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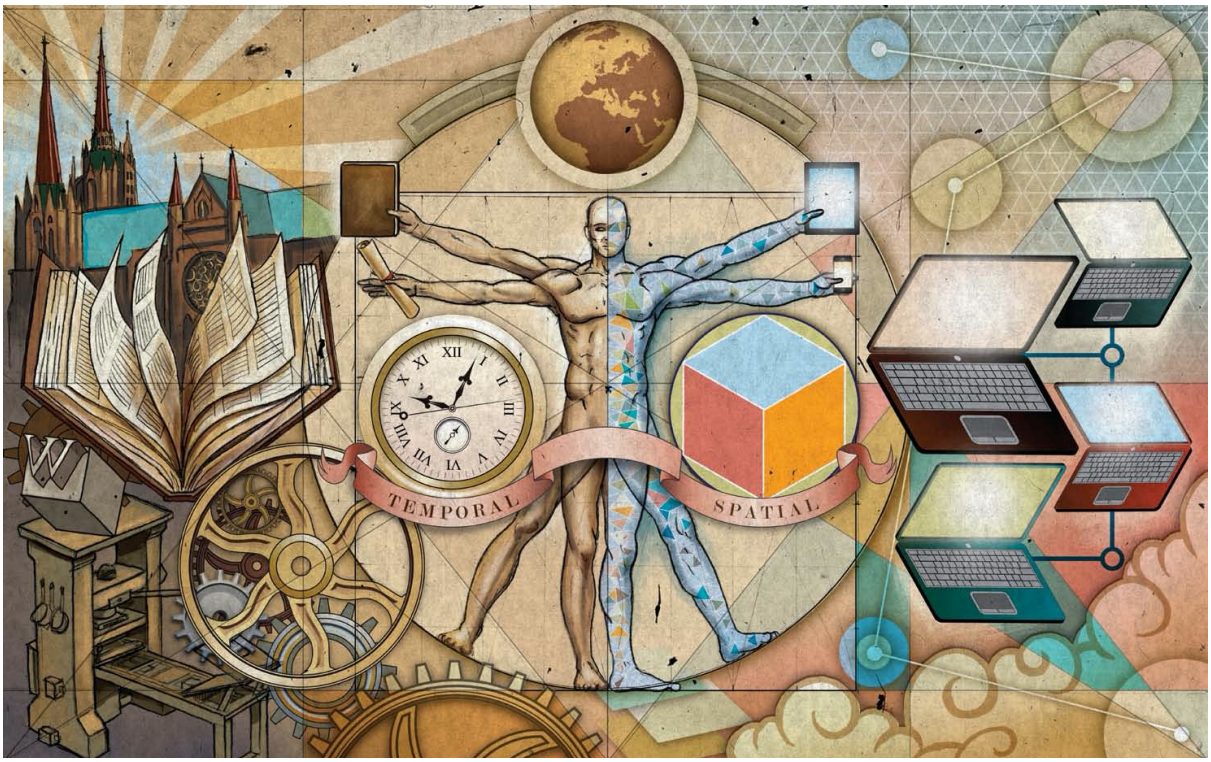
The Exploitation of the Works of Nature



Learning Guide

Your name:

Your Age:

Your discoveries:

Your discoveries:

The Exploitation of the Works of Nature (Tiangong Kaiwu)

Tiangong kaiwu (Exploitation of the works of nature), an integrated work on agriculture and handicrafts, is one of the most important works on science and technology in the history of China. A European scholar has called it a 17th-century version of the Denis Diderot's *Encyclopédie* published in France in the 18th century. The author was the noted Ming dynasty scientist Song Yingxing. While working as an instructor in Fenyi County in Jiangxi province, he researched agricultural and artisanal technology, which he then organized into a book. This work was published with funding from his friend Tu Shaokui, in the tenth year of the Chongzhen reign (1637). The *Tiangong kaiwu* records all aspects of technology up to the mid-Ming period. Divided into three parts and including 121 illustrations, it describes the terms, configurations, and production stages for over 130 types of productive technology and tools. The book constitutes a complete system of science and technology, and provides a systematic summation of ancient Chinese technology, the experience accumulated by China in agriculture, and China's achievements in artisanal technology. Many of the production techniques described in the book are still in use today. The book was translated into Japanese, French, English, German, Italian, and Russian, and was widely circulated in Europe and Japan.

Song Yingxing's Curriculum vitae

Year	Age	Career	Reign
1587	Birth		Ming Emperor Shenzong 神宗
1593	7	traditional Confucian education	
1611	25		
1615	29	2d Degree Graduate	
1616	30	1st Attempt Metropolitan Exam	Hou Jin
1619	33	2d Attempt	Ming Emperor Guangzong 光宗
1622	36	3rd Attempt	Ming Emperor Xizong 熹宗
1625	39	4th Attempt	
1628	42	5th Attempt	Ming Emperor Zhuanglie 莊烈
1629	43	Father Song Guolin 宋國林 died	
1631	45	6th attempt (?)	
1632	46	Mother died	
1634	48	Teacher at the County School Fenyi 分宜	
1636	50	First publication, literary activity	Dynasty Proclamation of Qing
1637	51	Tiangong kaiwu 天工開物	
1640	54		
1642	56	Judge (*tuiguan* 推官)	
1645	59	Brother Yingsheng 應升 died	Qing Emperor Shizu 世祖
1662			Qing Emperor Shengzu 聖祖
1666?	80?	Died	

The 50 Greatest Breakthroughs Since the Wheel

Why did it take so long to invent the wheelbarrow? Have we hit peak innovation? What our list reveals about imagination, optimism, and the nature of progress.

By James Fallows

https://www.theatlantic.com/magazine/archive/2013/11/innovations-list/309536/#fission

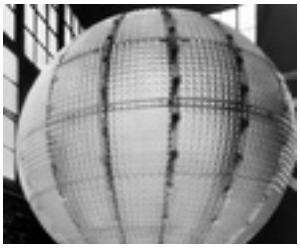
The List 50 Greatest Breakthroughs Since the Wheel

***The Atlantic* asked a dozen scientists, historians, and technologists to rank the top innovations since the wheel. Here are the results.**

You can also choose your own top five innovations, and see how the readers' choices stack up against the* Atlantic *experts'.

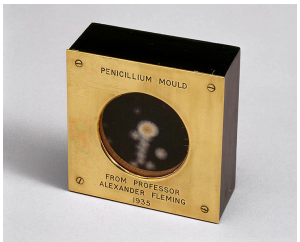
1. The printing press, 1430s

The printing press was nominated by 10 of our 12 panelists, five of whom ranked it in their top three. Dyson described its invention as the turning point at which "knowledge began freely replicating and quickly assumed a life of its own."



2. Electricity, late 19th century

And then there was light—and Nos. 4, 9, 16, 24, 28, 44, 45, and most of the rest of modern life.



3. Penicillin, 1928

Accidentally discovered in 1928, though antibiotics were not widely distributed until after World War II, when they became the silver bullet for any number of formerly deadly diseases

4. Semiconductor electronics, mid-20th century
The physical foundation of the virtual world

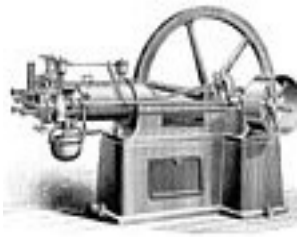
5. Optical lenses, 13th century

Refracting light through glass is one of those simple ideas that took a mysteriously long time to catch on. "The Romans had a glass industry, and there's even a passage in Seneca about the optical effects of a glass bowl of water," says Mokyr. But it was centuries before the invention of eyeglasses dramatically raised the collective human IQ, and eventually led to the creation of the microscope and the telescope.

