BELIEFS AND PHYSICS:
SOME LESSONS FROM THE ANCIENT GREEKS

Robert C. Newman
Interdisciplinary Biblical Research Institute
Biblical Theological Seminary
www.ibri.org

ABSTRACT

A brief sketch of ancient Greek physics from Thales to Aristotle reveals a strong interaction between metaphysical belief and the practice of physics. This interaction worked in both directions, as metaphysical views suggested (and inhibited) questions and approaches to the physical realm, and physical observations and experiments favored or disfavored various metaphysical views. Some lessons are suggested concerning how we should view current theories in modern physics.

How do metaphysical beliefs and physics interact? To formulate some answers to this question, we need to look at actual examples. Here we consider some of the earliest information we have on mankind seeking systematic understanding of our physical environment. Work of this sort may have been done in previous civilizations, but the first records we have come from the Greeks, beginning with Thales of Miletus shortly after 600 BC. We will carry our survey down to Aristotle in the fourth century BC, the first to attempt a comprehensive physics.

From our perspective at the end of the twentieth century, the physics of these early scientist-philosophers seems crude, rash, and often absurd. Yet scientists only 200 years from now may well think the same of our physics. Let us, then, try to give each ancient thinker a sympathetic reading, seeking to understand what forces led to each proposal, and how physical observation and research affected metaphysical views and vice versa.

There are some advantages in picking examples from so long ago, in spite of difficulties with historical sources. These early researchers first proposed a number of fundamental problems which have not been solved to this day. Yet we have advanced enough to see a good deal further along the road than they could. We can, perhaps, assess the fruit of their labors better than we can those of more recent physicists.

The Physical Substratum

How do we explain the nature of the material world which we observe? This question was apparently first answered in physical rather than supernatural terms by Thales of Miletus, a practical thinker reputed to have made contributions to law, politics, civil engineering, mathematics, and astronomy; he was even credited with successfully predicting an eclipse of the sun in 585 BC (Nahm, 1964, pp. 32-33; Farrington, 1949, p. 31).[1] Thales proposed that there was a single basic substance behind all the diverse phenomena we experience.[2] His rather tangible choice for this substance was water. Thales not only thought water was the substance on which the earth actually floated (Aristotle, 325BCb, 2.13 [294a]),[3] but also that it was the basis of all other materials. Aristotle (325BCa, 1.3 [983b]) suggests he made this proposal because of the obvious necessity of moisture for life. Nahm (1964, p. 33) thinks perhaps it was because Thales knew that water could assume the three forms — solid, liquid and vapor.

Thales' preference for natural causation, Farrington (1949, pp. 29-31) suggests, came from

---

[1]Some skepticism is recommended about the eclipse story, given first in Herodotus *Persian Wars* 1.74. See Sarton (1964, pp. 170-71).

[2]But see Lloyd (1970, pp. 18-20), who thinks Thales was speaking of the origin of different sorts of matter rather than their present composition.

[3]Most of the Classical references in this paper can be found in Nahm (1964), though I have translated his titles into English.

observing various agricultural and industrial techniques. He felt free to advocate this openly because of the relative intellectual freedom in Melitus, a city ruled at that time by merchants rather than a military or priestly caste. Though preferring natural causes, Thales does not appear to have been an atheist. Arisotle (325BCc, 1.5 [411a]) says he thought 'that all things are full of gods.' Perhaps he realized that technological processes depend on the natural attributes of the substances they manipulate, and this led him to extend the idea to processes operating in nature. The proposal turned out to be a fruitful one.

Anaximander (fl 555 BC)[4] followed Thales at Miletus, and was considered his student and successor (Theophrastus, 320BCb, 476). He also followed Thales' belief in a single natural universal substance, but rejected his choice, water. Aristotle (325BCd, 3.5 [204b]; see also Lloyd [1970], p. 20) suggests he did this because he could not see water as the source of fire, since their characteristics (cold and wet vs. hot and dry) were mutually destructive. Anaximander proposed an abstract substance unlike anything observed, which he called *apeiron*, meaning something like 'unlimited,' 'boundless,' or 'infinite.' This basic substance contained all the opposites, and formed such secondary substances as fire and water by separation (Aristotle, 325BCd, 3.5 [204b]; Simplicius, 530ADb, 32r). These secondary substances had their origin in the *apeiron* and returned to it when they were destroyed.

