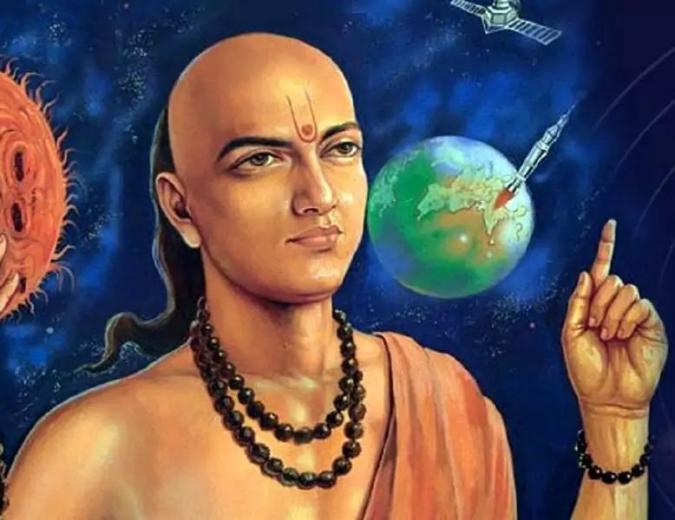
**ARYABATTA**



Aryabhata was one of the great mathematicians and astronomers from the classical era in India. In fact, he is considered to be the first great mathematician in a long line of visionary mathematicians who would emerge from India from the classical era onward. His published works were many years ahead of their time and a significant amount of modern mathematics and astronomy can be traced back to the studies and works associated with him.

##### **Early Life and Education**

Aryabhata was born around 475 A.D. in the region known as Ashmaka. Historians cannot be completely sure when he was born, but one of his works notes it was written around 3,600 years into the Kali Yuga, so a rough estimation about the time in which he was born can be ascertained. It is really not even known were for sure he was born as Ashmaka. It might be considered a nickname of sorts for Maharashtra or Dhaka.

The remaining historical records from the era piece together a hypothesis about his advanced level education taking place at Kusumapura and that he lived in this area for quite some time. There is some speculation that Kusumapura is actually another region and may really be Pataliputra, which was actually the location of where a major astronomical observatory was located.

Therefore, it would make great sense that this was where he would have invested a great deal of time learning to be a great astronomer. There were not exactly scores of other opportunities for him to take advantage during the classical era as institutions in which to learn astronomy were likely very limited.

Some historians believe, although there is no concrete proof this is the case, that Aryabhata would go on to become the actual person in charge of the university located at Nalanda. Others have asserted that Aryabhata went on to create an actual observatory that was built in Taregana within the Sun temple.

**Works**

Direct details of Aryabhata's work are known only from the *Aryabhatiya*. The name "Aryabhatiya" is due to later commentators. Aryabhata himself may not have given it a name. His disciple [Bhaskara I](https://en.wikipedia.org/wiki/Bhaskara_I" \o "Spherical trigonometry) calls it *Ashmakatantra* (or the treatise from the Ashmaka). It is also occasionally referred to as *Arya-shatas-aShTa* (literally, Aryabhata's 108), because there are 108 verses in the text. It is written in the very terse style typical of [sutra](https://en.wikipedia.org/wiki/Sutra" \o "Sutra) literature, in which each line is an aid to memory for a complex system. Thus, the explication of meaning is due to commentators. The text consists of the 108 verses and 13 introductory verses, and is divided into four *pāda*s or chapters:

