Eudoxus Of Cnidus | Encyclopedia.com

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(*b*. Cnidus, ca. 400 b.c.; *d*. Cnidus, *ca*. 347 b.c.)

astronomy, mathematics.

A scholar and scientist of great eminence, Eudoxus, son of a certain Aischines, contributed to the development of astronomy, mathematics, geography, and philosophy, as well as providing his native city with laws. As a young man he studied geometry with Archytas of Tarentum, from whom he may well have taken his interest in number theory and music; in medicine he was instructed by the physician Philiston; and his philosophical inquiries were stimulated by Plato, whose lectures he attended as an impecunious student during his first visit to Athens. Later his friends in Cnidus paid for a visit to Egypt, where he seems to have had diplomatic dealings with King Nekhtanibef II on behalf of Agesilaus II of Sparta.

Eudoxus spent more than a year in Egypt, some of the time in the company of the priests at Heliopolis. He was said to have composed his *Oktaeteris*, or eight-year calendric cycle, during his sojourn with them. Next he settled at Cyzicus in northwestern Asia Minor and founded a school. He also visited the dynast Mausolus in Caria. A second visit to Athens, to which he was followed by some of his pupils, brought a closer association with Plato, but it is not easy to determine mutual influences in their thinking on ethical and scientific matters. It is unlikely that Plato had any influence upon the development of Eudoxian planetary theory or much upon the Cnidian's philosophical doctrine of forms, which recalls Anaxagoras; but it is possible that Plato's *Philebos* was written with the Eudoxian view of *hedone* (that pleasure, correctly understood, is the highest good) in mind.

Back in Cnidus, Eudoxus lectured on theology, cosmology, and meteorology, wrote textbooks, and enjoyed the respect of his fellow citizens. In mathematics his thinking lies behind much of Euclid's *Elements*, especially books V, VI, and XII. Eudoxus investigated mathematical proportion, the method of exhaustion, and the axiomatic method—the "Euclidean" presentation of axioms and propositions may well have been first systematized by him. The importance of his doctrine of proportion lay in its power to embrace incommensurable quantities.

It is difficult to exaggerate the significance of the theory, for it amounts to a rigorous definition of real number. Number theory was allowed to advance again, after the paralysis imposed on it by the Pythagorean discovery of irrationals, to the inestimable benefit of all subsequent mathematics. Indeed, as T. L. Heath declares (*A History of Greek Mathematics*, I [Oxford, 1921], 326–327), "The greatness of the new theory itself needs no further argument when it is remembered that the definition of equal ratios in Eucl. V, Def. 5 corresponds exactly to the modern theory of irrationals due to Dedekind, and that it is word for word the same as Weierstrass's definition of equal numbers."

Eudoxus also attacked the so-called "Delian problem," the traditional one of duplicating the cube; that is, he tried to find two mean proportions in continued proportion between two given quantities. His strictly geometrical solution is lost, and he may also have constructed an apparatus with which to describe an approximate mechanical solution; an epigram ascribed to Eratosthenes (who studied the works of Eudoxus closely) refers to his use of "lines of a bent form" in his solution to the Delian problem: the "organic" demonstration may be meant here. Plato is said to have objected to the use by Eudoxus (and by Archytas) of such devices, believing that they debased pure or ideal geometry. Proclus mentions "general theorems" of Eudoxus; they are lost but may have embraced all concepts of magnitude, the doctrine of proportion included. Related to the treatment of proportion (as found in *Elements* V) was his method of exhaustion, which was used in the calculation of the volume of solids. The method was an important step toward the development of integral calculus.

Archimedes states that Eudoxus proved that the volume of a pyramid is one-third the volume of the prism having the same base and equal height and that the volume of a cone is one-third the volume of the cylinder having the same base and height (these propositions may already have been known by Democritus, but Eudoxus was, it seems, the first to prove them). Archimedes also implies that Eudoxus showed that the areas of circles are to each other as the squares on their respective diameters and that the volumes of spheres to each other are as the cubes of their diameters. All four propositions are found in *Elements XII*, which closely reflects his work. Eudoxus is also said to have added to the first three classes of mathematical mean (arithmetic, geometric, and harmonic) two more, the subcontraries to harmonic and to geometric, but the attribution to him is not quite certain.

Perhaps the most important, and certainly the most influential, part of Eudoxus' lifework was his application of spherical geometry to astronomy. In his book *On Speeds* he expounded a system of geocentric, homocentric rotating spheres designed to explain the irregularities in the motion of planets as seen from the earth. Eudoxus may have regarded his system simply as an abstract geometrical model, but Aristotle took it to be a description of the physical world and complicated it by the addition of more spheres; still more were added by Callippus later in the fourth century b.c. By suitable combination of spheres the periodic motions of planets could be represented approximately, but the system is also, as geometry, of intrinsic merit because of the hippopede, or "horse fetter," an eight-shaped curve, by which Eudoxus represented a planet's apparent motion in latitude as well as its retrogradation.