6. Paper, second century

"The idea of stamping images is natural if you have paper, but until then, it's economically unaffordable." — *Charles C. Mann*

7. The internal combustion engine, late 19th century



Turned air and fuel into power, eventually replacing the steam engine (No. 10)

8. Vaccination, 1796

The British doctor Edward Jenner used the cowpox virus to protect against smallpox in 1796, but it wasn't until Louis Pasteur developed a rabies vaccine in 1885 that medicine—and government—began to accept the idea that making someone sick could prevent further sickness.

9. The Internet, 1960s

The infrastructure of the digital age

10. The steam engine, 1712

Powered the factories, trains, and ships that drove the Industrial Revolution

11. Nitrogen fixation, 1918

The German chemist Fritz Haber, also the father of chemical weapons, won a Nobel Prize for his development of the ammonia-synthesis process, which was used to create a new class of fertilizers central to the green revolution (No. 22).

12. Sanitation systems, mid-19th century

A major reason we live 40 years longer than we did in 1880 (see "Die Another Day")

13. Refrigeration, 1850s

"Discovering how to make cold would change the way we eat—and live—almost as profoundly as discovering how to cook." — *George Dyson*

14. Gunpowder, 10th century

Outsourced killing to a machine

15. The airplane, 1903

Transformed travel, warfare, and our view of the world (see No. 40)

16. The personal computer, 1970s

Like the lever (No. 48) and the abacus (No. 43), it augmented human capabilities.

17. The compass, 12th century

Oriented us, even at sea

18. The automobile, late 19th century

Transformed daily life, our culture, and our landscape

19. Industrial steelmaking, 1850s

Mass-produced steel, made possible by a method known as the Bessemer process, became the basis of modern industry.

20. The pill, 1960
Launched a social revolution

21. Nuclear fission, 1939

Gave humans new power for destruction, and creation

22. The green revolution, mid-20th century
Combining technologies like synthetic fertilizers (No. 11) and scientific plant breeding (No. 38) hugely increased the world's food output. Norman Borlaug, the agricultural economist who devised this approach, has been credited with saving more than 1 billion people from starvation.

23. The sextant, 1757

It made maps out of stars.

24. The telephone, 1876
Allowed our voices to travel

25. Alphabetization, first millennium B.C.
Made knowledge accessible and searchable—and may have contributed to the rise of societies that used phonetic letters over those that used ideographic ones

26. The telegraph, 1837

Before it, Joel Mokyr says, "information could move no faster than a man on horseback."

27. The mechanized clock, 15th century
It quantified time.

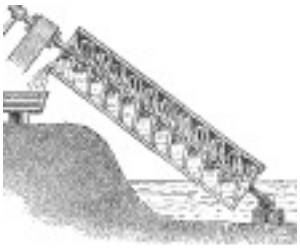
28. Radio, 1906

The first demonstration of electronic mass media's power to spread ideas and homogenize culture

29. Photography, early 19th century
Changed journalism, art, culture, and how we see ourselves

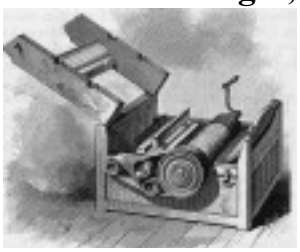
30. The moldboard plow, 18th century

The first plow that not only dug soil up but turned it over, allowing for the cultivation of harder ground. Without it, agriculture as we know it would not exist in northern Europe or the American Midwest.



31. Archimedes' screw, third century B.C.
The Greek scientist is believed to have designed one of the first water pumps, a rotating corkscrew that pushed water up a tube. It transformed irrigation and remains in use today at many sewage-treatment plants.

32. The cotton gin, 1793



Institutionalized the cotton industry—and slavery—in the American South

33. Pasteurization, 1863

One of the first practical applications of Louis Pasteur's germ theory, this method for using heat to sterilize wine, beer, and milk is widely considered to be one of history's most effective public-health interventions.

34. The Gregorian calendar, 1582

Debugged the Julian calendar, jumping ahead 10 days to synchronize the world with the seasons

35. Oil refining, mid-19th century

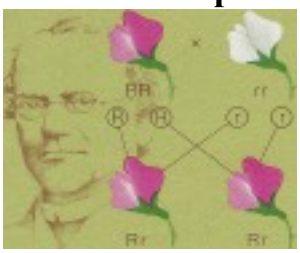
Without it, oil drilling (No. 39) would be pointless.

36. The steam turbine, 1884

A less heralded cousin of steam engines (No. 10), turbines are the backbone of today's energy infrastructure: they generate 80 percent of the world's power.

37. Cement, first millennium B.C.
The foundation of civilization. Literally.

38. Scientific plant breeding, 1920s



Humans have been manipulating plant species for nearly as long as we've grown them, but it wasn't until early-20th-century scientists discovered a forgotten 1866 paper by the Austrian botanist Gregor Mendel that we figured out how plant breeding—and, later on, human genetics—worked.

39. Oil drilling, 1859

Fueled the modern economy, established its geopolitics, and changed the climate

40. The sailboat, fourth millennium B.C.

Transformed travel, warfare, and our view of the world (see No. 15)

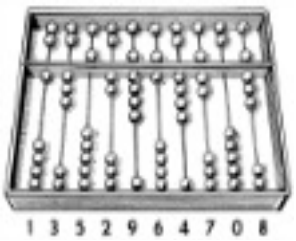
41. Rocketry, 1926

"Our only way off the planet—so far." — *George Dyson*

42. Paper money, 11th century

The abstraction at the core of the modern economy

43. The abacus, third millennium B.C.



One of the first devices to augment human intelligence

44. Air-conditioning, 1902

Would you start a business in Houston or Bangalore without it?

45. Television, early 20th century

Brought the world into people's homes

46. Anesthesia, 1846

In response to the first public demonstration of ether, Oliver Wendell Holmes Sr. wrote: "The fierce extremity of suffering has been steeped in the waters of forgetfulness, and the deepest furrow in the knotted brow of agony has been smoothed for ever."

47. The nail, second millennium B.C.

"Extended lives by enabling people to have shelter." — *Leslie Berlin*

48. The lever, third millennium B.C.

The Egyptians had not yet discovered the wheel when they built their pyramids; they are thought to have relied heavily on levers.

49. The assembly line, 1913

Turned a craft-based economy into a mass-market one

50. The combine harvester, 1930s

Mechanized the farm, freeing people to do new types of work

Our Panel of Experts

The scientists, historians, and technologists we consulted to make this list.