1. *Gitikapada*: (13 verses): large units of time—*kalpa*, *manvantra*, and *yuga*—which present a cosmology different from earlier texts such as Lagadha's *[Vedanga Jyotisha](https://en.wikipedia.org/wiki/Vedanga_Jyotisha" \o "Vedanga Jyotisha)* (c. 1st century BCE). There is also a table of sines (*[jya](https://en.wikipedia.org/wiki/Jya" \o "Jya)*), given in a single verse. The duration of the planetary revolutions during a *mahayuga* is given as 4.32 million years.
2. *Ganitapada* (33 verses): covering [mensuration](https://en.wikipedia.org/wiki/Mensuration_(mathematics)" \o "Mensuration (mathematics)) (*kṣetra vyāvahāra*), arithmetic and geometric progressions, [gnomon](https://en.wikipedia.org/wiki/Gnomon" \o "Gnomon) / shadows (*shanku*-*chhAyA*), simple, [quadratic](https://en.wikipedia.org/wiki/Quadratic_equations" \o "Quadratic equations), [simultaneous](https://en.wikipedia.org/wiki/Simultaneous_equations" \o "Simultaneous equations), and [indeterminate](https://en.wikipedia.org/wiki/Diophantine_equations" \o "Diophantine equations) equations (*kuṭṭaka*).
3. *Kalakriyapada* (25 verses): different units of time and a method for determining the positions of planets for a given day, calculations concerning the intercalary month (*adhikamAsa*), *kShaya-tithi*s, and a seven-day week with names for the days of week.
4. *Golapada* (50 verses): Geometric/[trigonometric](https://en.wikipedia.org/wiki/Trigonometric" \o "Trigonometric) aspects of the [celestial sphere](https://en.wikipedia.org/wiki/Celestial_sphere" \o "Celestial sphere), features of the [ecliptic](https://en.wikipedia.org/wiki/Ecliptic" \o "Ecliptic), [celestial equator](https://en.wikipedia.org/wiki/Celestial_equator" \o "Celestial equator), node, shape of the earth, cause of day and night, rising of [zodiacal signs](https://en.wikipedia.org/wiki/Zodiacal_sign" \o "Zodiacal sign) on horizon, etc. In addition, some versions cite a few [colophons](https://en.wikipedia.org/wiki/Colophon_(publishing)" \o "Colophon (publishing)) added at the end, extolling the virtues of the work, etc.

The Aryabhatiya presented a number of innovations in mathematics and astronomy in verse form, which were influential for many centuries. The extreme brevity of the text was elaborated in commentaries by his disciple Bhaskara I (*Bhashya*, c. 600 CE) and by [Nilakantha Somayaji](https://en.wikipedia.org/wiki/Nilakantha_Somayaji" \o "Nilakantha Somayaji) in his *Aryabhatiya Bhasya,* (1465 CE).

The Aryabhatiya is also remarkable for its description of relativity of motion. He expressed this relativity thus: "Just as a man in a boat moving forward sees the stationary objects (on the shore) as moving backward, just so are the stationary stars seen by the people on earth as moving exactly towards the west."

**In Mathematics**

### **Place value system and zero**

The [place-value](https://en.wikipedia.org/wiki/Place-value" \o "Continued fraction) system, first seen in the 3rd-century [Bakhshali Manuscript](https://en.wikipedia.org/wiki/Bakhshali_Manuscript" \o "Bakhshali Manuscript), was clearly in place in his work. While he did not use a symbol for [zero](https://en.wikipedia.org/wiki/Zero), the French mathematician [Georges Ifrah](https://en.wikipedia.org/wiki/Georges_Ifrah" \o "Georges Ifrah) argues that knowledge of zero was implicit in Aryabhata's [place-value system](https://en.wikipedia.org/wiki/Place-value_system" \o "Place-value system) as a place holder for the powers of ten with [null](https://en.wikipedia.org/wiki/Null_(mathematics)" \o "Null (mathematics)) [coefficients](https://en.wikipedia.org/wiki/Coefficients" \o "Coefficients).

However, Aryabhata did not use the Brahmi numerals. Continuing the [Sanskritic](https://en.wikipedia.org/wiki/Sanskrit" \o "Sanskrit) tradition from [Vedic times](https://en.wikipedia.org/wiki/Vedic_period" \o "Vedic period), he used letters of the alphabet to denote numbers, expressing quantities, such as the table of sines in a [mnemonic](https://en.wikipedia.org/wiki/Mnemonic" \o "Mnemonic) form.

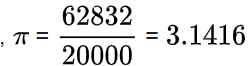
### **Approximation of *π***

Aryabhata worked on the approximation for [pi](https://en.wikipedia.org/wiki/Pi" \o "Pi) (π), and may have come to the conclusion that π is irrational. In the second part of the *Aryabhatiyam* (*gaṇitapāda* 10), he writes:

*caturadhikaṃ śatamaṣṭaguṇaṃ dvāṣaṣṭistathā sahasrāṇām*  
*ayutadvayaviṣkambhasyāsanno vṛttapariṇāhaḥ.*

"Add four to 100, multiply by eight, and then add 62,000. By this rule the circumference of a circle with a diameter of 20,000 can be approached."

This implies that for a circle whose diameter is 20000, the circumference will be 62832

i.e,  {\displaystyle \pi }{\displaystyle 3.1416} , which is accurate to three [decimal places](https://en.wikipedia.org/wiki/Decimal_places" \o "Decimal places).

