# Eratosthenes of Cyrene

Born: 276 BC in Cyrene, North Africa (now Shahhat, Libya)

Died: 194 BC in Alexandria, Egypt

Eratosthenes was born in Cyrene which is now in Libya in North Africa. His teachers included the scholar Lysanias of Cyrene and the philosopher Ariston of Chios who had studied under Zeno, the founder of the  Stoic school of philosophy. Eratosthenes also studied under the poet and scholar Callimachus who had also been born in Cyrene. Eratosthenes then spent some years studying in Athens.

The library at Alexandria was planned by Ptolemy I Soter and the project came to fruition under his son Ptolemy II Philadelphus. The library was based on copies of the works in the library of  Aristotle. Ptolemy II Philadelphus appointed one of Eratosthenes' teachers Callimachus as the second librarian. When Ptolemy III Euergetes succeeded his father in 245 BC and he persuaded Eratosthenes to go to Alexandria as the tutor of his son Philopator. On the death of Callimachus in about 240 BC, Eratosthenes became the third librarian at Alexandria, in the library in a temple of the Muses called the Mouseion. The library is said to have contained hundreds of thousands of papyrus and vellum scrolls.

Despite being a leading all-round scholar, Eratosthenes was considered to fall short of the highest rank.  Heath writes:-

[Eratosthenes] was, indeed, recognised by his contemporaries as a man of great distinction in all branches of knowledge, though in each subject he just fell short of the highest place. On the latter ground he was called Beta, and another nickname applied to him, Pentathlos, has the same implication, representing as it does an all-round athlete who was not the first runner or wrestler but took the second prize in these contests as well as others.

Certainly this is a harsh nickname to give to a man whose accomplishments in many different areas are remembered today not only as historically important but, remarkably in many cases, still providing a basis for modern scientific methods.

One of the important works of Eratosthenes was Platonicus which dealt with the mathematics which underlie  Plato's philosophy. This work was heavily used by  Theon of Smyrna when he wrote Expositio rerum mathematicarum and, although Platonicus is now lost,  Theon of Smyrna tells us that Eratosthenes' work studied the basic definitions of geometry and arithmetic, as well as covering such topics as music.

One rather surprising source of information concerning Eratosthenes is from a forged letter. In his commentary on Proposition 1 of  Archimedes' Sphere and cylinder Book II,  Eutocius reproduces a letter reputed to have been written by Eratosthenes to Ptolemy III Euergetes. The letter describes the history of the problem of the  duplication of the cube and, in particular, it describes a mechanical device invented by Eratosthenes to find line segments x and y so that, for given segments a and b,

a : x = x : y = y : b.

By the famous result of  Hippocrates it was known that solving the problem of finding two mean proportionals between a number and its double was equivalent to solving the problem of duplicating the cube. Although the letter is a forgery, parts of it are taken from Eratosthenes' own writing. The letter, which occupies an important place in the history of mathematics, is discussed in detail in . An original Arabic text of this letter was once kept in the library of the St Joseph University in Beirut. However it has now vanished and the details given in  come from photographs taken of the letter before its disappearance.

Other details of what Eratosthenes wrote in Platonicus are given by  Theon of Smyrna. In particular he described there the history of the problem of duplicating the cube (see  Heath):-

... when the god proclaimed to the Delians through the oracle that, in order to get rid of a plague, they should construct an alter double that of the existing one, their craftsmen fell into great perplexity in their efforts to discover how a solid could be made the double of a similar solid; they therefore went to ask  Plato about it, and he replied that the oracle meant, not that the god wanted an alter of double the size, but that he wished, in setting them the task, to shame the Greeks for their neglect of mathematics and their contempt of geometry.

Eratosthenes erected a column at Alexandria with an epigram inscribed on it relating to his own mechanical solution to the problem of doubling the cube:-

If, good friend, thou mindest to obtain from any small cube a cube the double of it, and duly to change any solid figure into another, this is in thy power; thou canst find the measure of a fold, a pit, or the broad basin of a hollow well, by this method, that is, if thou thus catch between two rulers two means with their extreme ends converging. Do not thou seek to do the difficult business of  Archytas's cylinders, or to cut the cone in the triads of  Menaechmus, or to compass such a curved form of lines as is described by the god-fearing  Eudoxus. Nay thou couldst, on these tablets, easily find a myriad of means, beginning from a small base. Happy art thou, Ptolemy, in that, as a father the equal of his son in youthful vigour, thou hast thyself given him all that is dear to muses and Kings, and may be in the future, O Zeus, god of heaven, also receive the sceptre at thy hands. Thus may it be, and let any one who sees this offering say "This is the gift of Eratosthenes of Cyrene".