Michelle Alexopoulos
Professor of economics, University of Toronto

Leslie Berlin
Historian of business and technology, Stanford; author, *The Man Behind the Microchip: Robert Noyce and the Invention of Silicon Valley*

John Doerr
General partner, Kleiner Perkins Caufield & Byers

George Dyson
Historian of technology; author, *Turing's Cathedral and Darwin Among the Machines*

Walter Isaacson
President and CEO, the Aspen Institute; author, Steve Jobs , *Einstein: His Life and Universe*, and *Benjamin Franklin: An American Life*

Joi Ito
Director, MIT Media Lab

Alexis Madrigal
Senior editor, *The Atlantic*; author, *Powering the Dream: The History and Promise of Green Technology*

Charles C. Mann
Journalist; author, 1491: New Revelations of the Americas Before Columbus and 1493: Uncovring the New World Columbus Created

Joel Mokyr
Professor of economics and history, Northwestern University

Linda Sanford
Senior vice president for enterprise transformation, IBM

Astro Teller
Captain of moonshots, Google[x]; co-founder, Cerebellum Capital and BodyMedia

Padmasree Warrior
Chief technology and strategy officer, Cisco Systems

Timeline of scientific discoveries

(Adapted from: https://en.wikipedia.org/wiki/Timeline_of_scientific_discoveries)

The timeline below shows the date of publication of possible major scientific breakthroughs, theories and discoveries, along with the discoverer. For the purposes of this article, we do not regard mere speculation as discovery, although imperfect reasoned arguments, arguments based on elegance/simplicity, and numerically/experimentally verified conjectures qualify (as otherwise no scientific discovery before the late 19th century would count). We begin our timeline at the Bronze Age, as it is difficult to estimate the timeline before this point, such as of the discovery of counting, natural numbers and arithmetic.

Bronze Age

Many early innovations of the Bronze Age were requirements resulting from the increase in trade, and this also applies to the scientific advances of this period. For context, the major civilizations of this period are Egypt, Mesopotamia, and the Indus Valley, with Greece rising in importance towards the end of the third millennium BC. It is to be noted that the Indus Valley script remains undeciphered and there are very little surviving fragments of its writing, thus any inference about scientific discoveries in the region must be made based only on archaeological digs.

Mathematics

Numbers, measurement and arithmetic

- Around 3000 BC: Units of measurement are developed in the major Bronze Age civilisations: Egypt, Mesopotamia, Elam and the Indus Valley. The Indus Valley may have been the major innovator on this, as the first measurement devices (rulers, protractors, weighing scales) were invented in Lothal in Gujarat, India.[1][2][3][4]
- 1800 BC: Fractions were first studied by the Egyptians in their study of Egyptian fractions.

Geometry and trigonometry

- 2100 BC: The concept of area is first recognised in Babylonian clay tablets,[5] and 3-dimensional volume is discussed in an Egyptian papyrus. This begins the study of geometry.
- Early 2nd millennium BC: Similar triangles and side-ratios are studied in Egypt (e.g. in the Rhind Mathematical Papyrus, a copy of an older Middle Kingdom text) for the construction of pyramids, paving the way for the field of trigonometry.[6]

Algebra

- 2100 BC: Quadratic equations, in the form of problems relating the areas and sides of rectangles, are solved by Babylonians.[5]

Number theory and discrete mathematics

- 2000 BC: Pythagorean triples are first discussed in Babylon and Egypt, and appear on later manuscripts such as the Berlin Papyrus 6619.[7]

Numerical mathematics and algorithms

- 2000 BC: Multiplication tables in Babylon.[8]

- 1800 BC – 1600 BC: A numerical approximation for the square root of two, accurate to 6 decimal places, is recorded on YBC 7289, a Babylonian clay tablet believed to belong to a student.[9]
- 19th to 17th century BCE: A Babylonian tablet uses $25/8$ as an approximation for π, which has an error of 0.5%.[10][11][12]
- Early 2nd millennium BCE: The Rhind Mathematical Papyrus (a copy of an older Middle Kingdom text) contains the first documented instance of inscribing a polygon (in this case, an octagon) into a circle to estimate the value of π.[13][14]

Notation and conventions

- 3000 BC: The first deciphered numeral system is that of the Egyptian numerals, a sign-value system (as opposed to a place-value system).[15]
- 2000 BC: Primitive positional notation for numerals is seen in the Babylonian cuneiform numerals.[16] However, the lack of clarity around the notion of zero made their system highly ambiguous (e.g. 13200 would be written the same as 132).[17]

Astronomy

- Early 2nd millennium BC: The periodicity of planetary phenomenon is recognised by Babylonian astronomers.

Biology and anatomy

- Early 2nd millennium BC: Ancient Egyptians study anatomy, as recorded in the Edwin Smith Papyrus. They identified the heart and its vessels, liver, spleen, kidneys, hypothalamus, uterus, and bladder, and correctly identified that blood

vessels emanated from the heart (however, they also believed that tears, urine, and semen, but not saliva and sweat, originated in the heart, see Cardiocentric hypothesis).[18]

Iron Age

Mathematics

Geometry and trigonometry

- c. 700 BC: The Pythagoras theorem is discovered by Baudhayana in the Hindu Shulba Sutras in Upanishadic India.[19] However, Indian mathematics, especially North Indian mathematics, generally did not have a tradition of communicating proofs, and it is not fully certain that Baudhayana or Apastamba knew of a proof.

Number theory and discrete mathematics

- c. 700 BC: Pell's equations are first studied by Baudhayana in India, the first diophantine equations known to be studied.[20]

Geometry and trigonometry

- c. 600 BC: Thales of Miletus discovers Thales's theorem.

Biology and anatomy

- 600 BC – 200 BC: The Sushruta Samhita (3.V) shows an understanding of musculoskeletal structure (including joints, ligaments and muscles and their functions).[21]

- 600 BC – 200 BC: The Sushruta Samhita refers to the cardiovascular system as a closed circuit.[22]
- 600 BC – 200 BC: The Sushruta Samhita (3.IX) identifies the existence of nerves.[21]

Social science

Linguistics

- c. 700 BC: Grammar is first studied in India (note that Sanskrit Vyākaraṇa predates Pāṇini).

500 BC – 1 BC

The Greeks make numerous advances in mathematics and astronomy through the Archaic, Classical and Hellenistic periods.

Mathematics

Logic and proof

- 4th century BC: Greek philosophers study the properties of logical negation.
- 4th century BC: The first true formal system is constructed by Pāṇini in his Sanskrit grammar.[23][24]
- c. 300 BC: Greek mathematician Euclid in the *Elements* describes a primitive form of formal proof and axiomatic systems. However, modern mathematicians generally believe that his axioms were highly incomplete, and that his definitions were not really used in his proofs.

Numbers, measurement and arithmetic

- 4th century BC: Eudoxus of Cnidus states the Archimedean property.[25]
- 4th-3rd century BC: In Mauryan India, The Jain mathematical text Surya Prajnapati draws a distinction between countable and uncountable infinities.[26]
- 3rd century BC: Pingala in Mauryan India studies binary numbers, making him the first to study the radix (numerical base) in history.[27]

Algebra

- 5th century BC: Possible date of the discovery of the triangular numbers (i.e. the sum of consecutive integers), by the Pythagoreans.[28]
- c. 300 BC: Finite geometric progressions are studied by Euclid in Ptolemaic Egypt.[29]
- 3rd century BC: Archimedes relates problems in geometric series to those in arithmetic series, foreshadowing the logarithm.[30]
- 190 BC: Magic squares appear in China. The theory of magic squares can be considered the first example of a vector space.
- 165-142 BC: Zhang Cang in Northern China is credited with the development of Gaussian elimination.[31]

Number theory and discrete mathematics

- c. 500 BC: Hippasus, a Pythagorean, discovers irrational numbers.[32][33]
- 4th century BC: Thaetetus shows that square roots are either integer or irrational.
- 4th century BC: Thaetetus enumerates the Platonic solids, an early work in graph theory.
- 3rd century BC: Pingala in Mauryan India describes the Fibonacci sequence.[34][35]
- c. 300 BC: Euclid proves the infinitude of primes.[36]
- c. 300 BC: Euclid proves the Fundamental Theorem of Arithmetic.

