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(b. Athens[?];fl. earlysecond century b.c.)

mathematics.

Zenodorus is known to have been the author of a treatise on isoperimetric figures-plane figures of equal perimeter but differing areas, and solid figures of equal surface but differing volumes.[1] This has not survived as such, but it is epitomized in Pappus' *Collection* in the commentary by Theon of Alexandria on Ptolemy's *Almagest* and in the anonymous *Introductioin to the Almagest*

Older writers placed the date of Zenodorus in the fifth century B.C., but this was through a mistaken identification with a Zenodrus who is said by Proclus to have belonged "to the succession of Oenopides."[2] From several references by Zenodorus to Archimedes, Nokk rightly concluded that he must have flourished after, say, 200 b.c.[3] Because Quitilian showed awareness of isoperimetry, F. Hultsch and M. Cantor conjectured a lower limit of a.d. 90 for his life; but Zenordorus made no claim to have been the only, or even the first, person to have written on the subject and the deduction is erroneous.[4] Until recently all that could be said with certainly was that he lived after Archimedes and before Pappus, say 200 B.C-A.D. 300; but it is now established that he must have flourished in the early part of the second century B.C. Afragment from a biography of the Epicurean philosopher Philonides, found in the Herculaneum papyrus roll no. 1044, mentions among his acquaintances a Zenodorus at least once and perhaps twice. In publishing the fragment, W.Crönert identified him with the mathematician.[5] G.J.Toomer, in an elaborate study of occurrences of the name, concluded that unless Zenodorus was a Hellenized Semite (which is not impossible), the comparative rarity of the name confirms Cronert's identification.[6] This is made certain by the fact that in the Arabic translation of Diocles' treatise On Burning Mirrors, which has been discovered and edited by Toomer, Zenodorus is mentioned as having posed a problem to Diocles. Toomer's literal translation reads:

The book of Diocles on burning mirrors. He said: Pythion the geometer, who was of the people of Thasos.wrote a letter to Conon in which he asked him how to find a mirror surface such that when it is placed facing the sun the rays reflected from it meet the circumference of a circle. And when Zenodorus the astronomer came down to Arcadia and was introduced ['?] to us, he asked us how to find a mirror surface such that when it is placed facing the sun the rays reflected from it meet a point and thus cause burning. So we want to explain the answer to the problem posed by Pythion and to that posed by Zenodorus; in the couse of this we shall make use of the premises established by our predecessors.[7]

It is no bar to the identification of this Zenodorus with the author of the isoperimetric propositions that he is here called an astronomer. There was considerable overlap between mathematics and astronomy-Euclid, Archimedes, and Apollonius are notable examples-and Zenodorus may well have written astronomical works of which we have no knowledge. A Vatican manuscript gives a catalog of astronomers–οἱ περί τοῦ πόλου συν τύξαντεςwhich includes the name Zenodorus.[8] In accordance with the principle of not multiplying entities unnecessarily, it would seem that he, too, should be identified with the mathematician

The Herculaneum fragments mention two visits by Zenodorus to Athens. On the onomastic evidence he could be from Cyrene, or Ptolemaic Egypt, or possibly from Chios or Erythrae. But the name is attested eight or nine times in Athens: and on the assumption that he was an Athenian, Toomer has plausibly identified him with a member of the Lamptrai family mentioned in an inscription that lists contributions for some unknown purpose during the archonship of Hermogenes (183-182 B.c.).[9]

It is only in Theon's commentary that the isoperimetridc propositions are specificlly attributed to Zenodorus, but the passages in Pappus' *Collection* and the *Introduction* are so similar that they also must be derived from him. They are not, however, simply lifted from Zenodorus; there are considerable differences in the order and wording of the propositions in the three sources, and the question which is nearest to the original has given rise to some discussion. In all probability Pappus, like Theon, reproduced the propositions of Zenodorus at the relevant point in his commentary on the first book of the *Almagest*, where Ptolemy says "Among different figures having an equal perimeter, since that which has the more angles is greater, of plane figures the circle is the greatest and of solid figures the spehre."[10] If so, this may have been the most exact reproduction of Zenodorus' text, ascribed to him by name as in Theon; when he came to compile his *Collection* Pappus varied the presentation, added the proposition "Of all segments of a circle having equal circumferences, the semicircle is the greatest in area," and proceeded to a disquisition on the semiregular solids of Archimedes.[11] Theon would have been drawn upon Pappus, and the anonymous author of the *Introduction* upon both.

It would appear that Zenodorus' treatise contained fourteen propositions. There is agreement in the three versions that the first was "Of regular polygons having the same perimeter, the greater is that which has the more angles." The final proposition, stated but not actually proved, was almost certainly" If a sphere and a regular polyhedron have the same surface [area], the sphere is the greater." In between came such propositions as the following:

"If a circle and a regular polygon have the same perimeter, the circle is the greater."

"If on the base of an isosceles triangle there be set up a non-isosceles triangle having the same perimeter, the isosceles triangle is the greater."

"Given two similar right-angled triangles, the squareon the sum of the hypotenuses is equal to the sum of the squares on the corresponding sides taken together."

"If on unequal bases there be set up two similar isosceles triangles, and on the same bases there be set up two dissimilar isosceles triangles having together the same perimeter as the two similar triangles, the sum of the similar triangles is greater than the sum of the dissimilar triangles."

"Among polygons with an equal perimeter and an equal number of sides, the regular polygon is the greatest."

"If a regular polygon [with an even number of sides] revolves about one of the longest diagonals, there is generated a solid bounded by conical surfaces that is less than the sphere having the same surface."

"Each of the five regular solids is less than the sphere with equal surface."

