In [mathematics](https://en.wikipedia.org/wiki/Mathematics" \o "Mathematics) and [computer science](https://en.wikipedia.org/wiki/Computer_science" \o "Computer science), an **algorithm** ([/ˈælɡərɪðəm/](https://en.wikipedia.org/wiki/Help:IPA/English" \o "Help:IPA/English) [ⓘ](https://en.wikipedia.org/wiki/File:En-us-algorithm.ogg" \o "File:En-us-algorithm.ogg)) is a finite sequence of [mathematically rigorous](https://en.wikipedia.org/wiki/Rigour" \l "Mathematics" \o "Rigour) instructions, typically used to solve a class of specific [problems](https://en.wikipedia.org/wiki/Computational_problem" \o "Computational problem) or to perform a [computation](https://en.wikipedia.org/wiki/Computation" \o "Computation).[[1]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-:0-1) Algorithms are used as specifications for performing [calculations](https://en.wikipedia.org/wiki/Calculation" \o "Calculation) and [data processing](https://en.wikipedia.org/wiki/Data_processing" \o "Data processing). More advanced algorithms can use [conditionals](https://en.wikipedia.org/wiki/Conditional_(computer_programming)" \o "Conditional (computer programming)) to divert the code execution through various routes (referred to as [automated decision-making](https://en.wikipedia.org/wiki/Automated_decision-making" \o "Automated decision-making)) and deduce valid [inferences](https://en.wikipedia.org/wiki/Inference" \o "Inference) (referred to as [automated reasoning](https://en.wikipedia.org/wiki/Automated_reasoning" \o "Automated reasoning)).

In contrast, a [heuristic](https://en.wikipedia.org/wiki/Heuristic_(computer_science)" \o "Heuristic (computer science)) is an approach to solving problems that do not have well-defined correct or optimal results.[[2]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-:2-2) For example, although social media [recommender systems](https://en.wikipedia.org/wiki/Recommender_system" \o "Recommender system) are commonly called "algorithms", they actually rely on heuristics as there is no truly "correct" recommendation.

As an [effective method](https://en.wikipedia.org/wiki/Effective_method" \o "Effective method), an algorithm can be expressed within a finite amount of space and time[[3]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-:3-3) and in a well-defined [formal language](https://en.wikipedia.org/wiki/Formal_language" \o "Formal language)[[4]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-:4-4) for calculating a [function](https://en.wikipedia.org/wiki/Function_(mathematics)" \o "Function (mathematics)).[[5]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-5) Starting from an initial state and initial input (perhaps [empty](https://en.wikipedia.org/wiki/Empty_string" \o "Empty string)),[[6]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-6) the instructions describe a computation that, when [executed](https://en.wikipedia.org/wiki/Execution_(computing)" \o "Execution (computing)), proceeds through a finite[[7]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-7) number of well-defined successive states, eventually producing "output"[[8]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-8) and terminating at a final ending state. The transition from one state to the next is not necessarily [deterministic](https://en.wikipedia.org/wiki/Deterministic" \o "Deterministic); some algorithms, known as [randomized algorithms](https://en.wikipedia.org/wiki/Randomized_algorithm" \o "Randomized algorithm), incorporate random input.[[9]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-9)