- c. 300 BC: Euclid discovers the Euclidean algorithm.
- 3rd century BC: Pingala in Mauryan India discovers the binomial coefficients in a combinatorial context and the additive formula for generating them [37][38], i.e. a prose description of Pascal's triangle, and derived formulae relating to the sums and alternating sums of binomial coefficients. It has been suggested that he may have also discovered the binomial theorem in this context.[39]
- 3rd century BC: Eratosthenes discovers the Sieve of Eratosthenes.[40]

Geometry and trigonometry

- 5th century BC: The Greeks start experimenting with straightedge-and-compass constructions.[41]
- 4th century BC: Menaechmus discovers conic sections.[42]
- 4th century BC: Menaechmus develops co-ordinate geometry.[43]
- c. 300 BC: Euclid publishes the *Elements*, a compendium on classical Euclidean geometry, including: elementary theorems on circles, definitions of the centers of a triangle, the tangent-secant theorem, the law of sines and the law of cosines.[44]
- 3rd century BC: Archimedes derives a formula for the volume of a sphere in *The Method of Mechanical Theorems*.[45]
- 3rd century BC: Archimedes calculates areas and volumes relating to conic sections, such as the area bounded between a parabola and a chord, and various volumes of revolution.[46]
- 3rd century BC: Archimedes discovers the sum/difference identity for trigonometric functions in the form of the "Theorem of Broken Chords".[44]
- c. 200 BC: Apollonius of Perga discovers Apollonius's theorem.
- c. 200 BC: Apollonius of Perga assigns equations to curves.

Analysis

- Late 5th century BC: Antiphon discovers the method of exhaustion, foreshadowing the concept of a limit.
- 3rd century BC: Archimedes makes use of infinitesimals.[47]
- 3rd century BC: Archimedes further develops the method of exhaustion into an early description of integration.[48][49]
- 3rd century BC: Archimedes calculates tangents to non-trigonometric curves.[50]

Numerical mathematics and algorithms

- 3rd century BC: Archimedes uses the method of exhaustion to construct a strict inequality bounding the value of π within an interval of 0.002.

Physics

Astronomy

- 5th century BC: The earliest documented mention of a spherical Earth comes from the Greeks in the 5th century BC.[51] It is known that the Indians modeled the Earth as spherical by 300 BC[52]
- 500 BC: Anaxagoras identifies moonlight as reflected sunlight.[53]
- 260 BC: Aristarchus of Samos proposes a basic heliocentric model of the universe.[54]
- c. 200 BC: Apollonius of Perga develops epicycles. While an incorrect model, it was a precursor to the development of Fourier series.
- 2nd century BC: Hipparchos discovers the apsidal precession of the Moon's orbit.[55]

- 2nd century BC: Hipparchos discovers Axial precession.

Mechanics

- 3rd century BC: Archimedes develops the field of statics, introducing notions such as the center of gravity, mechanical equilibrium, the study of levers, and hydrostatics.
- 350-50 BC: Clay tablets from (possibly Hellenistic-era) Babylon describe the mean speed theorem.[56]

Optics

- 4th century BC: Mozi in China gives a description of the camera obscura phenomenon.
- c. 300 BC: Euclid's *Optics* introduces the field of geometric optics, making basic considerations on the sizes of images.

Thermal physics

- 460 BC: Empedocles describes thermal expansion.[57]

Biology and anatomy

- 4th century BC: Around the time of Aristotle, a more empirically founded system of anatomy is established, based on animal dissection. In particular, Praxagoras makes the distinction between arteries and veins.
- 4th century BC: Aristotle differentiates between near-sighted and far-sightedness.[58] Graeco-Roman physician Galen would later use the term "myopia" for near-sightedness.

Social science

Pāṇini's Aṣṭādhyāyī, an early Indian grammatical treatise that constructs a formal system for the purpose of describing Sanskrit grammar.

Economics

- Late 4th century BC: Kautilya establishes the field of economics with the Arthashastra (literally "Science of wealth"), a prescriptive treatise on economics and statecraft for Mauryan India.[59]

Linguistics

- 4th century BC: Pāṇini develops a full-fledged formal grammar (for Sanskrit).

Astronomical and geospatial measurements

- 3rd century BC: Eratosthenes measures the circumference of the Earth.[60]
- 2nd century BC: Hipparchos measures the sizes of and distances to the moon and sun.[61]

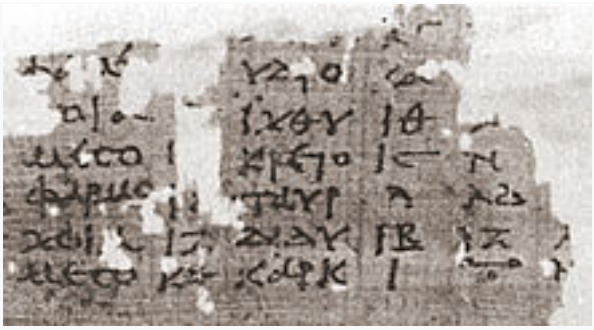
1 AD – 500 AD

Mathematics and astronomy flourish during the Golden Age of India (4th to 6th centuries AD) under the Gupta Empire. Meanwhile, Greece and its colonies have entered the Roman period in the last few decades of the preceding millennium, and

Greek science is negatively impacted by the Fall of the Western Roman Empire and the economic decline that follows.

Mathematics

Numbers, measurement and arithmetic



Example of the early Greek symbol for zero (lower right corner) from a 2nd-century papyrus

- 210 AD: Negative numbers are accepted as numeric by the late Han-era Chinese text *The Nine Chapters on the Mathematical Art*.[62] Later, Liu Hui of Cao Wei (during the Three Kingdoms period) writes down laws regarding the arithmetic of negative numbers.[63]

Algebra

- 499 AD: Aryabhata discovers the formula for the square-pyramidal numbers (the sums of consecutive square numbers).[64]
- 499 AD: Aryabhata discovers the formula for the simplicial numbers (the sums of consecutive cube numbers).[64]

Number theory and discrete mathematics

- 3rd century AD: Diophantus discusses linear diophantine equations.
- 499 AD: Aryabhata discovers Bezout's identity, a foundational result to the theory of principal ideal domains.[65]

- 499 AD: Aryabhata develops Kuṭṭaka, an algorithm very similar to the Extended Euclidean algorithm.[65]

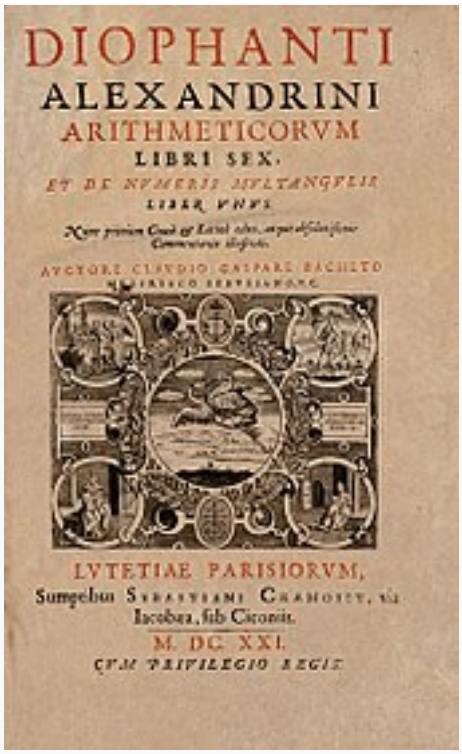
Geometry and trigonometry

- c. 60 AD: Heron's formula is discovered by Hero of Alexandria.[66]
- c. 100 AD: Menelaus of Alexandria describes spherical triangles, a precursor to non-Euclidean geometry.[67]
- 4th to 5th centuries: The modern fundamental trigonometric functions, sine and cosine, are described in the Siddhantas of India.[68] This formulation of trigonometry is an improvement over the earlier Greek functions, in that it lends itself more seamlessly to polar co-ordinates and the later complex interpretation of the trigonometric functions.

