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(*b*. Chios: ft. fifth century B.C.)

astronomy, mathematics.

The notice of Pythagoras in Proclus' summary of the history of geometry is followed by the sentence,[1] ";After him Anaxagoras of Clazomenae touched many questions concerning geometry, as also did Oenopides of Chios, being a little younger than Anaxagoras, both of whom Plato mentioned in the *Erastae*[2] as having acquired a reputation for mathematics." This fixes the birthplace of Oenopides as the island of Chios and puts his active life in the second third of the fifth century B.C.[3] Anaxagoras was born about 500 B.C. and died about 428 B.C. There is confirmation from Oenopides' researches into the "great year" (see below), which suggest that he could not have differed greatly in date from Meton, who proposed his own Great Year in 432. Like Anaxagoras, Oenopides almost certainly conducted his researches in Athens.

In the opening words of the *Erastae*, to which Proclus refers, Socrates is represented as going into the school of Dionysius the grammarian, Plato's own teacher,[4] and seeing two youths earnestly discussing some astronomical subject. He could not quite catch what they were saying, but they appeared to be disputing about Anaxagoras or Oenopides, and to be drawing circles and imitating some inclinations with their hands. In the light of other passages in Greek authors, this is a clear reference to the obliquity of the ecliptic tn relation to the celestial equator. Eudemus in his history of astronomy, according to Dercyllides as transmitted by Theon of Smyrna, related that Oenopides was the first to discover the obliquity of the zodiac,[5] and there appears to have been a wide-spread Greek belief to that effect. Macrobius,[6] for example, drawing on Apollodorus, notes that Apollo was given the epithet *Λοξίας* because the sun moves in an oblique circle from west to east, "as Oenopides says."; Aëtius[7] says that Pythagoras was the first to discover the obliquity of the ecliptic, and that Oenopides claimed the discovery as his own, while Diodorus[8] says that it was from the Egyptian priests and astronomers that he learned the path of the sun to be oblique and opposite to the motion of the stars (that is, fixed stars). He is not recorded as having given any value to the obliquity, but it was probably he who settled on the value of 24°, which was accepted in Greece until refined by Eratosthenes.[9] Indeed, if Oenopides did not fix on this or some other figure, it is difficult to know in what his achievement consisted, for the Babylonians no less than the Pythagoreans and Egyptians must have realized from early days that the apparent path of the sun was inclined to the celestial equator.

In the same passage as that already mentioned, Theon of Smyrna[10] attributes to Oenopides the discovery of the period of the Great Year. This came to mean a period in which all the heavenly bodies returned to their original relative positions, but in early days only the motions of the sun and moon were taken into account and the Great Year was the least number of solar years which coincided with an exact number of lunations. Before Oenopides it was calculated that the sun and the moon returned to the same relative positions after a period of eight years, the octaëteris, in which three years of thirteen months or 384 days were distributed among five years of twelve months or 354 days, giving the solar year an average of days and making the lunar month a shade over days. Oenopides appears to have been the first to give a more exact rendering, possibly in an attempt to take account also of the planetary motions. Aelian records that he set up at Olympia a bronze inscription stating that the Great Year consisted of fifty-nine years, and Aëtius confirms the period,[11] while Censorinus[12] states that he made the year to be days, which implies a Great Year of 21,557 days. Oenopides no doubt fixed upon a period of fifty-nine years, as P. Tannery[13] first showed, by taking the figures of days for a lunar month and 365 days for a solar year, and deducing that in fifty-nine years there would on this basis be exactly 730 lunations. Observation would have established. Tannery argued, that in 730 lunar months there were 21,557 days, from which it follows that the year consists of or 365.37288 days and the month of 29.53013 days. The cycle of nineteen years that Meton and Euctemon proposed in 432 B.C., on which the present ecclesiastical calendar is ultimately based, gives a year of or 365.26315 days and a month of 29.53191 days. The modern value for the sidereal year is 365.25637 days and for the mean synodic month is 29.53059 days.