It is speculated that Aryabhata used the word *āsanna* (approaching), to mean that not only is this an approximation but that the value is incommensurable (or [irrational](https://en.wikipedia.org/wiki/Irrational" \o "Irrational)). If this is correct, it is quite a sophisticated insight, because the irrationality of pi (π) was proved in Europe only in 1761 by [Lambert](https://en.wikipedia.org/wiki/Johann_Heinrich_Lambert" \o "Johann Heinrich Lambert).

After Aryabhatiya was translated into [Arabic](https://en.wikipedia.org/wiki/Arabic_language" \o "Arabic language) (c. 820 CE) this approximation was mentioned in [Al-Khwarizmi](https://en.wikipedia.org/wiki/Al-Khwarizmi" \o "Al-Khwarizmi)'s book on algebra.

### **Trigonometry**

In Ganitapada 6, Aryabhata gives the area of a triangle as

*tribhujasya phalaśarīraṃ samadalakoṭī bhujārdhasaṃvargaḥ*

that translates to: "for a triangle, the result of a perpendicular with the half-side is the area."

Aryabhata discussed the concept of *[sine](https://en.wikipedia.org/wiki/Sine" \o "Sine)* in his work by the name of *[ardha-jya](https://en.wikipedia.org/wiki/Ardha-jya" \o "Ardha-jya)*, which literally means "half-chord". For simplicity, people started calling it *[jya](https://en.wikipedia.org/wiki/Jya" \o "Jya)*. When Arabic writers translated his works from [Sanskrit](https://en.wikipedia.org/wiki/Sanskrit" \o "Sanskrit) into Arabic, they referred it as *jiba*. However, in Arabic writings, vowels are omitted, and it was abbreviated as *jb*. Later writers substituted it with *jaib*, meaning "pocket" or "fold (in a garment)". (In Arabic, *jiba* is a meaningless word.) Later in the 12th century, when [Gherardo of Cremona](https://en.wikipedia.org/wiki/Gherardo_of_Cremona" \o "Gherardo of Cremona) translated these writings from Arabic into Latin, he replaced the Arabic *jaib* with its Latin counterpart, *sinus*, which means "cove" or "bay"; thence comes the English word *sine*.

### **Indeterminate equations**

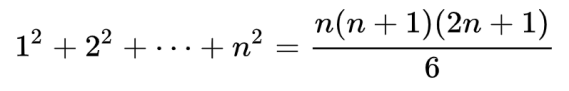
A problem of great interest to [Indian mathematicians](https://en.wikipedia.org/wiki/Indian_mathematicians" \o "Indian mathematicians) since ancient times has been to find integer solutions to [Diophantine equations](https://en.wikipedia.org/wiki/Diophantine_equations" \o "Diophantine equations) that have the form ax + by = c. (This problem was also studied in ancient Chinese mathematics, and its solution is usually referred to as the [Chinese remainder theorem](https://en.wikipedia.org/wiki/Chinese_remainder_theorem" \o "Chinese remainder theorem).) This is an example from [Bhāskara](https://en.wikipedia.org/wiki/Bh%C4%81skara_I" \o "Bhāskara I)'s commentary on Aryabhatiya:

Find the number which gives 5 as the remainder when divided by 8, 4 as the remainder when divided by 9, and 1 as the remainder when divided by 7

That is, find N = 8x+5 = 9y+4 = 7z+1. It turns out that the smallest value for N is 85. In general, diophantine equations, such as this, can be notoriously difficult. They were discussed extensively in ancient Vedic text [Sulba Sutras](https://en.wikipedia.org/wiki/Sulba_Sutras" \o "Sulba Sutras), whose more ancient parts might date to 800 BCE. Aryabhata's method of solving such problems, elaborated by Bhaskara in 621 CE, is called the *kuṭṭaka* (कुट्टक) method. *[Kuṭṭaka](https://en.wikipedia.org/wiki/Ku%E1%B9%AD%E1%B9%ADaka" \o "Kuṭṭaka)* means "pulverizing" or "breaking into small pieces", and the method involves a recursive algorithm for writing the original factors in smaller numbers. This algorithm became the standard method for solving first-order diophantine equations in Indian mathematics, and initially the whole subject of algebra was called *kuṭṭaka-gaṇita* or simply *kuṭṭaka*.