Anaximenes (fl 535) was a third Milesian to investigate the basic constitution of matter. He too favored a single ultimate substance, but turned to an observable material, air, for his choice. Perhaps he felt his predecessor's *apeiron* was too far removed from observation.[5] Anaximenes explained the diverse observed materials as various manifestations of air. When rarefied, air becomes fire; condensed, it forms successively wind, cloud, water, earth, and stone as the degree of condensation increases (Hippolytus, 236AD, 1.6).

The cosmologies the Milesians proposed were based on their physics. Thales had his earth floating on water. Anaximander formed the cold earth and fiery heavens by separation from the *apeiron* (Plutarch, 100ADb, 2). Anaximenes floated his earth on air, and employed the wind to push his stars around (Hippolytus, 236AD, 1.6).

> The history of Milesian views about the primary substance is chiefly remarkable for the way in which the awareness of the problems grew from one philosopher to the next. . . . As is usual in the history of science, their actual theories strike a later age as childish C they already appeared so to Aristotle. But the measure of their achievement is the advance they made in grasping the problems. They rejected supernatural causation and appreciated that naturalistic explanations can and should be given of a wide range of phenomena: and they took the first tentative steps towards an understanding of the

[4]Chronological data on the various ancients comes from Lloyd (1970) or the *Oxford Classical Dictionary*.

[5]Simplicius, 530ADb, 6r: '... he regards [the basic substance] as not indeterminate but determinate.'

problem of change (Lloyd, 1970, pp 22-23).

A Mathematical Substratum

A different approach to the question of what underlies the physical world was proposed by Pythagoras (fl 525), or possibly by one of his followers, the Pythagoreans. Having observed that harmonious sounds are produced by vibrating strings whose lengths have simple ratios, he proposed that reality consists of numbers (Aristotle, 325BCa, 13.6 [1080b], 14.3 [1090a]). Though the Pythagoreans apparently understood this in a rather crudely literal sense, their suggestion led to increasing interest in the form rather than the substance of matter. This suggestion also proved fruitful for research from antiquity onward, turning the attention of physicists and astronomers to numerical measurement and mathematical modeling. It led to substantial advances in knowledge among the Pythagorean astronomers. Unfortunately, it also produced a great deal of 'mumbo-jumbo and crude number-mysticism' (Lloyd, 1970, p. 27).

Plato (428-347) was influenced by the Pythagoreans, and counted knowledge of geometry a necessity for admission to his Academy. He observed that geometric drawings are at best only a rough approximation to the ideas that lie behind them. For example, a true tangent meets its circle at one point only, but it is impossible to draw this. Plato apparently extrapolated this observation to reality in general, coming to the conclusion that ultimate reality consists of eternal, unchanging ideas, which are only imperfectly represented in the changing world of objects observable by our senses. True knowledge is knowledge of these eternal ideas rather than of unreliable sensory data. The results are described by Clagett (1963, p. 84):

> We do not have to wait until medieval or early modern times for the application of geometry to the investigation of nature, for it began in both physics and astronomy in the fourth century [BC] and matured in the Hellenistic and Greco-Roman periods. We have already suggested the basic importance of the Pythagorean mathematical point of view of nature; but when the mathematical view was coupled with something close to scorn of the world of the senses, as it was in some of the Platonic dialogues, little sound physics could arise. Even the most apologetic Platonist will not stand behind Plato's *Timaeus* as a work of high scientific caliber, although it is true that some of the ideas suggested therein were not without their influence on Aristotle and later authors.