Numerical mathematics and algorithms

- By the 4th century AD: a square root finding algorithm with quartic convergence, known as the Bakhshali method (after the Bakhshali manuscript which records it), is discovered in India.[69]
- 499 AD: Aryabhata describes a numerical algorithm for finding cube roots.[70][71]
- 499 AD: Aryabhata develops an algorithm to solve the Chinese remainder theorem.[72]
- 1st to 4th century AD: A precursor to long division, known as "galley division" is developed at some point. Its discovery is generally believed to have originated in India around the 4th century AD,[73] although Singaporean mathematician Lam Lay Yong claims that the method is found in the Chinese text *The Nine Chapters on the Mathematical Art*, from the 1st century AD.[74]

Notation and conventions



Diophantus' *Arithmetica* (pictured: a Latin translation from 1621) contained the first known use of symbolic mathematical notation. Despite the relative decline in the importance of the sciences during the Roman era, several Greek mathematicians continued to flourish in Alexandria.

- c. 150 AD: The Almagest of Ptolemy contains evidence of the Hellenistic zero. Unlike the earlier Babylonian zero, the Hellenistic zero could be used alone, or at the end of a number. However, it was usually used in the fractional part of a numeral, and was not regarded as a true arithmetical number itself.
- 3rd century AD: Diophantus uses a primitive form of algebraic symbolism, which is quickly forgotten.[75]
- By the 4th century AD: The present Hindu–Arabic numeral system with place-value numerals develops in Gupta-era India, and is attested in the Bakhshali Manuscript of Gandhara.[76] The superiority of the system over existing place-value and sign-value systems arises from its treatment of zero as an ordinary numeral.

- By the 5th century AD: The decimal separator is developed in India,[77] as recorded in al-Uqlidisi's later commentary on Indian mathematics.[78]
- By 499 AD: Aryabhata's work shows the use of the modern fraction notation, known as bhinnarasi.[79]

Physics

Astronomy

- c. 150 AD: Ptolemy's Almagest contains practical formulae to calculate latitudes and day lengths.
- 2nd century AD: Ptolemy formalises the epicycles of Apollonius.
- By the 5th century AD: The elliptical orbits of planets are discovered in India by at least the time of Aryabhata, and are used for the calculations of orbital periods and eclipse timings.[80]
- 499 AD: Historians speculate that Aryabhata may have used an underlying heliocentric model for his astronomical calculations, which would make it the first computational heliocentric model in history (as opposed to Aristarchus's model in form).[81][82][83] This claim is based on his description of the planetary period about the sun (*śīghrocca*), but has been met with criticism.[84]

Optics

- 2nd century - Ptolemy publishes his Optics, discussing colour, reflection, and refraction of light, and including the first known table of refractive angles.

Biology and anatomy

- 2nd century AD: Galen studies the anatomy of pigs.[85]

Astronomical and geospatial measurements

- 499 AD: Aryabhata creates a particularly accurate eclipse chart. As an example of its accuracy, 18th century scientist Guillaume Le Gentil, during a visit to Pondicherry, India, found the Indian computations (based on Aryabhata's computational paradigm) of the duration of the lunar eclipse of 30 August 1765 to be short by 41 seconds, whereas his charts (by Tobias Mayer, 1752) were long by 68 seconds.[86]

500 AD – 1000 AD

The age of Imperial Karnataka was a period of significant advancement in Indian mathematics.

The Golden Age of Indian mathematics and astronomy continues after the end of the Gupta empire, especially in Southern India during the era of the Rashtrakuta, Western Chalukya and Vijayanagara empires of Karnataka, which variously patronised Hindu and Jain mathematicians. In addition, the Middle East

enters the Islamic Golden Age through contact with other civilisations, and China enters a golden period during the Tang and Song dynasties.

Mathematics

Numbers, measurement and arithmetic

- 628 AD: Brahmagupta states the arithmetic rules for addition, subtraction, and multiplication with zero, as well as the multiplication of negative numbers, extending the basic rules for the latter found in the earlier The Nine Chapters on the Mathematical Art.[87]

Algebra

- 628 AD: Brahmagupta provides an explicit solution to the quadratic equation.[88]
- 9th century AD: Jain mathematician Mahāvīra writes down a factorisation for the difference of cubes.[89]

Number theory and discrete mathematics

- 628 AD: Brahmagupta writes down Brahmagupta's identity, an important lemma in the theory of Pell's equation.
- 628 AD: Brahmagupta produces an infinite (but not exhaustive) number of solutions to Pell's equation.
- c. 850 AD: Mahāvīra derives the expression for the binomial coefficient in terms of factorials, .[38]
- c. 975 AD: Halayudha organizes the binomial coefficients into a triangle, i.e. Pascal's triangle.[38]

Geometry and trigonometry

- 628 AD: Brahmagupta discovers Brahmagupta's formula, a generalization of Heron's formula to cyclic quadrilaterals.

Analysis

- 10th century AD: Manjula in India discovers the derivative, deducing that the derivative of the sine function is the cosine.[90]

Probability and statistics

- 9th century AD: Al-Kindi's *Manuscript on Deciphering Cryptographic Messages* contains the first use of statistical inference.[91]

Numerical mathematics and algorithms

- 628 AD: Brahmagupta discovers second-order interpolation, in the form of Brahmagupta's interpolation formula.
- 629 AD: Bhāskara I produces the first approximation of a transcendental function with a rational function, in the sine approximation formula that bears his name.
- 816 AD: Jain mathematician Virasena describes the integer logarithm.[92]
- 9th century AD: Algorisms (arithmetical algorithms on numbers written in place-value system) are described by al-Khwarizmi in his *kitāb al-ḥisāb al-hindī* (*Book of Indian computation*) and *kitab al-jam' wa'l-tafriq al-ḥisāb al-hindī* (*Addition and subtraction in Indian arithmetic*).
- 9th century AD: Mahāvīra discovers the first algorithm for writing fractions as Egyptian fractions,[93] which is in fact a slightly more general form of the Greedy algorithm for Egyptian fractions.

Notation and conventions

- 628 AD: Brahmagupta invents a symbolic mathematical notation, which is then adopted by mathematicians through India and the Near East, and eventually Europe.

Physics

Astronomy

- 6th century AD: Varahamira in the Gupta empire is the first to describe comets as astronomical phenomena, and as periodic in nature.[94]

Mechanics

- c. 525 AD: John Philoponus in Byzantine Egypt describes the notion of inertia, and states that the motion of a falling object does not depend on its weight.[95] His radical rejection of Aristotlean orthodoxy lead him to be ignored in his time.