Oenopides' figure for the lunar month is, therefore, if Tannery is right, more exact than that of Meton (indeed, very exact, for the error does not exceed a third of a day in the whole fifty-nine years), but his figure for the year is considerably less exact, amounting to seven days for the whole period.

But could Oenopides have calculated at that date so exact a figure for the mean synodic month (which requires a long period of observation) when he had so inaccurate a figure for the solar year (to establish which as about days would require only a few consecutive observations of the times of the solstices)? In a private communication G. J. Toomer is skeptical. He believes that Oenopides did not assign any specific number of days to the Great Year, and the year-length of days attributed to him by Censorinus is a later reconstruction. Someone at this later date asked himself what is the length of the year according to Oenopides. He answered the question by taking the standard length of the mean synodic month of his own time, namely (expressed sexagesimally) 29; 31, 50. 8, 20 days. This is found in Geminus as well as the *Almagest* and was a fundamental

Babylonian parameter adopted by Hipparchus. The hypothetical investigator multiplied this by the 730 months of Oenopides' period and obtained 21,557 days and a fraction of a day. Dividing 21,557 by the 59 years of the cycle, he declared that Oenopides' year consisted of days—that is to say, the figure is a later deduction using a completely anachronistic value for the month. This is credible. The critical question is whether Oenopides could have had at his disposal records extending over more than his own adult life showing that in 730 lunations there were 21,557 days; if he did, it would be strange for him not to have known a more exact figure for the year.

Tannery[14] holds that Oenopides' Great Year was intended to cover the revolutions of the planets and of the sun and moon, but he is forced to conclude that Oenopides could not have taken them all into account. The ancient cosmographers gave the time for Saturn to traverse its orbit as thirty years, for Jupiter twelve years, and for Mars two years, which would allow two revolutions for Saturn in the Great Year, five for Jupiter, and thirty or thirty-one for Mars. If the latter figure is taken as the more correct, and the figure of 21,557 days in the Great Year is divided by these numbers, we get values for the revolutions of the three planets which do not differ by more than one percent from the correct values. Tannery considers that the degree of inaccuracy ought rather to be judged by the error in the mean position of the heavenly body at the end of the period; this would be only 2° in the case of Saturn and 9° for the sun, but 107° for Mars. If Oenopides had indicated in which sign of the zodiac the planet would be found at the end of the period, the error would have been obvious when the time came.

According to Achilles Tatius,[15] Oenopides was among those who believed that the path of the sun was formerly the Milky Way; the sun turned away in horror from the banquet of Thyestes and has ever since moved in the path defined by the zodiac.

Two propositions in geometry were discovered by Oenopides according to Eudemus as preserved by Proclus. Commenting on Euclid 1.12 (";to a given infinite straight line from a given point which is not upon it to draw a perpendicular straight line") Proclus[16] says; "Oenopides was the first to investigate this problem, thinking it useful for astronomy. But, in the ancient manner, he calls the perpendicular'a line drawn gnomon-wise,' because the gnomon is at right angles to the horizon." When he comes to Euclid 1.23 (";on a given straight line and at a given point on it, to construct a rectilineal angle equal to a given rectilineal angle") Proclus[17] comments: "This problem is rather the discovery of Oenopides, as Eudemus relates." Heath[18] justly observes that the geometrical reputation of Oenopides can hardly have rested on such simple propositions as these, nor could he have been the first to draw a perpendicular in practice. Possibly he was the first to draw a perpendicular to a straight line by means of a ruler and compass (instead of a set-square), and it may have been he who introduced into Greek geometry the limitation of the use of instruments in all plane constructions—that is, in all problems equivalent to the solution of algebraic equations of the second degree—to the ruler and compasses. He also may have been the first to give a theoretical construction to Euclid I.23.

