SOME PHILOSOPHERS AND SCIENTISTS LOOK AT NATURE

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The scientific viewpoints of Archimedes and Ptolemy, both implied and stated, illuminate the philosophical ideas of Plato and Aristotle in a striking way, so after outlining some doctrines of the great philosophers, seeing where they agree and where they differ, we will turn to the scientists and let them highlight the particulars.

Plato and Aristotle

Plato's doctrine of Ideas founds his entire philosophy. According to his view, the things we are aware of by our senses are only imitations of reality. The true entities, those he calls Forms or Ideas, are eternal and unchanging, and completely independent of the sensible world, and of our ideas about it. But the physical world is not conversely independent of these Forms, for they give the world its distinctive character. Any quality that an object has, any relation between one thing and another, is a particular example and imitation of an eternal Idea. All beautiful things are such by virtue of their participation in the Idea of beauty; when two things are equal they derive from the original Equality; and every chair is an imitation of the essential Idea of chair.[1]

That which distinguishes the perishable world from imperishable reality Plato variously calls "receptacle," "space," or "matter," and it is the stuff of the natural world which receives the stamp of unchanging Form, being itself formless. It is the source of change, and accounts for the plurality of chairs of which one chair-Idea can be the pattern, and for the individual differences between one chair and another.[2] Plato thus makes the sharpest distinction possible between form and matter.

This affects the way we know things. We do not gain knowledge primarily from the physical world; we have *a priori* knowledge directly from the Ideas themselves. The ideas we form about the world are, equally with sensible objects, imitations of real Forms, for we can abstract our ideas from physical things. And we can apprehend these Forms indirectly through their imitations of

[1] Encylopaedia Britannica. *Great Books of the Western World.* Vol. 2, pp. 528-529

[2] *Ibid.* p. 530

nature.[3] The thoughts we have about material objects are merely opinions; the source of true knowledge is the Forms themselves.[4]

As a result of this, Plato never put much stock in particular natural events. His line of thought progressed from generals to particulars, and was founded as much as possible on pure reason rather than on observation.[5] His conclusions about the world are the kind that can't be proved. This was one of Aristotle's chief objections to the doctrine of Ideas.[6]

Plato's views of reality led quite naturally to a strong bias for mathematics, whose precision and lack of ambiguity approached the spirit of Ideas more closely than any other science. The significance which he attributes to numbers and forms owes much to Pythagoras,[7] who believed that numbers were the building-blocks of the universe. An example of this appears in Plato's cosmological dialogue *Timaeus,* where he equates the four elements—earth, air, fire, and water—with four of the regular solids, while the fifth solid, the dodecahedron, he reserves for a prior principle which he calls quintessence. Also in the *Timaeus* we find the idea of God as the Divine Craftsman, and of the world-soul which later led to the macrocosm-microcosm concept.[8]

Plato's interest in mathematics led him in turn to a high regard for astronomy, which exhibited the most ideal form. Some of the ideas he originated and perpetuated in this discipline had far-reaching consequences, as we shall see.

In contrast to the Platonic view, Aristotle believed that forms have no independent existence apart from the objects in which they appear, and that "their being consists in informing or determining matter, just as the being of matter consists in the capacity to receive these forms and be determined by them."[9] All substance is the union of form and matter. Matter is identified as the potential of substance for form, and form is the actuality of substance. This is the doctrine of immanent or indwelling forms. There is no Chair apart from individual chairs, no Beauty independent of beautiful things, and no Equality separate from things which are equal. Those universal, abstract ideas to which Plato ascribed autonomous existence dwell

[3] *Ibid.* p. 528

[4] Sarton, George. *A History of Science,* p. 402

[5] Singer, Charles. *A Short History of Scientific Ideas,* p. 40

[6] Encyc. Brit. *Great Books. Op. cit.* p. 530

[7] Singer, C. *Op. cit.* p. 39

[8] *Ibid.* p. 43

[9] Encyc. Brit. *Great Books. Op. cit.* p. 531

only in the mind, resulting from "the intellect's power to abstract this form from its matter."[10] This is the source of knowledge.