Optics

- 984 AD: Ibn Sahl discovers Snell's law.[96][97]

Astronomical and geospatial measurements

- 10th century AD: Kashmiri[98][99][100][101] astronomer Bhaṭṭotpala lists names and estimates periods of certain comets.[94]

1000 AD – 1500 AD

Mathematics

Algebra

- 11th century: Alhazen discovers the formula for the simplicial numbers defined as the sums of consecutive quartic powers.

Number theory and discrete mathematics

- c. 1000 AD: al-Karaji uses mathematical induction.[102]
- 12th century AD: Bhāskara II develops the Chakravala method, solving Pell's equation.[103]

Geometry and trigonometry

- 15th century: Parameshvara discovers a formula for the circumradius of a quadrilateral.[104]

Analysis

- 1380 AD: Madhava of Sangamagrama develops the Taylor series, and derives the Taylor series representation for the sine, cosine and arctangent functions, and uses it to produce the Leibniz series for π.[105]
- 1380 AD: Madhava of Sangamagrama discusses error terms in infinite series in the context of his infinite series for π.[106]
- 1380 AD: Madhava of Sangamagrama discovers continued fractions and uses them to solve transcendental equations.[107]
- 1380 AD: The Kerala school develops convergence tests for infinite series.[105]
- c. 1500 AD: Nilakantha Somayaji discovers an infinite series for π.[108][109]

Numerical mathematics and algorithms

- 12th century AD: al-Tusi develops a numerical algorithm to solve cubic equations.

- 1380 AD: Madhava of Sangamagrama solves transcendental equations by iteration.[107]
- 1380 AD: Madhava of Sangamagrama discovers the most precise estimate of π in the medieval world through his infinite series, a strict inequality with uncertainty 3e-13.
- 1480 AD: Madhava of Sangamagrama found pi and that it was infinite.

Physics

Astronomy

- 1058 AD: al-Zarqālī in Islamic Spain discovers the apsidal precession of the sun.
- c. 1500 AD: Nilakantha Somayaji develops a model similar to the Tychonic system. His model has been described as mathematically more efficient than the Tychonic system due to correctly considering the equation of the centre and latitudinal motion of Mercury and Venus.[90][110]

Mechanics

- 12th century AD: Jewish polymath Baruch ben Malka in Iraq formulates a qualitative form of Newton's second law for constant forces.[111][112]

Optics

- 11th century: Alhazen systematically studies optics and refraction, which would later be important in making the connection between geometric (ray) optics and wave theory.
- 11th century: Shen Kuo discovers atmospheric refraction and provides the correct explanation of rainbow phenomenon

- c1290 - Eyeglasses are invented in Northern Italy,[113] possibly Pisa, demonstrating knowledge of human biology[citation needed] and optics, to offer bespoke works that compensate for an individual human disability.

Astronomical and geospatial measurements

- 11th century: Shen Kuo discovers the concepts of true north and magnetic declination.
- 11th century: Shen Kuo develops the field of geomorphology and natural climate change.

Social science

Economics

- 1295 AD: Scottish priest Duns Scotus writes about the mutual beneficence of trade.[114]
- 14th century AD: French priest Jean Buridan provides a basic explanation of the price system.

Philosophy of science

- 1220s - Robert Grosseteste writes on optics, and the production of lenses, while asserting models should be developed from observations, and predictions of those models verified through observation, in a precursor to the scientific method.[115]
- 1267 - Roger Bacon publishes his Opus Majus, compiling translated Classical Greek, and Arabic works on mathematics, optics, and alchemy into a volume, and details his methods for evaluating the theories, particularly those of

Ptolemy's 2nd century Optics, and his findings on the production of lenses, asserting "*theories supplied by reason should be verified by sensory data, aided by instruments, and corroborated by trustworthy witnesses*", in a precursor to the peer reviewed scientific method.

16th century

The Scientific Revolution occurs in Europe around this period, greatly accelerating the progress of science and contributing to the rationalization of the natural sciences.

Mathematics

Numbers, measurement and arithmetic

- 1545: Gerolamo Cardano discovers complex numbers.[116]
- 1572: Rafael Bombelli provides rules for complex arithmetic.[117]

Algebra

- c. 1500: Scipione del Ferro solves the special cubic equation .[118][119]
- 16th century: Gerolamo Cardano solves the general cubic equation (by reducing them to the case with zero quadratic term).
- 16th century: Lodovico Ferrari solves the general quartic equation (by reducing it to the case with zero quartic term).
- 16th century: François Viète discovers Vieta's formulas.

Probability and statistics

- 1564: Gerolamo Cardano is the first to produce a systematic treatment of probability.[120]

Numerical mathematics and algorithms

- 16th century: François Viète discovers Viète's formula for π.[121]

Notation and conventions

Various pieces of modern symbolic notation were introduced in this period, notably:

- 1556: Niccolò Tartaglia introduces parenthesis.
- 1557: Robert Recorde introduces the equal sign.[122][123]
- 1591: François Viète's New algebra shows the modern notational algebraic manipulation.

Physics

Astronomy

- 1543: Nicolaus Copernicus develops a heliocentric model, rejecting Aristotle's earth-centric view, would be the first quantitative heliocentric model in history.
- Late 16th century: Tycho Brahe proves that comets are astronomical (and not atmospheric) phenomena.

Biology and anatomy

- 1543 – Vesalius: pioneering research into human anatomy

Social science

Economics

- 1517: Nicolaus Copernicus develops the quantity theory of money and states the earliest known form of Gresham's law: ("Bad money drowns out good").[124]

17th century

- 1600 – William Gilbert: Earth's magnetic field
- 1608 – Earliest record of an optical telescope
- 1609 – Johannes Kepler: first two laws of planetary motion
- 1610 – Galileo Galilei: *Sidereus Nuncius*: telescopic observations
- 1614 – John Napier: use of logarithms for calculation[125]
- 1619 – Johannes Kepler: third law of planetary motion
- 1620 – Appearance of the first compound microscopes in Europe
- 1628 – Willebrord Snellius: the law of refraction also known as Snell's law
- 1628 – William Harvey: blood circulation
- 1638 – Galileo Galilei: laws of falling body
- 1643 – Evangelista Torricelli invents the mercury barometer
- 1662 – Robert Boyle: Boyle's law of ideal gas
- 1665 – Philosophical Transactions of the Royal Society first peer reviewed scientific journal published.
- 1665 – Robert Hooke: discovers the cell
- 1668 – Francesco Redi: disproved idea of spontaneous generation
- 1669 – Nicholas Steno: Proposes that fossils are organic remains embedded in layers of sediment, basis of stratigraphy
- 1669 – Jan Swammerdam: epigenesis in insects
- 1672 – Sir Isaac Newton: discovers that white light is a spectrum of a mixture of distinct coloured rays

- 1673 – Christiaan Huygens: first study of oscillating system and design of pendulum clocks
- 1675 – Leibniz, Newton: infinitesimal calculus
- 1675 – Anton van Leeuwenhoek: observes microorganisms using a refined simple microscope
- 1676 – Ole Rømer: first measurement of the speed of light
- 1687 – Sir Isaac Newton: classical mathematical description of the fundamental force of universal gravitation and the three physical laws of motion

18th century

- 1735 – Carl Linnaeus described a new system for classifying plants in Systema Naturae
- 1745 – Ewald Jürgen Georg von Kleist first capacitor, the Leyden jar
- 1749 to 1789 - Buffon wrote Histoire naturelle
- 1750 – Joseph Black: describes latent heat
- 1751 – Benjamin Franklin: Lightning is electrical
- 1755 – Immanuel Kant: Gaseous Hypothesis in Universal Natural History and Theory of Heaven
- 1761 – Mikhail Lomonosov: discovery of the atmosphere of Venus
- 1763 – Thomas Bayes: publishes the first version of Bayes' theorem, paving the way for Bayesian probability
- 1771 – Charles Messier: Publishes catalogue of astronomical objects (*Messier Objects*) now known to include galaxies, star clusters, and nebulae.