### **Algebra**

In *Aryabhatiya*, Aryabhata provided elegant results for the summation of [series](https://en.wikipedia.org/wiki/Series_(mathematics)" \o "Series (mathematics)) of squares and cubes:

{\displaystyle 1^{3}+2^{3}+\cdots +n^{3}=(1+2+\cdots +n)^{2}}

and

­



**Astronomy**

Aryabhata's system of astronomy was called the *audAyaka system*, in which days are reckoned from *uday*, dawn at *lanka* or "equator". Some of his later writings on astronomy, which apparently proposed a second model (or *ardha-rAtrikA*, midnight) are lost but can be partly reconstructed from the discussion in [Brahmagupta](https://en.wikipedia.org/wiki/Brahmagupta" \o "Brahmagupta)'s *[Khandakhadyaka](https://en.wikipedia.org/wiki/Khandakhadyaka" \o "Khandakhadyaka)*. In some texts, he seems to ascribe the apparent motions of the heavens to the [Earth's rotation](https://en.wikipedia.org/wiki/Earth%27s_rotation" \o "Earth's rotation). He may have believed that the planet's orbits as [elliptical](https://en.wikipedia.org/wiki/Ellipse" \o "Ellipse) rather than circular.

### **Motions of the solar system**

Aryabhata correctly insisted that the earth rotates about its axis daily, and that the apparent movement of the stars is a relative motion caused by the rotation of the earth, contrary to the then-prevailing view, that the sky rotated. This is indicated in the first chapter of the *Aryabhatiya*, where he gives the number of rotations of the earth in a *yuga*, and made more explicit in his *gola* chapter :

In the same way that someone in a boat going forward sees an unmoving [object] going backward, so [someone] on the equator sees the unmoving stars going uniformly westward. The cause of rising and setting [is that] the sphere of the stars together with the planets [apparently?] turns due west at the equator, constantly pushed by the [cosmic wind](https://en.wikipedia.org/wiki/Cosmic_wind" \o "Cosmic wind).

Aryabhata described a [geocentric](https://en.wikipedia.org/wiki/Geocentric" \o "Geocentric) model of the solar system, in which the Sun and Moon are each carried by [epicycles](https://en.wikipedia.org/wiki/Epicycle" \o "Epicycle). They in turn revolve around the Earth. In this model, which is also found in the *Paitāmahasiddhānta* (c. CE 425), the motions of the planets are each governed by two epicycles, a smaller *manda* (slow) and a larger *śīghra* (fast). The order of the planets in terms of distance from earth is taken as: the [Moon](https://en.wikipedia.org/wiki/Moon" \o "Moon), [Mercury](https://en.wikipedia.org/wiki/Mercury_(planet)" \o "Mercury (planet)), [Venus](https://en.wikipedia.org/wiki/Venus" \o "Venus), the [Sun](https://en.wikipedia.org/wiki/Sun" \o "Sun), [Mars](https://en.wikipedia.org/wiki/Mars" \o "Mars), [Jupiter](https://en.wikipedia.org/wiki/Jupiter" \o "Jupiter), [Saturn](https://en.wikipedia.org/wiki/Saturn" \o "Saturn), and the [asterisms](https://en.wikipedia.org/wiki/Asterism_(astronomy)" \o "Asterism (astronomy))."

The positions and periods of the planets was calculated relative to uniformly moving points. In the case of Mercury and Venus, they move around the Earth at the same mean speed as the Sun. In the case of Mars, Jupiter, and Saturn, they move around the Earth at specific speeds, representing each planet's motion through the zodiac. Most historians of astronomy consider that this two-epicycle model reflects elements of pre-Ptolemaic [Greek astronomy](https://en.wikipedia.org/wiki/Hellenistic_astronomy" \o "Hellenistic astronomy). Another element in Aryabhata's model, the *śīghrocca*, the basic planetary period in relation to the Sun, is seen by some historians as a sign of an underlying [heliocentric](https://en.wikipedia.org/wiki/Heliocentric" \o "Heliocentric) model.