The inseparability of matter and form makes the relationship between the two far more intimate and complicated than in Plato's scheme. Aristotle feels constrained, as Plato never does, to account for and classify individual differences in objects. He distinguishes between substantial form—what a thing is made of—and accidental form, which deals with more superficial attributes such as shape, position, size, and color.[11] In his work on *Physics,* which looks exclusively at natural phenomena, although he begins with generalizations, determining the number of basic principles necessary to the working of nature as no more and no less than three, he then proceeds to subdivide attributes, causes, and kinds of change into numerous categories to suit every occasion.

This tendency to look at specific things grew out of Aristotle's early work in biology.[12] Living things influenced him profoundly by their unique blend of similarities and differences; little of the rich complexity of life was lost on Aristotle. Drawing on his extensive experience in observation, he proceeded from the basis of individual events to general conclusions. His "ladder of Nature," a hierarchy of living things which contains the germ of the evolutionary idea, is an example of this fruitful process.[13] Plato could never be bothered with this sort of inductive reasoning. Why reason from imitations when you can reason from reality?

Aristotle's preoccupation with life also led to his concept of the soul, which he regards as the substantial form of living things.[14] He distinguishes between the vegetative, animal, and rational souls. Although the soul does not have a separate existence, it is a distinct principle which works to a predetermined end—organizing natural phenomena toward a perfect individual. All things have purpose and show evidence of design.[15]

In astronomy Aristotle was more a follower than a leader, for he was not a quantitative experimenter.[16] He accepted and elaborated on Plato's assumptions: that the earth is the center of the universe,

[10] *Ibid*

[11] *Ibid.* p. 532

[12] Singer, C. *Op. cit.* p. 45

[13] *Ibid. p. 45-46*

[14] Encyc. Brit. *Great Books. Op. cit. p.* 532

[15] Singer, C. *Op. cit. p.* 48

[16] Asimov, Isaac. *Isaac Asimov's Biographical Encyclopedia of Science and Technology*

that the laws governing celestial and earthly motions are completely different, and that the stars and planets move in circular paths. Aristotle himself characterizes earthly motions as rectilinear, in contrast to the heavenly circles; earthly substances move vertically, as a result of the striving of each element to achieve its natural state of equilibrium.

Both Plato and Aristotle believed that the parts could be explained in the light of the whole. Aristotle particularly reacted against the atomic reductionist ideas of Democritus, and because these ideas associate the discreteness of matter with materialism, Aristotle stressed the continuity of matter as consistent with the interdependence of purpose and activity in the universe.[17]

Archimedes

If ever there was a man who dwelt in the exalted realm of Platonic being, it was Archimedes. This mental posture was so deeply ingrained in him that it can hardly be called a conscious attitude. It is unlikely that the extent of his knowledge of Plato had much bearing on Archimedes' views or way of life. He was not a disciple of Plato's philosophy but an example of it. What could be more Platonic than to follow pure knowledge to the exclusion of all mundane activities such as eating, bathing, and sleeping? But more than that, Archimedes trusted and built on the reality of mathematics; by successfully imposing the structure of it on the physical world, he proved its validity and showed that the world, too, made sense and could be trusted; and the sensibility of it depended on the sensibility of mathematics. Of course Archimedes' discoveries and applications could not prove either Plato or Aristotle correct; it is the attitude they reflect that is revealing. The fact that Archimedes published his mathematical but not his mechanical discoveries[18] can be construed as a Platonic disdain for the importance of material things; but perhaps it is merely a Platonic tendency to overlook them that prompted this action.