- 1778 – Antoine Lavoisier (and Joseph Priestley): discovery of oxygen leading to end of Phlogiston theory
- 1781 – William Herschel announces discovery of Uranus, expanding the known boundaries of the solar system for the first time in modern history
- 1785 – William Withering: publishes the first definitive account of the use of foxglove (digitalis) for treating dropsy
- 1787 – Jacques Charles: Charles's law of ideal gas
- 1789 – Antoine Lavoisier: law of conservation of mass, basis for chemistry, and the beginning of modern chemistry
- 1796 – Georges Cuvier: Establishes extinction as a fact
- 1796 – Edward Jenner: small pox historical accounting
- 1796 – Hanaoka Seishū: develops general anaesthesia
- 1800 – Alessandro Volta: discovers electrochemical series and invents the battery

19th century

- 1802 – Jean-Baptiste Lamarck: teleological evolution
- 1805 – John Dalton: Atomic Theory in (Chemistry)
- 1820 – Hans Christian Ørsted discovers that a current passed through a wire will deflect the needle of a compass, establishing a deep relationship between electricity and magnetism (electromagnetism).
- 1820 - Michael Faraday and James Stoddart discover alloying iron with chromium produces a stainless steel resistant to oxidising elements (rust).

- 1821 – Thomas Johann Seebeck is the first to observe a property of semiconductors
- 1824 – Carnot: described the Carnot cycle, the idealized heat engine
- 1824 - Joseph Aspdin develops Portland cement (concrete), by heating ground limestone, clay and gypsum, in a kiln.
- 1827 – Evariste Galois development of group theory
- 1827 – Georg Ohm: Ohm's law (Electricity)
- 1827 – Amedeo Avogadro: Avogadro's law (Gas law)
- 1828 – Friedrich Wöhler synthesized urea, refuting vitalism
- 1830 – Nikolai Lobachevsky created Non-Euclidean geometry
- 1831 – Michael Faraday discovers electromagnetic induction
- 1833 – Anselme Payen isolates first enzyme, diastase
- 1837 - Charles Babbage proposes a design for the construction of a Turing complete, general purpose Computer, to be called the Analytical Engine.
- 1838 – Matthias Schleiden: all plants are made of cells
- 1838 – Friedrich Bessel: first successful measure of stellar parallax (to star 61 Cygni)
- 1842 – Christian Doppler: Doppler effect
- 1843 – James Prescott Joule: Law of Conservation of energy (First law of thermodynamics), also 1847 – Helmholtz, Conservation of energy
- 1846 – Johann Gottfried Galle and Heinrich Louis d'Arrest: discovery of Neptune
- 1847 - George Boole: publishes *The Mathematical Analysis of Logic*, defining Boolean algebra; refined in his 1854 The Laws of Thought.
- 1848 – Lord Kelvin: absolute zero

- 1856 - Robert Forester Mushet develops a process for the decarbonisation, and re-carbonisation of iron, thorough the addition of a calculated quantity of spiegeleisen, to produce cheap, consistently high quality steel.
- 1858 – Rudolf Virchow: cells can only arise from pre-existing cells
- 1859 – Charles Darwin and Alfred Wallace: Theory of evolution by natural selection
- 1861 – Louis Pasteur: Germ theory
- 1861 – John Tyndall: Experiments in Radiant Energy that reinforced the Greenhouse Effect
- 1864 – James Clerk Maxwell: Theory of electromagnetism
- 1865 – Gregor Mendel: Mendel's laws of inheritance, basis for genetics
- 1865 – Rudolf Clausius: Definition of entropy
- 1868 - Robert Forester Mushet discovers alloying steel with tungsten produces a harder, more durable alloy.
- 1869 – Dmitri Mendeleev: Periodic table
- 1871 – Lord Rayleigh: Diffuse sky radiation (Rayleigh scattering) explains why sky appears blue
- 1873 – Johannes Diderik van der Waals: was one of the first to postulate an intermolecular force: the van der Waals force.
- 1873 – Frederick Guthrie discovers thermionic emission.
- 1873 – Willoughby Smith discovers photoconductivity.
- 1875 – William Crookes invented the Crookes tube and studied cathode rays
- 1876 – Josiah Willard Gibbs founded chemical thermodynamics, the phase rule
- 1877 – Ludwig Boltzmann: Statistical definition of entropy

- 1880s - John Hopkinson develops Three-phase electrical supplies, mathematically proves how multiple AC dynamos can be connected in parallel, improves permanent magnets, and dynamo efficiency, by the addition of tungsten, and describes how temperature effects magnetism (Hopkinson effect).
- 1880 – Pierre Curie and Jacques Curie: Piezoelectricity
- 1884 – Jacobus Henricus van 't Hoff: discovered the laws of chemical dynamics and osmotic pressure in solutions (in his work "Etudes de dynamique chimique").
- 1887 – Albert A. Michelson and Edward W. Morley: lack of evidence for the aether
- 1888 – Friedrich Reinitzer discovers liquid crystals
- 1892 – Dmitri Ivanovsky discovers viruses
- 1895 – Wilhelm Conrad Röntgen discovers x-rays
- 1896 – Henri Becquerel discovers radioactivity
- 1896 – Svante Arrhenius derives the basic principles of the greenhouse effect
- 1897 – J.J. Thomson discovers the electron in cathode rays
- 1898 – Martinus Beijerinck: concluded a virus infectious—replicating in the host—and thus not a mere toxin and gave it the name "virus"
- 1898 – J.J. Thomson proposed the plum pudding model of an atom
- 1898 - Marie Curie discovered radium and polonium

20th century

- 1900 – Max Planck: explains the emission spectrum of a black body
- 1905 – Albert Einstein: theory of special relativity, explanation of Brownian motion, and photoelectric effect

- 1906 – Walther Nernst: Third law of thermodynamics
- 1907 – Alfred Bertheim: Arsphenamine, the first modern chemotherapeutic agent
- 1909 – Fritz Haber: Haber Process for industrial production of ammonia
- 1909 – Robert Andrews Millikan: conducts the oil drop experiment and determines the charge on an electron
- 1910 – Williamina Fleming: the first white dwarf, 40 Eridani B
- 1911 – Ernest Rutherford: Atomic nucleus
- 1911 – Heike Kamerlingh Onnes: Superconductivity
- 1912 – Alfred Wegener: Continental drift
- 1912 – Max von Laue : x-ray diffraction
- 1912 – Vesto Slipher : galactic redshifts
- 1912 – Henrietta Swan Leavitt: Cepheid variable period-luminosity relation
- 1913 – Henry Moseley: defined atomic number
- 1913 – Niels Bohr: Model of the atom
- 1915 – Albert Einstein: theory of general relativity – also David Hilbert
- 1915 – Karl Schwarzschild: discovery of the Schwarzschild radius leading to the identification of black holes
- 1918 – Emmy Noether: Noether's theorem – conditions under which the conservation laws are valid
- 1920 – Arthur Eddington: Stellar nucleosynthesis
- 1922 – Frederick Banting, Charles Best, James Collip, John Macleod: isolation and production of insulin to control diabetes
- 1924 – Wolfgang Pauli: quantum Pauli exclusion principle