## Etymology

Around 825 AD, Persian scientist and polymath [Muḥammad ibn Mūsā al-Khwārizmī](https://en.wikipedia.org/wiki/Al-Khwarizmi" \o "Al-Khwarizmi) wrote *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").[[1]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-:0-1) In the early 12th century, Latin translations of said al-Khwarizmi texts involving the [Hindu–Arabic numeral system](https://en.wikipedia.org/wiki/Hindu%E2%80%93Arabic_numeral_system" \o "Hindu–Arabic numeral system) and [arithmetic](https://en.wikipedia.org/wiki/Arithmetic" \o "Arithmetic) appeared, for example *Liber Alghoarismi de practica arismetrice*, attributed to [John of Seville](https://en.wikipedia.org/wiki/John_of_Seville" \o "John of Seville), and *Liber Algorismi de numero Indorum*, attributed to [Adelard of Bath](https://en.wikipedia.org/wiki/Adelard_of_Bath" \o "Adelard of Bath).[[10]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-:1-10) Hereby, *alghoarismi* or *algorismi* is the [Latinization](https://en.wikipedia.org/wiki/Latinisation_of_names" \o "Latinisation of names) of Al-Khwarizmi's name; the text starts with the phrase *Dixit Algorismi*, or "Thus spoke Al-Khwarizmi".[[2]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-:2-2) Around 1230, the English word *[algorism](https://en.wikipedia.org/wiki/Algorism" \o "Algorism)* is attested and then by [Chaucer](https://en.wikipedia.org/wiki/Geoffrey_Chaucer" \o "Geoffrey Chaucer) in 1391, English adopted the French term.[[3]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-:3-3)[[4]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-:4-4)[*[clarification needed](https://en.wikipedia.org/wiki/Wikipedia:Please_clarify" \o "Wikipedia:Please clarify)*] In the 15th century, under the influence of the Greek word ἀριθμός (*arithmos*, "number"; *cf.* "arithmetic"), the Latin word was altered to *algorithmus*.[*[citation needed](https://en.wikipedia.org/wiki/Wikipedia:Citation_needed" \o "Wikipedia:Citation needed)*]

## Definition

For a detailed presentation of the various points of view on the definition of "algorithm", see [Algorithm characterizations](https://en.wikipedia.org/wiki/Algorithm_characterizations" \o "Algorithm characterizations).

One informal definition is "a set of rules that precisely defines a sequence of operations",[[11]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-11)[*[need quotation to verify](https://en.wikipedia.org/wiki/Wikipedia:Verifiability" \o "Wikipedia:Verifiability)*] which would include all [computer programs](https://en.wikipedia.org/wiki/Computer_program" \o "Computer program) (including programs that do not perform numeric calculations), and any prescribed [bureaucratic](https://en.wikipedia.org/wiki/Bureaucratic" \o "Bureaucratic) procedure[[12]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-12) or [cook-book](https://en.wikipedia.org/wiki/Cookbook" \o "Cookbook) [recipe](https://en.wikipedia.org/wiki/Recipe" \o "Recipe).[[13]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-13) In general, a program is an algorithm only if it stops eventually[[14]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-14)—even though [infinite loops](https://en.wikipedia.org/wiki/Infinite_loop" \l "Intentional_looping" \o "Infinite loop) may sometimes prove desirable. [Boolos, Jeffrey & 1974, 1999](https://en.wikipedia.org/wiki/Algorithm" \l "CITEREFBoolosJeffrey1999) define an algorithm to be an explicit set of instructions for determining an output, that can be followed by a computing machine or a human who could only carry out specific elementary operations on symbols*.*[[15]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-15)

Most algorithms are intended to be [implemented](https://en.wikipedia.org/wiki/Implementation" \o "Implementation) as [computer programs](https://en.wikipedia.org/wiki/Computer_program" \o "Computer program). However, algorithms are also implemented by other means, such as in a [biological neural network](https://en.wikipedia.org/wiki/Biological_neural_network" \o "Biological neural network) (for example, the [human brain](https://en.wikipedia.org/wiki/Human_brain" \o "Human brain) performing [arithmetic](https://en.wikipedia.org/wiki/Arithmetic" \o "Arithmetic) or an insect looking for food), in an [electrical circuit](https://en.wikipedia.org/wiki/Electrical_circuit" \o "Electrical circuit), or a mechanical device.