This question bears on an interesting problem to which Kurt von Fritz[19] has devoted much attention. According to Proclus,[20] "Zenodotus, who stood in the succession of Oenopides but was one of the pupils of Andron, distinguished the theorem from the problem by the fact that the theorem seeks what is the property predicated of its subject-matter, but the problem seeks to find what is the cause of what effect" (as translated by Heath,[21] but Glenn R. Morrow[22] translates τίνος ὄντος τί ἐστιν as "under what conditions something exists"). The meaning was probably no clearer to Proclus than it is to us, but it may be that Oenopides was one of those who helped to create the distinction between theorems and problems. Taken in conjunction with what was said in the previous paragraph, it would appear that he made a special study of the methodology of mathematics.

Oenopides had an original theory to account for the Nile floods. He held that the water beneath the earth is cold in the summer and warm in the winter, a phenomenon proved by the temperature of deep wells. In winter, when there are no rains in Egypt, the heat that is shut up in the earth carries off most of the moisture, but in summer the moisture is not so carried off and overflows the Nile. Diodorus Siculus, who recorded the theory, reasonably objected that other rivers of Libya, similar in position and direction to the Nile, are not so affected.[23]

It is related that Oenopides, seeing an uneducated youth who had amassed many books, observed, "Not in your coffer but in your breast."[24] Sextus Empiricus[25] says that Oenopides laid special emphasis on fire and air as first principles. Aëtius[26] says that Diogenes (of Apollonia), Cleanthes, and Oenopides made the soul of the world to be divine. Cleanthes left a hymn to Zeus in which the universe is considered a living being with God as its soul, and if Aëtius is correct then Oenopides must have anticipated these views by more than a century. Diogenes is known to have revived the doctrine of Anaximenes that the primary substance is air, and presumably Oenopides in part shared this view but gave equal primacy to fire as a first principle.

NOTES

1. Proclus: *Procli Diadochi in primum Euclidis, Elementorum librum commentarii*, G. Friedlein, ed. (Leipzig, 1873, repr. 1967), pp. 65.21–66.4.

2. Plato, *Erastae (Amatores)*, 132 A.B, in J. Burnet, ed., *Platonis opera*, II (Oxford, 1901, repr. 1946). The Platonic authorship of the *Erastae* has been denied, but this does not affect its evidence for Oenopides.

3. The "Vita Ptolemaei e schedis Savilianis descripta" found in a Naples MS (Erwin Rohde, *Kleine Schriften*, I [Tübingen-Leipzig, 1901], p. 123, n. 4) is therefore in error in saying that Oenopides lived "towards the end of the Peloponnesian war" but more accurate in adding "at the same time as Gorgias the orator and Zeno of Elea and, as some say, Herodotus, the

historian, of Halicarnassus." Diogenes Laërtius IX. 41 (H.S. Long, ed., II [Oxford, 1964], 450 23–25) says that Democritus "would be a contemporary of Archelaus, the pupil of Anaxagoras, and of the circle of Oenopides"; and he adds that Democritus makes mention of Oenopides—presumably in a work that has nor survived.

4. Diogenes Laërtius III. 4 (H.S. Long, ed., I [Oxford, 1964], 122.13).

5. Theon of Smyrna, *Expositio rerum mathematicarum ad legendum Platonem utilium*, E. Hiller, ed. (Leipzig, 1878), 198.14–16. H. Diels's conjecture λόξωσιν (";obliquity") for διάζωσιν ("girdle") is almost certainly correct.

6. Macrobius, *Saturnalia* 1.17.31, F. Eyssenhardt, ed., 2nd ed. (Leipzig, 1893), 93.28–94.2.

7. Aëtius, II.12, 2, Ps.-Plutarch, *De placitis philosophorum*, B. N. Bernardakis, ed. (*Plutarchi Chaeronensis Moralia*, Teubner, V [Leipzig, 1893]), 284.8–9.

8. Diodorus Siculus, *Bibliotheca historica*, I.98.3, C. H. Oldfather, ed., I (London-New York, 1933), pp. 334.29, 337.4.

