers mark a dramatic break with all that went before in the Greek and non-Greek worlds. G. E. R. Lloyd sees two basic innovations in their thought: "First, there is what may be described as the discovery of nature, and second the practice of rational criticism and debate."[19] By "discovery of nature," Lloyd means "the appreciation of the distinction between the 'natural and the 'supernatural', that is the recognition that natural phenomena are not the products of random or arbitrary influences, but regular and governed by determinable

[16] Kathleen Freeman, *Ancilla to the Pre-Socratic Philosophers: A Complete Translation of the Fragments in Diels, "Fragmente der Vorsokratiker"* (Oxford: Basil Blackwell, 1948), 19.
[17] Freeman, ibid., 93. [18] Ibid., 105.
[19] G. E. R. Lloyd, *Early Greek Science: Thales to Aristotle* (New York: W. W. Norton, 1970), 8.

sequences of cause and effect."[20] Consequently, although "the idea of the divine often figures in their cosmologies, the supernatural plays no part in their explanations."[21]

There can be no doubt that this was a monumental change of outlook.[22] It was a new approach that was added to the mythological explanations of the world that had characterized earlier Greek descriptions of physical phenomena by the likes of Hesiod and Homer. Pre-Socratics no longer explained natural phenomena, such as earthquakes, lightning, storms, and eclipses, as the actions of happy or angry gods, but as the actions of natural forces that regularly produced such effects. Thus, Thales of Miletus, who is regarded as the first of the Greek investigators into nature, is said to have declared that "the world is held up by water and rides like a ship, and when it is said to 'quake' it is actually rocking because of the water's movement."[23] Rather than attribute earthquakes to Poseidon, god of the sea, as Greeks had done for centuries, Thales chose to give a natural explanation, as did all the Pre-Socratics who followed him.

Not only did the Pre-Socratics eliminate the gods as the causes of natural phenomena and replace them with natural causes, but they also adopted a number of different approaches to explain the apparent diversity and change they observed in the world around them. In the process, they enunciated some of the most basic problems that would shape the discipline that was eventually known as physics, or natural philosophy. The first wave of Pre-Socratics is often called monists because they sought to explain changes in the world in terms of a single substance, or stuff. They coped with what has been called the one-many problem, in which they sought to explain how the many things that we see and experience could come from one basic substance or stuff. Thus, Thales is said to have taken water as the basic substance, whereas Anaximander (ca. 610–ca. 547 BC) assumed the existence of an indeterminate substance called the *apeiron*, or boundless, out of which things came and to which they returned. Anaximander introduced an idea that became an integral part of Greek explanations of change. He regarded change as the product of an interchange of opposite qualities, namely, hot and cold, which came out of the basic substance – which he called "the boundless" – and

[20] Ibid. [21] Ibid., 9.

[22] For three excellent accounts of the substance and significance of pre-Socratic contributions to the physical inquiry about the world, see Clagett, *Greek Science in Antiquity*, chs. 2 ("Greek Science: Origins and Methods"), 21–33, and 3 ("Science and Early Natural Philosophy"), 34–38; G. E. R. Lloyd, *Early Greek Science: Thales to Aristotle*, chs. 2 ("The Theories of the Milesians"), 16–23; 3 ("The Pythagoreans"), 24–35; and 4 ("The Problem of Change"), 36–49; and David C. Lindberg, *The Beginnings of Western Science*, 25–35.

[23] This attribution to Thales is by the Roman philosopher, Seneca, in his *Natural Questions*, III, 14, and translated by G. S. Kirk and J. E. Raven, *The Presocratic Philosophers: A Critical History with a Selection of Texts* (Cambridge: Cambridge University Press, 1957), 92. See also Lloyd's discussion in *Early Greek Science*, 9.

returned to it. An eternal motion of the boundless produces hot and cold that together form many worlds. Anaximander also used the principle of sufficient reason, or insufficient reason, when he argued that the earth lies unsupported, but motionless, because it is equidistant from everything and therefore has no reason or desire to move toward anything. Perhaps, as Lloyd explains, Anaximander "appreciated that Thales' view, and views like it, run into an obvious difficulty: if water holds the earth up, what holds the water up?"[24]