### **Eclipses**

Solar and lunar eclipses were scientifically explained by Aryabhata. He states that the [Moon](https://en.wikipedia.org/wiki/Moon" \o "Moon) and planets shine by reflected sunlight. Instead of the prevailing cosmogony in which eclipses were caused by [Rahu](https://en.wikipedia.org/wiki/Rahu" \o "Rahu) and [Ketu](https://en.wikipedia.org/wiki/Ketu_(mythology)" \o "Ketu (mythology)) (identified as the pseudo-planetary [lunar nodes](https://en.wikipedia.org/wiki/Lunar_nodes" \o "Lunar nodes)), he explains eclipses in terms of shadows cast by and falling on Earth. Thus, the lunar eclipse occurs when the Moon enters into the Earth's shadow (verse gola.37). He discusses at length the size and extent of the Earth's shadow (verses gola.38–48) and then provides the computation and the size of the eclipsed part during an eclipse. Later Indian astronomers improved on the calculations, but Aryabhata's methods provided the core. His computational paradigm was so accurate that 18th-century scientist [Guillaume Le Gentil](https://en.wikipedia.org/wiki/Guillaume_Le_Gentil" \o "Guillaume Le Gentil), during a visit to Pondicherry, India, found the Indian computations of the duration of the [lunar eclipse](https://en.wikipedia.org/wiki/Lunar_eclipse" \o "Lunar eclipse) of 30 August 1765 to be short by 41 seconds, whereas his charts (by Tobias Mayer, 1752) were long by 68 seconds.

### **Sidereal periods**

Considered in modern English units of time, Aryabhata calculated the [sidereal rotation](https://en.wikipedia.org/wiki/Sidereal_rotation" \o "Sidereal rotation) (the rotation of the earth referencing the fixed stars) as 23 hours, 56 minutes, and 4.1 seconds; the modern value is 23:56:4.091. Similarly, his value for the length of the [sidereal year](https://en.wikipedia.org/wiki/Sidereal_year" \o "Sidereal year) at 365 days, 6 hours, 12 minutes, and 30 seconds (365.25858 days) is an error of 3 minutes and 20 seconds over the length of a year (365.25636 days).

### **Heliocentrism**

As mentioned, Aryabhata advocated an astronomical model in which the Earth turns on its own axis. His model also gave corrections (the *śīgra* anomaly) for the speeds of the planets in the sky in terms of the mean speed of the Sun. Thus, it has been suggested that Aryabhata's calculations were based on an underlying [heliocentric](https://en.wikipedia.org/wiki/Heliocentrism" \o "Heliocentrism) model, in which the planets orbit the Sun, though this has been rebutted. It has also been suggested that aspects of Aryabhata's system may have been derived from an earlier, likely pre-Ptolemaic [Greek](https://en.wikipedia.org/wiki/Greek_astronomy" \o "Greek astronomy), heliocentric model of which Indian astronomers were unaware, though the evidence is scant. The general consensus is that a synodic anomaly (depending on the position of the Sun) does not imply a physically heliocentric orbit (such corrections being also present in late [Babylonian astronomical texts](https://en.wikipedia.org/wiki/Babylonian_astronomical_diaries" \o "Babylonian astronomical diaries)), and that Aryabhata's system was not explicitly heliocentric.

**Legacy**

Aryabhata's work was of great influence in the Indian astronomical tradition and influenced several neighbouring cultures through translations. The [Arabic](https://en.wikipedia.org/wiki/Arabic_language" \o "Arabic language) translation during the [Islamic Golden Age](https://en.wikipedia.org/wiki/Islamic_Golden_Age" \o "Islamic Golden Age) (c. 820 CE), was particularly influential. Some of his results are cited by [Al-Khwarizmi](https://en.wikipedia.org/wiki/Al-Khwarizmi" \o "Al-Khwarizmi) and in the 10th century [Al-Biruni](https://en.wikipedia.org/wiki/Al-Biruni" \o "Al-Biruni) stated that Aryabhata's followers believed that the Earth rotated on its axis.

His definitions of [sine](https://en.wikipedia.org/wiki/Sine" \o "Sine) (*[jya](https://en.wikipedia.org/wiki/Jya" \o "Jya)*), cosine (*[kojya](https://en.wikipedia.org/wiki/Kojya" \o "Kojya)*), versine (*[utkrama-jya](https://en.wikipedia.org/wiki/Utkrama-jya" \o "Utkrama-jya)*), and inverse sine (*otkram jya*) influenced the birth of [trigonometry](https://en.wikipedia.org/wiki/Trigonometry" \o "Trigonometry). He was also the first to specify sine and [versine](https://en.wikipedia.org/wiki/Versine" \o "Versine) (1 − cos *x*) tables, in 3.75° intervals from 0° to 90°, to an accuracy of 4 decimal places.

In fact, modern names "sine" and "cosine" are mistranscriptions of the words *jya* and *kojya* as introduced by Aryabhata. As mentioned, they were translated as *jiba* and *kojiba* in Arabic and then misunderstood by [Gerard of Cremona](https://en.wikipedia.org/wiki/Gerard_of_Cremona" \o "Gerard of Cremona) while translating an Arabic geometry text to [Latin](https://en.wikipedia.org/wiki/Latin" \o "Latin). He assumed that *jiba* was the Arabic word *jaib*, which means "fold in a garment", L. *sinus* (c. 1150).