9. Proclus, *In primum Euclidis*, Friedlein, ed., p. 269.11–21, states that Euclid IV.16 (which shows how to construct a regular polygon of fifteen sides in a circle, each side therefore subtending an angle of 24° at the center) was inserted "in view of its use in astronomy." Erastosthenes found the distance between the tropical circles to be 11/83 of the whole meridian, giving a value for the obliquity of 23°51′20″ as Ptolemy records in *Syntaxis*, J. L. Heiberg, ed., I.12 (Leipzig, 1898), p. 68.3–6.

10. Theon of Smyrna, *op. cit.*, p. 198.15.

11. Aelian, *Varia historia*, X.7, C.G. Kuehn ed., II (Leipzig, 1780), 65–67; Aëtius, II.32.2, *op. cit.*, 316.1–7.

12. Censorinus, *De die natali* 19.2, F. Hultsch, ed. (Leipzig, 1867), 40.19–20.

13. Paul Tannery, *Mémories scientifiques*, II (Toulouse–Paris, 1912), 359.

14.*Ibid.*, 358, 362–363.

15. Achilles Tatius, *Introductio in Aratum* 24, E. Maass ed., *Commentariorum in Aratum reliquiae* (Berlin, 1898), p. 55.18–21. (Cambridge, Mass. 1919, repr. Hildesheim, 1967), notes that certain of the so-called Pythagoreans held the same view and pointedly asks why the zodiac circle was not scorched in the same way.

16. Proclus, *In primum Euclidis*, Friedlein, ed., 283.7–10.

17.*Ibid.*, 333.5–6.

18. Thomas Heath, *A History of Greek Mathematics*, I (Oxford, 1921), 175.

19. Kurt von Fritz, "Oinopides" in Pauly-Wissowa, **17** (Stuttgart, 1937), cols. 2267–2272.

20. Proclus, *In primum Euclidis*, Friedlein, ed., p. 80.15–20.

21. Thomas L. Heath, *The Thirteen Books of Euclid's Elements,* 2nd ed., I (Cambridge, 1926; New York, 1956), 126.

22. Glenn R. Morrow, *Proclus: A Commentary on the First Book of Euclid's Elements* (Princeton, 1970), p. 66.

23. Diodorus Siculus I. 41.1–3. *op. cit.*, vol. 1, pp. 144.23–147.17.

24.*Gnomologium Vaticanum* 743, L. Sternbach, ed. (Berlin, 1963), n. 420.

25. Sextus Empiricus, *Pyrrhoniae hypotyposes,* iii. 30.

26. Aëtius, 1.7, 17, *op. cit.*, 284.8–9.

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No works by Oenopides have survived, nor are the titles of any known. The ancient references to him are collected in Diels-Kranz, *Die Fragmente der Vorsokratiker*, 6th ed. (Dublin-Zurich, 1969), 41(29), 393–395. The most useful modern studies are

Paul Tannery, “La grande année d’Aristarque de Samos,” in *Mémoires de la Société des sciences physiques et naturelles de Bordeaux,* 3rd ser., **4** (1888), 79–96, reprinted in *Mémoires scientifiques*, J. L. Heiberg and H. G. Zeuthen, ed., **2** (Paris-Toulouse, 1912), 345–366; Thomas Heath, *Aristarchus of Samos*. *The Ancient Copernicus* (Oxford, 1913), 130–133; Kurt von Fritz, “Oinopides,” in Pauly-Wissowa-Kroil, *Real-Encyclopädie der classischen Altertumswisseenschaft*, **17** (Stuttgart, 1937), cols. 2258–2272; D. R. Dicks, *Early Greek Astronomy to Aristotle* (London, 1970). 88–89, 157, 172; Jürgen Mau, “Oinopides,” in *Der Kleine Pauly*, IV (Stuttgart, 1972), cols. 263–264.

Ivor Bulmer-Thomas