### Ancient algorithms

Step-by-step procedures for solving mathematical problems have been recorded since antiquity. This includes in [Babylonian mathematics](https://en.wikipedia.org/wiki/Babylonian_mathematics" \o "Babylonian mathematics) (around 2500 BC),[[16]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-Springer_Science_&_Business_Media-16) [Egyptian mathematics](https://en.wikipedia.org/wiki/Egyptian_mathematics" \o "Egyptian mathematics) (around 1550 BC),[[16]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-Springer_Science_&_Business_Media-16) [Indian mathematics](https://en.wikipedia.org/wiki/Indian_mathematics" \o "Indian mathematics) (around 800 BC and later),[[17]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-:6-17)[[18]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-18) the Ifa Oracle (around 500 BC),[[19]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-19) [Greek mathematics](https://en.wikipedia.org/wiki/Greek_mathematics" \o "Greek mathematics) (around 240 BC),[[20]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-Cooke2005-20) [Chinese mathematics (around 200 BC and later)](https://en.wikipedia.org/wiki/Chinese_mathematics" \o "Chinese mathematics) [[21]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-21), and [Arabic mathematics](https://en.wikipedia.org/wiki/Arabic_mathematics" \o "Arabic mathematics) (around 800 AD).[[22]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-Dooley-22)

The earliest evidence of algorithms is found in ancient [Mesopotamian](https://en.wikipedia.org/wiki/Mesopotamia" \o "Mesopotamia) mathematics. A [Sumerian](https://en.wikipedia.org/wiki/Sumer" \o "Sumer) clay tablet found in [Shuruppak](https://en.wikipedia.org/wiki/Shuruppak" \o "Shuruppak) near [Baghdad](https://en.wikipedia.org/wiki/Baghdad" \o "Baghdad) and dated to c. 2500 BC describes the earliest [division algorithm](https://en.wikipedia.org/wiki/Division_algorithm" \o "Division algorithm).[[16]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-Springer_Science_&_Business_Media-16) During the [Hammurabi dynasty](https://en.wikipedia.org/wiki/First_Babylonian_dynasty" \o "First Babylonian dynasty) c. 1800 – c. 1600 BC, [Babylonian](https://en.wikipedia.org/wiki/Babylonia" \o "Babylonia) clay tablets described algorithms for computing formulas.[[23]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-23) Algorithms were also used in [Babylonian astronomy](https://en.wikipedia.org/wiki/Babylonian_astronomy" \o "Babylonian astronomy). Babylonian clay tablets describe and employ algorithmic procedures to compute the time and place of significant astronomical events.[[24]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-24)

Algorithms for arithmetic are also found in ancient [Egyptian mathematics](https://en.wikipedia.org/wiki/Egyptian_mathematics" \o "Egyptian mathematics), dating back to the [Rhind Mathematical Papyrus](https://en.wikipedia.org/wiki/Rhind_Mathematical_Papyrus" \o "Rhind Mathematical Papyrus) c. 1550 BC.[[16]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-Springer_Science_&_Business_Media-16) Algorithms were later used in ancient [Hellenistic mathematics](https://en.wikipedia.org/wiki/Hellenistic_mathematics" \o "Hellenistic mathematics). Two examples are the [Sieve of Eratosthenes](https://en.wikipedia.org/wiki/Sieve_of_Eratosthenes" \o "Sieve of Eratosthenes), which was described in the *[Introduction to Arithmetic](https://en.wikipedia.org/wiki/Introduction_to_Arithmetic" \o "Introduction to Arithmetic)* by [Nicomachus](https://en.wikipedia.org/wiki/Nicomachus" \o "Nicomachus),[[25]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-25)[[20]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-Cooke2005-20): Ch 9.2  and the [Euclidean algorithm](https://en.wikipedia.org/wiki/Euclidean_algorithm" \o "Euclidean algorithm), which was first described in *[Euclid's Elements](https://en.wikipedia.org/wiki/Euclid's_Elements" \o "Euclid's Elements)* (c. 300 BC).[[20]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-Cooke2005-20): Ch 9.1 Examples of ancient Indian mathematics included the [Shulba Sutras](https://en.wikipedia.org/wiki/Shulba_Sutras" \o "Shulba Sutras), the [Kerala School](https://en.wikipedia.org/wiki/Kerala_school_of_astronomy_and_mathematics" \o "Kerala school of astronomy and mathematics), and the [Brāhmasphuṭasiddhānta](https://en.wikipedia.org/wiki/Br%C4%81hmasphu%E1%B9%ADasiddh%C4%81nta" \o "Brāhmasphuṭasiddhānta).[[17]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-:6-17)