Anaximenes of Miletus (fl. 546 BC), like Thales, chose a sensible element, air, as the basic substance out of which all things emerged. Simplicius, an important commentator on Aristotle in the sixth century AD, reports that for Anaximenes the physical mechanism that causes the air to change is rarity and density. "Being made finer it becomes fire, being made thicker it becomes wind, then cloud, then (when thickened still more) water, then earth, then stones: And the rest come into being from these. He, too, makes motion eternal, and says that change, also comes about through it."[25]

From the Greeks who colonized the west and had come to Italy and Sicily, great contributions were forthcoming during the pre-Socratic period. In the course of the fifth century BC, Pythagoras and his followers, known as the Pythagorean School, formed a school in Italy that was largely religious in character. We know little about the contributions of Pythagoras himself, who was born on the island of Samos, off the coast of Asia Minor, and later migrated to Italy, and only a little more about the members of his school, which seems to have had a continuous existence for some centuries after the death of Pythagoras. A major source for our knowledge of the earliest Pythagoreans is Aristotle, who rarely refers to Pythagoras, the man, but usually speaks of the Pythagoreans as a group. From Aristotle, we learn that the Pythagoreans did not opt for a material cause as the basic substance of the world but assigned that role to number. The Pythagoreans focused their interests on mathematics, although precisely how the Pythagoreans understood a world in which number is the basis of all material things is a mystery.[26]

As the substratum underlying our world, however, they chose to emphasize a formal, rather than material, aspect. The idea of mathematics as the basis of nature would have a long history and represents another contribution by these early Greek thinkers.

[24] Lloyd, *Early Greek Science*, 20–21. For a detailed description of Anaximander's views, see Kirk and Raven, *The Presocratic Philosophers*, 99–142. Anaximander's ideas about the earth's centrality and immobility are reported by Aristotle in *On the Heavens* 2.13.295b.10–15.

[25] The translation is from Simplicius's *Commentary on Aristotle's Physics*, 149.32, and appears in James B. Wilbur and Harold J. Allen, *The Worlds of the Early Greek Philosophers* (Buffalo, NY: Prometheus Books, 1979), 44.

[26] Later in this chapter, the reader will find a passage from Aristotle on the Pythagorean attitude toward mathematics.

The underlying idea in the monist approach to nature was that the material – or, in the case of the Pythagoreans, formal – substratum that underlay all change was itself permanent and indestructible, an idea that would play a vital role in later natural philosophy. But the change that the monists assumed as self-evident was attacked by those philosophers who began to question the reliability of the senses and came to regard the whole notion of change as an illusion. Parmenides of Elea (ca. 515–ca. 450 BC), one of the giants of Western thought, was the foremost critic of monist thought based on a continually changing world. Writing in hexameter verse, Parmenides left a poem that divides into an introduction followed by two distinct parts. In the first major part, called the Way of Truth, Parmenides argues that change is impossible. He insists that the Way of Truth is a logical way of talking about things, because it claims only that what is is. That which exists could not have had a beginning and is therefore ungenerable and indestructible. What exists cannot have had a beginning, because it would have had to come from something that is not-being, which implies that a change took place from not-being to being, which is impossible. By a similar argument, what exists cannot be destroyed and come to an end, because that could only occur if what exists passed from being to not-being, which is impossible. Parmenides explains that

> One way only is left to be spoken of, that it *is*; and on this way are full many signs that what *is* is uncreated and imperishable, for it is entire, immovable and without end. It was not in the past, nor *shall* it be, since it *is* now, all at once, one, continuous; for what creation wilt thou seek for it? How and whence did it grow? Nor shall I allow thee to say or to think, "from that which is not"; for it is not to be said or thought that it is not.[27]

To reinforce his argument that being could not have come into existence, Parmenides invokes the principle of sufficient reason, asking, "What need would have driven it on to grow, starting from nothing, at a later time rather than an earlier?"[28]

Thus did Parmenides argue that change is an illusion and is logically impossible; therefore, motion is impossible. Nothing can come into existence or pass out of existence. The only thing that exists is what is. Parmenides distinguished three ways of thinking:

1. That what you can think must exist.[29]
2. What you cannot think cannot possibly exist.[30]

[27] Translation by Kirk and Raven, *The Presocratic Philosophers*, frag. 347, 273.
[28] Kirk and Raven, ibid.
[29] "For it is the same thing to think and to be," Parmenides argues. See Freeman, *Ancilla to the Pre-Socratic Philosophers*, 42.
[30] Parmenides encapsulates the first two ways of speaking in the following passage: "Come, I will tell you – and you must accept my word when you have heard it – the ways of inquiry