Motion and Vacuum

Meanwhile, the question of how motion could be reconciled with the idea of a single, universal substance was being considered by Parmenides (fl 480). He came to the rather startling conclusion that it couldn't. Parmenides believed the single universal substance to be *being itself*. A vacuum was thus non-being, which by definition could not exist. Therefore all space was filled with the single, ultimate substance which could not change without being non-ultimate and which had no room to move (Parmenides, 480BCb). Rather than accepting the testimony of human senses as indicating something must be wrong with his argument, Parmenides chose instead to believe that our senses are in error! (Parmenides, 480BCa). Parmenides' follower Zeno (fl 445) constructed several exceedingly clever arguments to prove that motion did not exist. These arguments were frequently ignored but not successfully refuted until the invention of calculus some 2000 years later.

One solution to the quandary posed by Parmenides was to adopt a pluralistic worldview rather than his monistic one C that there are several basic substances rather than only one. In this case, motion could take place as the different substances slipped by or mixed with one another, even if there was no vacuum to provide extra room to move about in. Empedocles (fl 445) adopted this approach, proposing that there were four elements instead of only one, namely earth, water, air and fire. All material things were a mixture of these, and change took place when the composition of various mixtures changed. The cause of such change Empedocles took to be two forces, which he called Love and Strife (we would call them attraction and repulsion). This model, as developed further by Plato and Aristotle, was to be the dominant view in physics through the rest of antiquity until modern times (Clagett, 1963, p. 84).

Anaxagoras (fl 445) carried the pluralistic idea to an extreme by postulating the existence of an infinite number of different sorts of things C 'seeds,' or 'germs,' he called them C which are infinitely small and eternal. Every existing thing is a mixture of these, so that when a human eats fruit (say), the body does not make flesh and bone out of some other substance, but it extracts the flesh and bone particles from the food (Anaxagoras, 445BC; Aristotle, 325BCd, 1.4 [187a-b]). Anaxagoras' influence does not appear to have been great, as he was going against the preferred tendency to explain the diversity of phenomena by as few items as possible. Occam's razor was already in use long before Occam was born!

The response to Parmenides which most neatly solved the problem he raised was the atomic theory, proposed by Leucippus (fl 435), developed by Democritus (fl 410) (Simplicius, 530ADb, 28.15; Hippolytus, 236AD, 1.10-11), and still further by Epicurus (341-270) (Aëtius, 100AD, 1.3.18; Cicero, 43BCa, 1.26.73). Reality, said the Atomists, consists of an eternally-existing, universal substance, but this occurs as an infinite number of unchangeable, invisibly small particles, called 'atoms' (indivisible) because they could not be cut into smaller pieces. The atoms were separated from one another by a void or vacuum, so that motion was possible, and in fact, continual (Aristotle, 325BCd, 8.9 [265b]; Cicero, 43BCb, 1.6.17).

Unlike Anaxagoras' seeds, atoms were all of the same substance, but differed in size and shape. They formed the various objects of our experience by collision and entanglement C the origin of a particular material occurring when the atoms came together, its destruction when the atoms separated. Thus change was real and didn't need to be explained away as an illusion. On the other hand, sensory characteristics themselves were due to the shapes and combinations of the atoms, not to real colors and tastes in the atoms. Democritus speculated elaborately on the nature of sensory experience, and on how such characteristics as hardness and softness, lightness and heaviness, were produced in various objects (Simplicius, 530ADa, 293.33; Plutarch, 100ADa, 8; Theophrastus, 320BCa, 6.1.6; Theophrastus, 320BCc, 49-82). Surprisingly, Democritus, too, felt rational thought was more reliable than observation (Sextus Empiricus, 200BC, 7.138). The ancient atomic theory never achieved dominance in antiquity like the modern atomic theory has. It ascribed the origin of the world to chance rather than intelligence, and it had nothing beyond necessity to explain large-scale organization within the world (Aristotle, 325BCd, 2.4 [196a-b]; Eusebius, 340AD, 14.27.4-5).[6]