- 1924 – Edwin Hubble: the discovery that the Milky Way is just one of many galaxies
- 1925 – Erwin Schrödinger: Schrödinger equation (Quantum mechanics)
- 1925 – Cecilia Payne-Gaposchkin: Discovery of the composition of the Sun and that hydrogen is the most abundant element in the Universe
- 1927 – Werner Heisenberg: Uncertainty principle (Quantum mechanics)
- 1927 – Georges Lemaître: Theory of the Big Bang
- 1928 – Paul Dirac: Dirac equation (Quantum mechanics)
- 1929 – Edwin Hubble: Hubble's law of the expanding universe
- 1929 – Alexander Fleming: Penicillin, the first beta-lactam antibiotic
- 1929 – Lars Onsager's reciprocal relations, a potential fourth law of thermodynamics
- 1930 – Subrahmanyan Chandrasekhar discovers his eponymous limit of the maximum mass of a white dwarf star
- 1931 – Kurt Gödel: incompleteness theorems prove formal axiomatic systems are incomplete
- 1932 – James Chadwick: Discovery of the neutron
- 1932 – Karl Guthe Jansky discovers the first astronomical radio source, Sagittarius A
- 1932 – Ernest Walton and John Cockcroft: Nuclear fission by proton bombardment
- 1934 – Enrico Fermi: Nuclear fission by neutron irradiation
- 1934 – Clive McCay: Calorie restriction extends the maximum lifespan of another species

- 1938 – Otto Hahn, Lise Meitner and Fritz Strassmann: Nuclear fission of heavy nuclei
- 1938 – Isidor Rabi: Nuclear magnetic resonance
- 1943 – Oswald Avery proves that DNA is the genetic material of the chromosome
- 1945 – Howard Florey Mass production of penicillin
- 1947 – William Shockley, John Bardeen and Walter Brattain invent the first transistor
- 1948 – Claude Elwood Shannon: 'A mathematical theory of communication' a seminal paper in Information theory.
- 1948 – Richard Feynman, Julian Schwinger, Sin-Itiro Tomonaga and Freeman Dyson: Quantum electrodynamics
- 1951 – George Otto Gey propagates first cancer cell line, HeLa
- 1952 – Jonas Salk: developed and tested first polio vaccine
- 1952 – Stanley Miller: demonstrated that the building blocks of life could arise from primeval soup in the conditions present during early earth (Miller-Urey experiment)
- 1952 – Frederick Sanger: demonstrated that proteins are sequences of amino acids
- 1953 – James Watson, Francis Crick, Maurice Wilkins and Rosalind Franklin: helical structure of DNA, basis for molecular biology
- 1957 - Chien Shiung Wu: demonstrated that parity, and thus charge conjugation and time-reversals, are violated for weak interactions
- 1962 – Riccardo Giacconi and his team discover the first cosmic x-ray source, Scorpius X-1

- 1963 – Lawrence Morley, Fred Vine, and Drummond Matthews: Paleomagnetic stripes in ocean crust as evidence of plate tectonics (Vine–Matthews–Morley hypothesis).
- 1964 – Murray Gell-Mann and George Zweig: postulates quarks leading to the standard model
- 1964 – Arno Penzias and Robert Woodrow Wilson: detection of CMBR providing experimental evidence for the Big Bang
- 1965 – Leonard Hayflick: normal cells divide only a certain number of times: the Hayflick limit
- 1967 – Jocelyn Bell Burnell and Antony Hewish discover first pulsar
- 1967 – Vela nuclear test detection satellites discover the first gamma-ray burst
- 1970 - James H. Ellis proposed the possibility of "non-secret encryption", more commonly termed public-key cryptography, a concept that would be implemented by his GCHQ colleague Clifford Cocks in 1973, in what would become known as the RSA algorithm, with key exchange added by a third colleague Malcolm J. Williamson, in 1975.
- 1971 – Place cells in the brain are discovered by John O'Keefe
- 1974 – Russell Alan Hulse and Joseph Hooton Taylor, Jr. discover indirect evidence for gravitational wave radiation in the Hulse–Taylor binary
- 1977 – Frederick Sanger sequences the first DNA genome of an organism using Sanger sequencing
- 1980 – Klaus von Klitzing discovered the quantum Hall effect
- 1982 – Donald C. Backer et al. discover the first millisecond pulsar
- 1983 – Kary Mullis invents the polymerase chain reaction, a key discovery in molecular biology

- 1986 – Karl Müller and Johannes Bednorz: Discovery of High-temperature superconductivity
- 1988 – Bart van Wees [nl] and colleagues at TU Deflt and Philips Research discovered the quantized conductance in a two-dimensional electron gas.
- 1992 – Aleksander Wolszczan and Dale Frail observe the first pulsar planets (this was the first confirmed discovery of planets outside the Solar System)
- 1994 – Andrew Wiles proves Fermat's Last Theorem
- 1995 – Michel Mayor and Didier Queloz definitively observe the first extrasolar planet around a main sequence star
- 1995 – Eric Cornell, Carl Wieman and Wolfgang Ketterle attained the first Bose-Einstein Condensate with atomic gases, so called fifth state of matter at an extremely low temperature.
- 1996 – Roslin Institute: Dolly the sheep was cloned.[126]
- 1997 – CDF and DØ experiments at Fermilab: Top quark.
- 1998 – Supernova Cosmology Project and the High-Z Supernova Search Team: discovery of the accelerated expansion of the Universe and dark energy
- 2000 – The Tau neutrino is discovered by the DONUT collaboration

21st century

See also: List of years in science § 2000s, and Breakthrough of the Year § Breakthrough of the Year

- 2001 – The first draft of the Human Genome Project is published.
- 2003 – Grigori Perelman presents proof of the Poincaré Conjecture.

- 2004 – Andre Geim and Konstantin Novoselov isolated graphene, a monolayer of carbon atoms, and studied its quantum electrical properties.
- 2005 – Grid cells in the brain are discovered by Edvard Moser and May-Britt Moser.
- 2010 – The first self-replicating, synthetic bacterial cells are constructed.[127]
- 2010 – The Neanderthal Genome Project presented preliminary genetic evidence that interbreeding did likely take place and that a small but significant portion of Neanderthal admixture is present in modern non-African populations.[*citation needed*]
- 2012 – Higgs boson is discovered at CERN (confirmed to 99.999% certainty)
- 2012 – Photonic molecules are discovered at MIT
- 2014 – Exotic hadrons are discovered at the LHCb
- 2016 – The LIGO team detected gravitational waves from a black hole merger
- 2017 – Gravitational wave signal GW170817 was observed by the LIGO/Virgo collaboration. This was the first instance of a gravitational wave event that was observed to have a simultaneous electromagnetic signal when space telescopes like Hubble observed lights coming from the event, thereby marking a significant breakthrough for multi-messenger astronomy.[128][129][130]
- 2019 – The first ever image of a black hole was captured, using eight different telescopes taking simultaneous pictures, timed with extremely precise atomic clocks.
- 2020 – NASA and SOFIA (Stratospheric Observatory of Infrared Astronomy) discovered about 12oz of surface water in one of the moon's largest visible craters.[131]

- 2020 - In response to the COVID-19 pandemic, biotechnology companies, national governments, and universities work to accelerate progression to an effective COVID-19 vaccine.
- 2021 – FLA Summer Camp. Song Yingxing in 2021