Eratosthenes also worked on  prime numbers. He is remembered for his prime number sieve, the 'Sieve of Eratosthenes' which, in modified form, is still an important tool in  number theory research. The sieve appears in the Introduction to arithmetic by  Nicomedes.

Another book written by Eratosthenes was On means and, although it is now lost, it is mentioned by  Pappus as one of the great books of geometry. In the field of geodesy, however, Eratosthenes will always be remembered for his measurements of the Earth.

Eratosthenes made a surprisingly accurate measurement of the circumference of the Earth. Details were given in his treatise On the measurement of the Earth which is now lost. However, some details of these calculations appear in works by other authors such as  Cleomedes,  Theon of Smyrna and  Strabo. Eratosthenes compared the noon shadow at midsummer between Syene (now Aswan on the Nile in Egypt) and Alexandria. He assumed that the sun was so far away that its rays were essentially parallel, and then with a knowledge of the distance between Syene and Alexandria, he gave the length of the circumference of the Earth as 250,000  stadia.

Of course how accurate this value is depends on the length of the stadium and scholars have argued over this for a long time. The article  discusses the various values scholars have given for the stadium. It is certainly true that Eratosthenes obtained a good result, even a remarkable result if one takes 157.2 metres for the stadium as some have deduced from values given by  Pliny. It is less good if 166.7 metres was the value used by Eratosthenes as Gulbekian suggests in .

Several of the papers referenced, for example ,  and , discuss the accuracy of Eratosthenes' result. The paper  is particularly interesting. In it Rawlins argues convincingly that the only measurement which Eratosthenes made himself in his calculations was the zenith distance on the summer  solstice at Alexandria, and that he obtained the value of 712'. Rawlins argues that this is in error by 16' while other data which Eratosthenes used, from unknown sources, was considerably more accurate.

Eratosthenes also measured the distance to the sun as 804,000,000 stadia and the distance to the Moon as 780,000 stadia. He computed these distances using data obtained during lunar eclipses.  Ptolemy tells us that Eratosthenes measured the tilt of the Earth's axis with great accuracy obtaining the value of 11/83 of 180, namely 23 51' 15".

The value 11/83 has fascinated historians of mathematics, for example the papers and  are written just to examine the source of this value. Perhaps the most commonly held view is that the value 11/83 is due to  Ptolemy and not to Eratosthenes.  Heath argues that Eratosthenes used 24 and that 11/83 of 180 was a refinement due to  Ptolemy. Taisbak  agrees with attributing 11/83 to  Ptolemy although he believes that Eratosthenes used the value 2/15 of 180. However Rawlins  believes that a  continued fraction method was used to calculate the value 11/83 while Fowler proposes that the anthyphairesis (or  Euclidean algorithm) method was used (see also).

Eratosthenes made many other major contributions to the progress of science. He worked out a calendar that included leap years, and he laid the foundations of a systematic chronography of the world when he tried to give the dates of literary and political events from the time of the siege of Troy. He is also said to have compiled a star catalogue containing 675 stars.

Eratosthenes made major contributions to geography. He sketched, quite accurately, the route of the Nile to Khartoum, showing the two Ethiopian tributaries. He also suggested that lakes were the source of the river. A study of the Nile had been made by many scholars before Eratosthenes and they had attempted to explain the rather strange behaviour of the river, but most like  Thales were quite wrong in their explanations. Eratosthenes was the first to give what is essentially the correct answer when he suggested that heavy rains sometimes fell in regions near the source of the river and that these would explain the flooding lower down the river. Another contribution that Eratosthenes made to geography was his description of the region "Eudaimon Arabia", now the Yemen, as inhabited by four different races. The situation was somewhat more complicated than that proposed by Eratosthenes, but today the names for the races proposed by Eratosthenes, namely Minaeans, Sabaeans, Qatabanians, and Hadramites, are still used.

Eratosthenes writings include the poem Hermes, inspired by astronomy, as well as literary works on the theatre and on  ethics which was a favourite topic of the Greeks. Eratosthenes is said to have became blind in old age and it has been claimed that he committed suicide by starvation.

J J O'Connor and E F Robertson