The Physics of Aristotle

By the time of Aristotle (382-322), Greek astronomy had progressed to the point that astronomical objects were obviously much larger and further away than meteorological phenomena (Lloyd, 1970, p. 110; Farrington, 1949, pp. 99-100). Heraclides of Pontus' (fl 330) proposal, that the daily movement of the sun, moon and stars was actually due to the earth's rotation, may have come too late to influence Aristotle; it did not meet with acceptance in any case (Clagett, 1963, p. 114; Sarton, 1964, pp. 506-08; Lloyd, 1970, pp. 94-97). Without telescopes, changes in the sky were not obvious beyond the moon, so it is not surprising that Aristotle proposed a two-realm version of physics. (1) Above the moon was a supralunar realm without change, where all motion was eternal and circular, following the scheme of Eudoxus (fl 365). (2) Below the moon was the sublunar realm of change, characterized by natural vertical motion as each of the four elements sought its own level (Clagett, 1963, pp. 84-87; Lloyd, 1970, pp. 109-10). Aristotle modified the four-element scheme of Empedocles by allowing the elements to be transformed from one into another, and by adding a fifth element, *aether*, from which the supralunar realm was constructed (Clagett, 1963, pp. 85, 87; Lloyd, 1970, pp. 108-11).

Aristotle also proposed four kinds of causation: (1) a material cause (like that of the Milesians), what something was made of; (2) a formal cause (like that of the Pythagoreans and Plato), how something was structured; (3) an efficient cause (like that of Empedocles), what forces produced it; and (4) a final cause, for what purpose the object was made (Farrington, 1949, pp. 123-24; Clagett, 1963, pp. 84-85; Lloyd, 1970, pp. 105-06).

Aristotle's physics and causation continued to have influence through antiquity and the medieval period until modern times, as they appeared to provide both consistency and believable explanations for the observed natural order (Clagett, 1963, p. 84; Lloyd, 1970, pp. 99, 122).

Interactions Between Metaphysics and Physics

We must now consider what we have learned about how metaphysical beliefs and physics interact.

How were physical concepts used to develop and evaluate metaphysical beliefs?

---

[6] See also the searching criticisms in Theophrastus (320BCc, 49-82).

The techniques of craftsmen may have suggested naturalistic explanations for physical phenomena to Thales and his followers.

The discovery that harmonious sounds were produced when vibrating strings had lengths in simple ratios may have led the Pythagoreans to postulate the idea that number is the ultimate feature of reality rather than matter.

The realization that geometric drawings are at best only rough approximations to the ideas that lie behind them apparently convinced Plato that ultimate reality consisted of eternal ideas which are only imperfectly realized in physical things.

Reluctance to abandon sensory evidence kept many from following Parmenides, proposing instead various models of reality in which change and motion were real. These included the multi-element schemes of Empedocles and Anaxagoras, and the Atomists' introduction of a void and breaking the ultimate substance into tiny pieces.

Astronomical evidence that the heavenly bodies were at great distances was in part responsible (together with Eudoxus' scheme for reducing the heavenly motions to circles) for Aristotle's distinction between the earthly realm of change and the changeless heavens.

How were metaphysical beliefs used to develop and evaluate physical concepts and theories?

The Milesians' metaphysic of natural causation led to their suggesting various natural explanations for everyday phenomena which Greek mythology had ascribed to Zeus, Poseidon, or one of the other gods. It also led to speculation regarding a most basic substance. This resulted, on the one hand, in beginning attempts to study the basis of matter; on the other, it consistently produced (unwarranted) optimism that the nature of the substratum could be easily discerned.

The Pythagorean metaphysic of number as the basis of nature proved very fruitful in some fields, and certainly was important in introducing mathematics as a tool to understand reality. However, it also led to considerable number-speculation where the subject of investigation was not hospitable to such an approach at that time.

Plato's view that reality was in the eternal ideas, rather than in their imperfect representations in nature, led him to devalue the use of observation and experiment on physical objects in favor of purely abstract reasoning, disconnecting theory from observation.

Parmenides' view that motion was logically impossible led him to reject the contrary testimony of the senses.

Democritus' view that reality could be completely described by atoms moving in the void led him to a number of striking insights, mixed with numerous unwarranted speculations. His strongly reductionistic explanations ignored the possibility of higher levels of structure and of design in nature.

The apparent completeness and consistency of Aristotle's division of the cosmos into two realms with two types of physics had long-term (and largely negative) effects on the practice of physics, which were not overcome until the late middle ages.