Eudoxus' model assumes that the planet remains at a constant distance from the center, but in fact, as critics were quick to point out, the planets vary in brightness and hence, it would seem, in distance from the earth. Another objection is that according to the model, each retrogradation of a planet is identical with the previous retrogradation in the shape of its curve, which also is not in accord with the facts. So, while the Eudoxian system testified to the geometrical skill of its author, it could not be accepted by serious astronomers as definitive, and in time the theory of epicycles was developed. But, partly through the blessing of Aristotle, the influence of Eudoxus on popular astronomical thought lasted through antiquity and the Middle Ages. In explaining the system, Eudoxus gave close estimates of the synodic periods of Saturn, Jupiter, Mars, Mercury, and Venus (hence the title of the book, *On Speeds*). Only the estimate for Mars is seriously faulty, and here the text of Simplicius, who gives the values, is almost certainly in error (Eudoxus, frag. 124 in Lasserre).

Eudoxus was a careful observer of the fixed stars, both during his visit to Egypt and at home in Cnidus, where he had an observatory. His results were published in two books, the *Enoptron* ("Mirror") and the *Phaenomena*. The works were criticized, in the light of superior knowledge, by the great astronomer Hipparchus two centuries later, but they were pioneering compendia and long proved useful. Several verbatim quotations are given by Hipparchus in his commentary on the astronomical poem of Aratus, which drew on Eudoxus and was also entitled *Phaenomena*. A book by Eudoxus called *Disappearances of the Sun* may have been concerned with eclipses, and perhaps with risings and settings as well. The statement in the *Suda Lexicon* that he composed an astronomical poem may result from a confusion with Aratus, but a genuine *Astronomia* in hexameters, in the Hesiodic tradition, is a possibility. A calendar of the seasonal risings and settings of constellations, together with weather signs, may have been included in the *Oktaeteris*. His observational instruments included sundials (Vitruvius, *De architectura* 9.8.1).

Eudoxus' knowledge of spherical astronomy must have been helpful to him in the geographical treatise *Ges periodos* ("Tour [Circuit] of the Earth"). About 100 fragments survive; they give some idea of the plan of the original work. Beginning with remote Asia, Eudoxus dealt systematically with each part of the known world in turn, adding political, historical, and ethnographic detail and making use of Greek mythology. His method is comparable with that of such early Ionian logographers as Hecataeus of Miletus. Egypt was treated in the second book, and Egyptian religion, about which Eudoxus could write with authority, was discussed in detail. The fourth book dealt with regions to the north of the Aegean, including Thrace. In the sixth book he wrote about mainland Hellas and, it seems, North Africa. The discussion of Italy in the seventh book included an excursus on the customs of the Pythagoreans, about whom Eudoxus may have learned much from his master Archytas of Tarentum (Eudoxus himself is sometimes called a Pythagorean).

It is greatly to be deplored that not a single work of Eudoxus is extant, for he was obviously a dominant figure in the intellectual life of Greece in the age of Plato and Aristotle (the latter also remarked on the upright and controlled character of the Cnidian, which made people believe him when he said that pleasure was the highest good).

BIBLIOGRAPHY

The biography of Eudoxus in Diogenes Laertius 8.86–8.90 is anecdotal but not worthless. The fragments have been collected, with commentary, in F. Lasserre's book Die *Fragmente des Eudoxos von Knidos* (Berlin, 1966). Eudoxian parts of Euclid's *Elements* are discussed by T. L. Heath in his edition of that work, 2nd ed., 3 vols. (Cambridge, 1926). The mathematical properties of the hippopede have been much studied; see especially O. Neugebauer, *The Exact Sciences in Antiquity*, 2nd ed. (Providence, R.I 1., 1957), 182–183. On the Ges periodos, see F. Gisinger, *Die Erdbeschreibung des Eudoxos von Knidos* (Leipzig-Berlin, 1921). A chronology of Eudoxus' life and travels is G. Huxley, "Eudoxian Topics," in *Greek, Roman and Byzantine Studies*, **4** (1963), 83–96.

See also Oskar Becker, "Eudoxos-Studien," in *Quellen und Studien zur Geschichte der Mathematik, Astronomie und Physik*, Abt. B, Studien, **2** (1933), 311–333, 369–387, and 3 (1936), 236–244, 370–410; Hans Künsberg, *Der Astronom, Mathematiker und Geograph Eudoxos von Knidos*, 2 pts. (Dinkelsbühl, 1888–1890); and G. Schiaparelli, *Scritti sulla storia della astronomia antica*, II (Bologna, 1926), 2–112.

G. L. Huxley