There is no little subtlely in the reasoning; indeed, rigorous proofs of the isoperimetric properties of the circle and sphere had to wait until H. A. Schwarz provided them in 1884.[12]

NOTES

1. The Greek title is given by Theon, *Commentaires de Papus et de Théon d' Alexandire sur l'Almageste, A. Rome, ed, II, 355.4, as Περί ἴσοπεριμέτρων σχημάτων. The earlier editors had read ίσομέτρων, but Rome showed that this was a variant reading in some MSS. "Isoperimetric" maskes better sense than "isometric" and is confirmed by the comment of Simplicius in his Commentarium in Aristotelis de caelo*, J. L. Heiberg, ed. in *Commentaria in Aristotelem Graeca,* VII (Berlin, 1894),412; δέδεικτι…παρά Ἄρχιμήδους καί παρά Ζηνοδώρου πλατύτερον, ὅτι τῶν ἰσοπεριμέτρωνσχημάτν τι τῶν ἰσοπεριμέτρωνσχεμάτωυν πολυχωρητότερός έν δέ τοῖς στερεοίσιν ή σφαιρα.

2. Proclus, *In primum Euclidis,* G. Friedlein, ed. (Leipzig, 1873; repe. Hildesheim, 1967),80.15–16; English trans, by Glenn R. Morrow, *Proclus: A Commentary on the first Book of Euclid's Elements* (Princeton, 1970),d66. There is one genuie refernce to Zendorus in Proclus, Frieldlein ed., 165. 24, where it is asserted that there are fur-sided trioangles, called "barblike" by some but "hollow-angled" (κοιλογώνια), by Zenodorus. The reference is to a quardrilateral with one angle. It was formarly believed that this word occurred in Theon's version, and Nokk (see note 3)used this as an argument for believing Theon's text to be the nearest the original;but Rome, *op. cit.,* 371, has shown that the word is interpolated and may, indeed, have been interpolated before Proclus read Theon. It remains in the *Introduction to the Almagest: Pappi Alexandrini Collectionis quae supersunt …,* F. Hultsch, ed., III 1194. 12, 13, 16.

3. Nokk, *Zenodorus' Abhandlung iiber die isoperimetrischen Figuren,* 27–29.

4. Quintilian, *De institutione oratorio* (1. 10, 39-45), L. Radermacher, ed. (Leipzig, 1907: 6th ed., enl. and c orr. b y V. Buchheit, 1971), 1, 63.12-64.12; also M. Winterbottom, ed. (Oxford, 1970), 1, 65.28-66.31. But B. L. van der Waerden, *Science Awakening*, 2nd English ed., 268, is in error in saying that Quintilian "mentions" Zenodorus. Also see F. Hultsch, *op. cit*., III, 1190; and M. Cantor, *Vorlesungen fiber Geschichte der Mathematik,* 3rd ed., I (Leipzig, 1907), 549.

5. W. Crönert, "Der Epikureer Philondies," The name occurs in fr. 31, II, 4–5 (Crönert, 953–954) and probably in fr. 34,1. 1 (Crönert,954).

6. G. J. Toomer, "The Mathematician Zenodorus," 186.

7.*ibid.,* 190–191. In both cases where the name occurs, Zendorus is an emendation, but Toomer regards it as certain.

8. Vaticanus Graecus 381, published by Ernst Maass in *Hermes,***16** (1881), 388, and more definitively in his *Aratea* (Berlin, 1892), 123 Maass himself indentified the Zenodorus of the catalog with the mathematician.

9. Toomer,*op.cit.,* 187-190.

10. Ptolemy, *Syntaxis mathematica (Almagest),* 1.3: *Claudii Ptolemaei Opera quae exstant omnia,* J.L. Heiberg., ed., I (Leipzig,1898), 13.16–19.

11. If Pappus in his commentary gave credit to Zenodorus, as Theon did, this would help to explain why Zenodorus is not mentioned in the *Collection;* there is no question of Pappus' trying to appropriate another's work as his own.

12. H. A. Schwarz, "Beweis des Satzes, dass die Kugel kleinere Oberfläche besitzt. als jeder andere Körper gleichen Volumens," in *Nachrichten von der Gesellschaft der Wissenschaften zu Göttingen* (1884). 1–13, repr. in Schwarz's *Gesammelte mathematische Abhandlungen,* II (Berlin, 1890), 327–340.

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II.Secondary Literature. See the following, listed chronologically: Nokk,*Zenodorus' Abhandlung über die isoperimetrischen Figuren nach den Auszügen welche uns die Alexandriner Theon und Pappus aus derselben iiberliefert haben* (Freiburg im Breisgau, 1860): James Gow, *A short History of Greek Mathematics* (cambridge, 1884), 271–272; W. Crönert, "Der Epikureer Philonides," in *Sitzungsberichte der Preussischen Akademie der Wissenschaften zu Berlin* (1900), 942–959; W. Schmidt, "Zur Geshichte der Isoperimetrie im Altertum," in *Bibliotheca mathematica,* 3rd ser., **2** (1901), 5–8: T. L. Heath, *A History of Greek Mathematics,* II (Oxford, 1921), 207–213; W. Müllet, "Das isoperimetrische problem im Altertum," in *Sudhoffs Archiv,***37** (1953), 39–71, with a German trans. of Theon's epitome: B. L. van der Waerden, *Science Awakening,* English trans. of *Ontwakende Wetenschap* with author's additions, 2nd ed. (Groningen, N.d.), 268–269; and G.J. Toomer, "The Mathematician Zenodorus," in *Greek, Roman and Byzantine Studies,***13** (1972), 177–192.

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