By the time of Plato and Aristotle, widening class divisions in the Greek city-states were discouraging the leisured class from involvement in hands-on, technical sorts of labor. This seems to have had a negative effect on any research which looked practical, leading to the devaluation of the sort of physical investigations which would later transform Western society in the centuries after the Reformation.

How do shared metaphysical beliefs of the physics/science community influence its research agenda?

There were apparently no really organized physics or science communities at the beginning of this era, but certainly the Milesians sought purely natural explanations of phenomena. Though this encouraged experimentation and observation, it made it difficult for them to explain the occurrence of order in nature.

The Pythagoreans were certainly a community, though more of a religious fellowship than a scientific society. They concentrated on applying mathematics to their investigations, producing some impressive results where this was possible at the time (astronomy and acoustics), but rather fantastic number-mysticism elsewhere.

The Academy of Plato was mainly successful in its mathematical work, as the emphasis on reason rather than observation tended to produce abstract, logical constructions. Plato's proposal that the movement of astronomical objects be explained by combinations of circular motions both helped and hindered astronomical research. Plato's admission of eternal forms gave better explanations for order in nature than the merely material causation of the Milesians and Atomists.

Aristotle's proposal of four types of causation (matter, structure, energy, and purpose) made better sense of the observed order in nature. Together with a restoration of the value of observation, this led to some effective biological research in the Lyceum of his time and later.

Some Lessons for Today

Can such a brief tour of ancient Greek physics teach us anything about how we should view physics today? I believe it can. Consider the following questions in the light of our survey.

Given a hierarchical structure to reality, is there any reason to believe an empirically *constructed 'bottom up' metaphysics will be anything more than accidentally correct before the 'final physics' is discovered?*

Ancient Greek science, though showing real progress, does not seem promising for this hope. Thales' and Anaximenes' proposals that water and air are the ultimate substances seem especially crude to us, but they were based on certain observations. Anaximander's more sophisticated idea of an unspecified stuff behind appearances is an improvement, and it sought to solve the problem of contrary attributes. Anaximenes' concept of condensation and rarefaction, presumably based on the conversion of water into ice and steam, also marked a step forward. Aristotle's version of Empedocles' four-element theory (earth, water, air, fire), though returning to visible material as basic, at least provided for one element to change into another. In retrospect, none of these suggestions were close to what we know to be the case today.

Even the ancient atomic theories, though a vast improvement with their invisible units of structure and space between them, were unable to explain macroscopic attributes except by arbitrary guesswork. Throughout the period we see increasing sophistication, coupled with the incorporation of additional evidence, which eventually was revived in modern times as a new atomic theory. But modern investigation has found that what we call atoms are composites of nucleons and electrons, and that nucleons are probably composites of quarks. There is no way yet for us to tell if quarks, too, may not be composite. We do not know how deep the hierarchy is, nor whether anything lies beneath it.

How does 'Occam's Razor' influence physics? Do we tend to jump to unwarranted conclusions about the completeness of very preliminary theories?

Though 'Occam's razor' is a medieval term, it describes a common human tendency to construct the simplest theory consistent with the known evidence; clearly, it is valuable as a method of procedure. But the ancient Greeks had no idea how complicated nature might be, and tended to think they were only one layer away from the bottom. We can see they were mistaken, having penetrated several more layers. But what about our theories? Are we only a layer away from the bottom of things, or do we also jump to conclusions when we ascribe to them an ultimacy they may not deserve?

In the area of kinematics, is it reasonable to believe nature can be limited to the three spatial dimensions and one time dimension of modern relativity theory?

This is certainly the simplest model consistent with our current, empirical, 'bottom up' physics. But mathematics has been worked out for larger dimensionalities; some of the recent 'grand unification theories' incorporate 11 or more dimensions; and certain features of the occult and of the supernatural in Scripture point to a more complex situation. One's worldview will have an influence on whether this is thought to be possible or probable, and whether it might be worth pursuing as a research strategy.

In the area of dynamics, is it reasonable to believe that the four currently-known forces are all that exist? That they may be unified into a single superforce?

