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(*fl*. Athens, fourth century b.c.)

mathematics.

According to Proclus (*Commentary on Euclid, Book I;* Friedlein, ed., 67.8–12),"Amyclas of Heraclea, one of the associates of Plato, and Menaechmus, a pupil of Eudoxus who had also studied with Plato, and his brother Dinostratus made the whole of geometry still more perfect." Dinostratus therefore lived in the middle of the fourth century b.c., and although there is no direct evidence his Platonic associations point to Athens as the scene of his activities. He must have ranged over the whole field of geometry, although only one of his achievements is recorded and the record bristles with difficulties. This is the application of the curve known as the quadratrix to the squaring of the circle.

The evidence rests solely on Pappus (*Collection*, IV. 30; Hultsch ed., 250.33–252.3), whose account is probably derived from Sporus (third century). Pappus says: "For the squaring of the circle there was used by Dinostratus, Nicomedes and certain other later persons a certain curve which took its name from this property; for it is called by them square-forming" (τετραγωνίζονσα *sc*. γραμμή quadratrix). The curve was not discovered by Dinostratus but by Hippias, for Proclus, whose account is derived from Eudemus, says: "Nicomedes trisected any rectilineal angle by means of the conchoidal curves, of which he had handed down the origin, order and properties, being himself the discoverer of their special characteristic. Others have done the same thing by means of the quadratrices of Hippias and Nicomedes" (Friedlein, ed., 272.3–10). It has been usual, following Bretschneider, to deduce that Hippias first discovered the curve and that Dinostratus first applied it to finding a square equal in area to a circle, whence it came to be called quadratrix. It is no objection that Proclus writes of the "quadratrix of Hippias," for we regularly speak of Dinostratus' brother Menaechmus as discovering the parabola and hyperbola, although these terms were not employed until Apollonius; nor is there any significance in the plural "quadratrices." It is a more serious objection that Proclus (Friedlein, ed., 356.11) says that different mathematicians have been accustomed to discourse about curves, showing the special property of each kind, as "Hippias with the quadratrices," for this suggests that Hippias may have written a whole treatise on such curves, and he could hardly have failed to omit the circle-squaring aspect; against this may be set the fact that the angle-dividing property of the curve is more fundamental than its circle-squaring property. It is also odd that Proclus does not mention the name of Dinostratus in connection with the quadratrix; nor does Iamblichus, as quoted by Simplicius (*On the Categories of Aristotle*, 7; Kalbfleisch, ed., 192.15–25), who writes of the quadrature of the circle as having been effected by the spiral of Archimedes, the quadratrix of Nicomedes, the "sister of the cochloid" invented by Apollonius, and a curve arising from double motion found by Carpus. Despite all these difficulties, posterity has firmly associated the name of Dinostratus with the quadrature of the circle by means of the quadratrix.

Pappus, IV.30 (Hultsch, ed., 252.5–25), describes how the curve is formed. Let *ABCD* be a square and *BED* a quadrant of a circle with center *A*. If the radius of the circle moves uniformly from *AB* to *AD* and in the same time the line *BC* moves, parallel to its original

position, from *BC* to *AD*, then at any given time the intersection of the moving radius and the moving straight line will determine a point *F*. The path traced by *F* is the quadratrix. If *G* is the point where it meets *AD*, it can be shown by *reductio per impossibile* (Pappus, IV.31–32; Hultsch, ed., 256.4-258.11) that

arc $BED:AB = AB:AG$.

This gives the circumference of the circle, the area of which may be deduced by using the proposition, later proved by Archimedes, that the area of a circle is equal to a right triangle in which the base is equal to the circumference and the perpendicular to the radius. If Dinostratus rectified the circle in the manner of Pappus' proof, it is one of the earliest examples in Greek mathematics of the indirect proof *per impossible* so widely employed by Euclid. (Pythagoras before him is said to have used the method to prove the irrationality of and Eudoxus must have used it for his proofs by exhaustion.) It is not out of the question that a mathematician of the Platonic school could have proved Archimedes, *Measurement of a Circle*, proposition 1, which is also proved *per impossible*, but he may only have suspected its truth without a rigorous proof.

According to Pappus, IV.31 (Hultsch, ed., 252.26–256.3), Sporus was displeased with the quadrature because the very thing that the construction was designed to achieve was assumed in the hypothesis. If *G* is known, the circle can indeed be rectified and thence squared, but Sporus asks two questions: How is it possible to make the two points moving from *B* reach their destinations at the same time unless we first know the ratio of the straight line *AB* to the circumference *BED?* Since in the limit the radius and the moving line do not intersect but coincide, how can *G* be found without knowing the ratio of the circumference to the straight line? Pappus endorsed these criticisms. Most modern mathematicians have agreed that the second is valid, for *G* can be found only by closer and closer approximation, but some, such as Hultsch, have thought that modern instrument makers would have no difficulty in making the moving radius and the moving straight line reach *AD* together. It is difficult, however, as Heath argues, to see how this could be done without, at some point, a conversion of circular into rectilinear motion, which assumes a knowledge of the thing sought. Both objections would therefore seem to be valid.

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