The form of Archimedes' mathematical demonstrations owes something to Plato too. It was Plato who endorsed neat, polished mathematical proofs, and this attitude probably played a part in inspiring Euclid to attempt the synthesis of all known mathematics.[19] Euclid in turn passed this legacy on to Archimedes, who drew freely on his propositions. Archimedes also made use of

[17] Singer, C. *Op. cit.* p.53

[18] Plutarch's *Lives.* Vol. 2, p. 282

[19] Singer, C. *Op. cit.* p. 42

Plato's method of assuming a problem to be solved, and working backwards to discover the truth or falsity of its foundations.[20]

Yet although Archimedes' demonstrations were impeccably logical, he never pretended that he arrived at them logically; he never belittled his own flashes of insight or tried to cover them up. He also had great respect for the insights of others, even when not backed up by proofs. In the *Method Treating of Mechanical Problems,* speaking of a certain theorem, he says, "We should give no small share of the credit to Democritus who was the first to make the assertion with regard to the said figure although he did not prove it."[21] The fact that Archimedes was generous enough to write the *Method* and allow people a glimpse of how he actually found the solutions to his problems, showed that he had a high regard for the importance of the inexplicable leap of the mind, the "Aha!" or in his case the "Eureka!" that transcends logic. It visited him often, and he had ample reason to thank it during his lifetime. In this instance it was the idea of plane equilibrium, or the center of gravity, that gave him a pointer on how to solve certain geometrical problems, even though, as he said, it "did not furnish an actual demonstration."[22] Just to know which way the wind was blowing helped him immeasurably in constructing his proofs. Using knowledge of natural phenomena to clarify his grasp of abstractions was also a very Platonic thing to do, whether he know it or not. This is not the same as explaining or accounting for them by natural phenomena, which is Aristotle's chief method of working.

Archimedes did not have much to say about astronomy, but since it partakes so much of mathematics he could not avoid it entirely. He is believed to have written a work, which is now lost, describing a water-powered model of the Eudoxan system of astronomy,[23] consisting of concentric spheres representing the paths of the planets, in which adjacent spheres interacted by rotating around shared axes. This system was universally accepted because it fitted well with observation and was compatible with currently held philosophy. If Archimedes built it, he probably accepted its validity, and very likely understood it better than most people did.

One of his most famous works, the *Sand-Reckoner,* reveals a good deal of Archimedes' astronomical views, although they are

[20] *Ibid.* p. 42-43

[21] Encyc. Brit. *Great Books.* Vol. 11, p. 570

[22] *Ibid*

[23] *Ibid.* p. 399

incidental to the main point. The purpose of the work is to present a numerical system which handles large numbers easily, and to show that anything can be measured, no matter how big. The significance of the title is that one can count the grains of sand required to fill the universe. To demonstrate this, he takes a figure for the earth's circumference that is ten times the accepted value; he looks at the geocentric and heliocentric systems, and chooses for his purposes a heliocentric model in which the circle that the earth describes about the sun has the same ratio to the perimeter of the universe as the earths circumference is usually assumed to have. He does not discuss the relative merits of any of these assumptions, or say which model he believes to be true. The implicit message is this: it doesn't matter how big the earth is, or how big the universe it; it is all one to him whether the sun goes around the earth or the earth circles the sun. These questions are not vital—they have no bearing on the rules of mathematics, or even on whether the universe can be measured. Mere magnitude does not frighten him, nor does the idea that the earth is not the center of all things. One might venture to call him an astronomical agnostic, which was probably a sensible position in the light of strictly scientific facts known at the time. At any rate, the important thing was the mathematical demonstration.

The indifference is unmatched even by Plato, and shows an extravagant contrast to the concern of Aristotle, who assiduously added spheres to the Eudoxan system, including one for each of the four elements, one for the quintessence, and one for the fixed stars, among others, arriving at a grand total of fifty-four,[24] and complicating things as usual. In fact, Aristotle interpreted these spheres, which Eudoxus probably intended as mathematical representations, to be actual crystalline spheres in which the planets were imbedded.[25] (This idea caught on surprisingly well.) Sometimes Aristotle's concreteness was misplaced. But Archimedes was never concrete if he could help it, and certainly not without a factual basis.

Ptolemy

Archimedes used the world to look at mathematics; Ptolemy used mathematics to look at the world. And he—Ptolemy—looked at a great deal of it, both the heavens and the earth. He was closer in spirit to Aristotle than to Plato, for he based his work on

[24] Asimov, I. *Op. ext.* p. 19
[25] Singer, C. *Op. ext.* p. 52

observations of visible phenomena, and tailored his mathematical formulas to fit them. He drew on Aristotelian concepts to support his astronomical assumptions:[26] for instance, his argument that the earth is the center of the universe is based on Aristotle's idea of rectilinear motion—all objects tend to fall toward the center of the universe; therefore, since they appear to fall toward the center of the earth, and moreover don't change direction at different times of the day or year, it follows that the earth must be fixed at the center of the universe.[27] Aristotle himself had argued for the centrality of the earth by the lack of apparent motion, except for their daily rotation, of the fixed stars.[28] It was a good argument, considering that nobody had the remotest idea how far away the stars really are.

