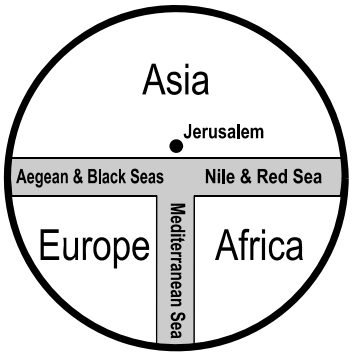
Preamble Earth's 5.972 sextillion metric tons or 5.9722 x 10^{24} kilograms mass is far greater than can be accounted for if we assume that it is made only of the rocks we walk upon or can sample directly by geological hammer or rock drill.[1] Compared to water, rocks are only rarely three times heavier whereas weight and size measurements of Earth find it to be five and a half times heavier.

d2 Earth's figure and weight < length of the degree >

> [Eratosthenes] estimated the distance at 5000 stades, a number so round as to create the suspicion that it was more a guess than a measurement. —John Lewis Heilbron, *Geometry Civilized*.[2]

Earth was assumed to be spherical after Aristotle's "proof" of this from 1) the shadow that eclipses Moon is circular and 2) the North celestial pole rises as one travels north. Earth's size was first convincingly and accurately calculated by Eratosthenes (276-194 BCE) after a (supposed) visit to Syênê (Aswan), which though north of the tropic by half a degree is so close that at summer solstice noon (reportedly) no shadow is cast by a sunlit gnomon (means "to know"), which is a vertical stick or an obelisk. In Alexandria, his home town 5000 stades to the north, at noon on the same day, the ratio of shadow length on a flat horizontal surface to a gnomon's height is 1/8 (geometrically a 1/50 wedge portion of a circle of radius 8 units). Keeping the numbers nice (that is divisible by the Babylonian number basis 60), he estimated Earth's circumference to be 252,000 stades (each 120 paces, which was the distance covered by a plough before turning, or 600 feet, or 157.50 m as argued for by Livio C. Stecchini).[3] Columbus' 1492 underestimation notwithstanding, this information was never really lost, although, after the fall of the Roman Empire in the 5th century, the expansion of the Church led to a diminished knowledge for the common person. In the Middle Ages, from the 7th through 12th centuries, map cartography devolved to a simplified and stylized Church-sponsored map of the world known as a **T-O** (*orbis terrarum*) **map**. These maps were drawn to illustrated a geography of faith. In them the universe is without the circular ocean "O" which surrounds a flat Earth that is subdivided by a "T" shaped body of water with its stem the Mediterranean and its crossbar the Aegean and Black Sea on the left and the Nile and Red Sea on the right into the three known continents: Asia (above), Europe (left), and Africa (right). The top of the "map" points to the "orient" (east—whence the term "orientation") for in that direction and above the circle was believed to be Paradise. (Maps before had, as is again customary, been oriented with north at the top). For Columbus (his brother Bartholomew was a chart maker) copperplate engravings of Ptolemaic maps would have been available.



Proof that Earth is a globe was Magellan's 1519-1522 circumnavigational voyage from Seville.[4]

By the 18th century, the spherical Earth had been measured with sufficient accuracy that the distortion of its figure due to its rotation—separately posited, in the prior century, as prolate (egg shaped) by Cartesians and oblate (pole flattened, waist bulging) by Isaac Newton and Christian Huygens— became significant to surveying. Expeditions were to Peru in 1735 by Pierre Bouguer (1698-1758) & Charles-Marie de La Condamine (1701-1774) and to Lapland in 1736 by Pierre-Lius Moreau de Maupertuis (1698-1759) to measure by triangulation survey the difference between the length of the degree near the equator and far north. Earth's oblate spheroid shape was found (approximated at the time by an equatorial diameter of 7,900 miles and a polar diameter 27 miles shorter). These determinations also required that surveyors allow for the gravitational effect of the rock masses that underlie the topography.[5] In the process, Earth's density as a whole was found to be roughly five times heavier than that of water. In 1798, a more accurate measure of Earth's mass was obtained by Henry Cavendish (1731-1810).[6] He made use of a torsion balance, invented ca. 1750 by John Michell, to compare the gravitational attraction of a known mass, on a test mass. This gave him a measure of G (the universal constant of gravitation) and since g (acceleration of free fall to Earth) had already been well measured, he was able to calculate the mass M of the whole Earth using $g = G\,M / r^2$ (where r is Earth's radius). He found Earth's density to be 5.52 gm/cc (water has a density 1 gm/cc at 4°C and 1 bar).[7] By comparison the density of common rocks averages between limestone 2.3 gm/cc and peridotite 3.4 gm/cc.[8] What and where is the denser material within? ❑