It is certainly reasonable to believe these things in the sense that we know of no reason why they might not be true. The discussion above, however, should make us wary of too much confidence here, since two of these forces (the strong and weak interactions) were only discovered in the past century, and we have generally been poor prophets of what advancing technology will turn up. The desire for unification and simplification has often been fruitful in research, but like Pythagoreanism, has equally often led astray.

In the area of dynamics, is it reasonable to believe that knowing the ultimate particles and physical forces will be sufficient to explain reality without recourse to special initial or boundary conditions?

Without making use of special revelation, we do not know the answer to this question. However, the 'fine-tuning' in our universe, currently being discussed as the 'anthropic principle,' suggests that planning rather than chance is the more basic characteristic of reality.

In the area of dynamics, it is reasonable to believe that the universe is an automaton (like a clock) that runs by itself C *whether accidental or designed* C *or may it be an instrument (like a guitar) that is designed for input?*

Again, input from special revelation is helpful here, though it is currently viewed as 'more scientific' to opt for a self-contained, closed universe.

After some 2500 years of doing physics from inside our universe, we still don't know whether there is an ultimate substratum, and if so, what it looks like. We have progressed enough to be sure it is not water, air, or atoms C in either the ancient or modern sense of the word.

There is a strange resonance in reality between mathematics in the human mind and the structure of nature. We don't know enough to say how pervasive this structure is or how it is imposed.

Parmenides and Zeno were certainly mistaken about the unreality of motion. If it finally turns out they were right about our senses being totally deceived, it will still have only been a lucky guess. The human sensory apparatus and its technological extensions have revealed an orderly world of much greater complexity than any of the ancients imagined.

The reductionism of Democritus is still with us in a suitably updated form, but it faces some real challenges from design in nature. Aristotle was wrong about there being two different kinds of physics for the terrestrial and astronomical realms. He might yet prove to be right for the earthly and the heavenly.

BIBLIOGRAPHY

Most of the items herein are ancient works. For some of these, such as Aëtius and Sextus Empiricus, the dates given are very approximate. For the other ancient works, the date given is the author's date of death or *floruit*. Dates before 1000 AD are marked AD or BC.

Aëtius. (100AD) *Relics of the Philosophers*.

Anaxagoras. (445BC) *Fragments*.

Aristotle. (325BCa) *Metaphysics*.

Aristotle. (325BCb) *On the Heavens*.

Aristotle. (325BCc) *On the Soul*.

Aristotle. (325BCd) *Physics*.

Cicero. (43BCa) *On the Nature of the Gods*.

Cicero. (43BCb) *On the Chief Good and Evil*.

Clagett, Marshall. (1963) *Greek Science in Antiquity*. New York: Collier.

Empedocles. (445BC) *Fragments*.

Eusebius. (340AD) *Preparation for the Gospel*.

Farrington, Benjamin. (1949) *Greek Science I: Thales to Aristotle*. Harmondsworth, Middlesex: Penguin.

Hippolytus. (236AD) *Refutation of All Heresies*.

Lloyd, G. E. R. (1970) *Early Greek Science: Thales to Aristotle*. New York: W. W. Norton.

Nahm, Milton C., ed. (1964) *Selections from Early Greek Philosophy*, 4th ed. Englewood Cliffs, NJ: Prentice-Hall.

Parmenides. (480BCa) *The Way of Opinion*.

Parmenides. (480BCb) *The Way of Truth*.

Plutarch. (100ADa) *Against Colotes*.

Plutarch. (100ADb) *Miscellanies*.

Sarton, George. (1964) *A History of Science: Ancient Science Through the Golden Age of Greece* (New York: Wiley Science Editions.

Sextus Empiricus. (200BC) *Against the Professors*.

Simplicius. (530ADa) *On the Heavens*.

Simplicius. (530ADb) *Physics*.

Theophrastus. (320BCa) *Causes of Plants*.

Theophrastus. (320BCb) *Doctrines of Natural Philosophy*.

Theophrastus. (320BCc) *On Sense Perception*.