Aryabhata's astronomical calculation methods were also very influential. Along with the trigonometric tables, they came to be widely used in the Islamic world and used to compute many [Arabic](https://en.wikipedia.org/wiki/Arabic" \o "Arabic) astronomical tables ([zijes](https://en.wikipedia.org/wiki/Zij" \o "Zij)). In particular, the astronomical tables in the work of the [Arabic Spain](https://en.wikipedia.org/wiki/Al-Andalus" \o "Al-Andalus) scientist [Al-Zarqali](https://en.wikipedia.org/wiki/Al-Zarqali" \o "Al-Zarqali) (11th century) were translated into Latin as the [Tables of Toledo](https://en.wikipedia.org/wiki/Tables_of_Toledo" \o "Tables of Toledo) (12th century) and remained the most accurate [ephemeris](https://en.wikipedia.org/wiki/Ephemeris" \o "Ephemeris) used in Europe for centuries.

Calendric calculations devised by Aryabhata and his followers have been in continuous use in India for the practical purposes of fixing the [Panchangam](https://en.wikipedia.org/wiki/Panchangam" \o "Panchangam) (the [Hindu calendar](https://en.wikipedia.org/wiki/Hindu_calendar" \o "Hindu calendar)). In the Islamic world, they formed the basis of the [Jalali calendar](https://en.wikipedia.org/wiki/Jalali_calendar" \o "Jalali calendar) introduced in 1073 CE by a group of astronomers including [Omar Khayyam](https://en.wikipedia.org/wiki/Omar_Khayyam" \o "Omar Khayyam), versions of which (modified in 1925) are the national calendars in use in [Iran](https://en.wikipedia.org/wiki/Iran" \o "Iran) and [Afghanistan](https://en.wikipedia.org/wiki/Afghanistan" \o "Afghanistan) today. The dates of the Jalali calendar are based on actual solar transit, as in Aryabhata and earlier [Siddhanta](https://en.wikipedia.org/wiki/Siddhanta" \o "Siddhanta) calendars. This type of calendar requires an ephemeris for calculating dates. Although dates were difficult to compute, seasonal errors were less in the Jalali calendar than in the [Gregorian calendar](https://en.wikipedia.org/wiki/Gregorian_calendar" \o "Gregorian calendar).

[Aryabhatta Knowledge University](https://en.wikipedia.org/wiki/Aryabhatta_Knowledge_University" \o "Aryabhatta Knowledge University) (AKU), Patna has been established by Government of Bihar for the development and management of educational infrastructure related to technical, medical, management and allied professional education in his honour. The university is governed by Bihar State University Act 2008.

India's first satellite [Aryabhata](https://en.wikipedia.org/wiki/Aryabhata_(satellite)" \o "Aryabhata (satellite)) and the [lunar crater](https://en.wikipedia.org/wiki/Lunar_crater" \o "Lunar crater) [Aryabhata](https://en.wikipedia.org/wiki/Aryabhata_(crater)" \o "Aryabhata (crater)) are both named in his honour, the Aryabhata satellite also featured on the reverse of the [Indian 2-rupee note](https://en.wikipedia.org/wiki/Indian_2-rupee_note" \o "Indian 2-rupee note). An Institute for conducting research in astronomy, astrophysics and atmospheric sciences is the [Aryabhatta Research Institute of Observational Sciences](https://en.wikipedia.org/wiki/Aryabhatta_Research_Institute_of_Observational_Sciences" \o "Aryabhatta Research Institute of Observational Sciences) (ARIES) near Nainital, India. The inter-school [Aryabhata Maths Competition](https://en.wikipedia.org/w/index.php?title=Aryabhata_Maths_Competition&action=edit&redlink=1" \o "Aryabhata Maths Competition (page does not exist)) is also named after him, as is *Bacillus aryabhata*, a species of bacteria discovered in the [stratosphere](https://en.wikipedia.org/wiki/Stratosphere" \o "Stratosphere) by [ISRO](https://en.wikipedia.org/wiki/ISRO" \o "ISRO) scientists in 2009.

**Death of Aryabhata Scientist**

Aryabhata died a successful mathematician, astronomer and a scientist at the age of 74. The place and time of death are still unknown. It was believed he spent most of his life in Kusumapura, Pataliputra.