Ptolemy followed the division between sublunary and translunary motion set down by his predecessors, and clarified the nature of the difference. The planets move in their separate spheres, following the paths dictated by their essential character, impervious to influence from without. The influence of Archimedean gravity extends only to the lunar sphere.[29]

Interestingly enough it was Plato who perpetuated the Pythagorean idea, so prevalent in Ptolemy's mathematical scheme of the heavens, that all motions of the planets must be explained, and all appearances accounted for, by circles and combinations of circles.[30] This follows from the dictate that the circle and sphere are the perfect geometric forms, and that the heavens display perfect motion;[31] they are inaccessible and utterly distinct from the sublunary world. The concepts of the epicycle and eccentric were not original with Ptolemy—he based his work largely on that of Hipparchus—but he handled them with great skill and did in fact originate the idea that an epicycle can be placed on an eccentric, thereby combining the two and increasing the flexibility of the system.[32]

Ptolemy respected mathematics highly, but never as an end in itself in the manner of Archimedes. He admired its certitude and exactness, as Plato did, but his concept of it was more concrete than Plato's. In his preface to the *Almagest*, he states, "The kind of science

[26] Encyc. Brit. *Great Books.* Vol. 16, p. 2
[27] Encyc. Brit. *Macropaedia.* Vol. 15, p. 179
[28] Singer, C. *Op. ext.* p. 56
[29] Encyc. Brit. *Great Books.* Vol. 16, p. 3
[30] Singer, C. *Op. ext.* p. 42
[31] *Ibid.* p. 39
[32] Encyc. Brit. *Great Books.* Vol. 16, p. 87

which shows up quality with respect to forms and local motions, seeking figure, number, and magnitude, and also place, time, and similar things, would be defined as mathematical.[7,33] It is not surprising that this statement has an Aristotelian flavor, grounding mathematics firmly in the natural world, when we look at its context. Here Ptolemy is setting forth Aristotle's three categories of the theoretical: the loftiest is theological, seeking after God; the basest is material, which deals with corruptible things; and mathematics falls between the two. Ptolemy explains that the theological and material branches of theory are not completely satisfactory because they can only be "expounded in terms of conjecture,"[34] the former because it is beyond the realm of experience, and the latter because its subject is constantly changing and falling into decay. But mathematics is just right—not too abstract and not too material. It is permanent yet visible and so can confer exact knowledge. And astronomy, being, as it were, the supreme example of mathematics, is the most reasonable subject for mathematical inquiry; for it is the realm, as Ptolemy says, where "things are always what they are."[35] The contemplation of the heavenly motions from a mathematical standpoint is, in Ptolemy's opinion, the best way to approach a knowledge of God, who is also perfect, eternal, and unchanging. In fact, studying the heavens should have a salutary effect on one's character:

> This same discipline would more than any other prepare understanding persons with respect to nobleness of actions and character by means of the sameness, good order, due proportion, and simple directness contemplated in Divine things, making its followers lovers of that Divine beauty, and making habitual in them, and as it were natural, a like condition of the soul.[36]

This idea appears to spring directly from Plato, who taught that a true knowledge of essential virtue leads to a virtuous life.[37] Who could resist the appeal of such staggering beauty? Archimedes forgot everything in the thrall of pure geometry. Even Aristotle declared, "The excellence of celestial things causes our scanty

[33] *Ibid.* p. 5
[34] *ibid*
[35] *Ibid.* p. 6
[36] *Ibid*
[37] Sartori, G. *Op. cit.* p. 403

knowledge of them to yield more pleasure than all our knowledge of the world in which we live."[38]

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[38] Singer, C. *Op. cit.* p. 46