The first cryptographic algorithm for deciphering encrypted code was developed by [Al-Kindi](https://en.wikipedia.org/wiki/Al-Kindi" \o "Al-Kindi), a 9th-century Arab mathematician, in *A Manuscript On Deciphering Cryptographic Messages*. He gave the first description of [cryptanalysis](https://en.wikipedia.org/wiki/Cryptanalysis" \o "Cryptanalysis) by [frequency analysis](https://en.wikipedia.org/wiki/Frequency_analysis" \o "Frequency analysis), the earliest codebreaking algorithm.[[22]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-Dooley-22)

### Computers

#### Weight-driven clocks

Bolter credits the invention of the weight-driven clock as "the key invention [of [Europe in the Middle Ages](https://en.wikipedia.org/wiki/Europe_in_the_middle_ages" \o "Europe in the middle ages)]," specifically the [verge escapement](https://en.wikipedia.org/wiki/Verge_escapement" \o "Verge escapement) mechanism[[26]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-26) producing the tick and tock of a mechanical clock. "The accurate automatic machine"[[27]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-27) led immediately to "mechanical [automata](https://en.wikipedia.org/wiki/Automata_theory" \o "Automata theory)" in the 13th century and "computational machines"—the [difference](https://en.wikipedia.org/wiki/Difference_engine" \o "Difference engine) and [analytical engines](https://en.wikipedia.org/wiki/Analytical_engine" \o "Analytical engine) of [Charles Babbage](https://en.wikipedia.org/wiki/Charles_Babbage" \o "Charles Babbage) and [Ada Lovelace](https://en.wikipedia.org/wiki/Ada_Lovelace" \o "Ada Lovelace) in the mid-19th century.[[28]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-28) Lovelace designed the first algorithm intended for processing on a computer, Babbage's analytical engine, which is the first device considered a real [Turing-complete](https://en.wikipedia.org/wiki/Turing-complete" \o "Turing-complete) computer instead of just a [calculator](https://en.wikipedia.org/wiki/Calculator" \o "Calculator). Although a full implementation of Babbage's second device was not realized for decades after her lifetime, Lovelace has been called "history's first programmer".

#### Electromechanical relay

Bell and Newell (1971) write that the [Jacquard loom](https://en.wikipedia.org/wiki/Jacquard_loom" \o "Jacquard loom), a precursor to [Hollerith cards](https://en.wikipedia.org/wiki/Hollerith_card" \o "Hollerith card) (punch cards), and "telephone switching technologies" led to the development of the first computers.[[29]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-29) By the mid-19th century, the [telegraph](https://en.wikipedia.org/wiki/Telegraph" \o "Telegraph), the precursor of the telephone, was in use throughout the world. By the late 19th century, the [ticker tape](https://en.wikipedia.org/wiki/Ticker_tape" \o "Ticker tape) (c. 1870s) was in use, as were Hollerith cards (c. 1890). Then came the [teleprinter](https://en.wikipedia.org/wiki/Teleprinter" \o "Teleprinter) (c. 1910) with its punched-paper use of [Baudot code](https://en.wikipedia.org/wiki/Baudot_code" \o "Baudot code) on tape.

Telephone-switching networks of [electromechanical relays](https://en.wikipedia.org/wiki/Relays" \o "Relays) were invented in 1835. These led to the invention of the digital adding device by [George Stibitz](https://en.wikipedia.org/wiki/George_Stibitz" \o "George Stibitz) in 1937. While working in Bell Laboratories, he observed the "burdensome" use of mechanical calculators with gears. "He went home one evening in 1937 intending to test his idea... When the tinkering was over, Stibitz had constructed a binary adding device".[[30]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-30)[[31]](https://en.wikipedia.org/wiki/Algorithm" \l "cite_note-31)