**Artificial intelligence** (**AI**) is [intelligence](https://en.wikipedia.org/wiki/Intelligence) demonstrated by [machines](https://en.wikipedia.org/wiki/Machine), as opposed to the **natural intelligence** displayed by [animals](https://en.wikipedia.org/wiki/Animal_cognition) including [humans](https://en.wikipedia.org/wiki/Human_intelligence). AI research has been defined as the field of study of [intelligent agents](https://en.wikipedia.org/wiki/Intelligent_agent), which refers to any system that perceives its environment and takes actions that maximize its chance of achieving its goals.[[a]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-Definition_of_AI-1)

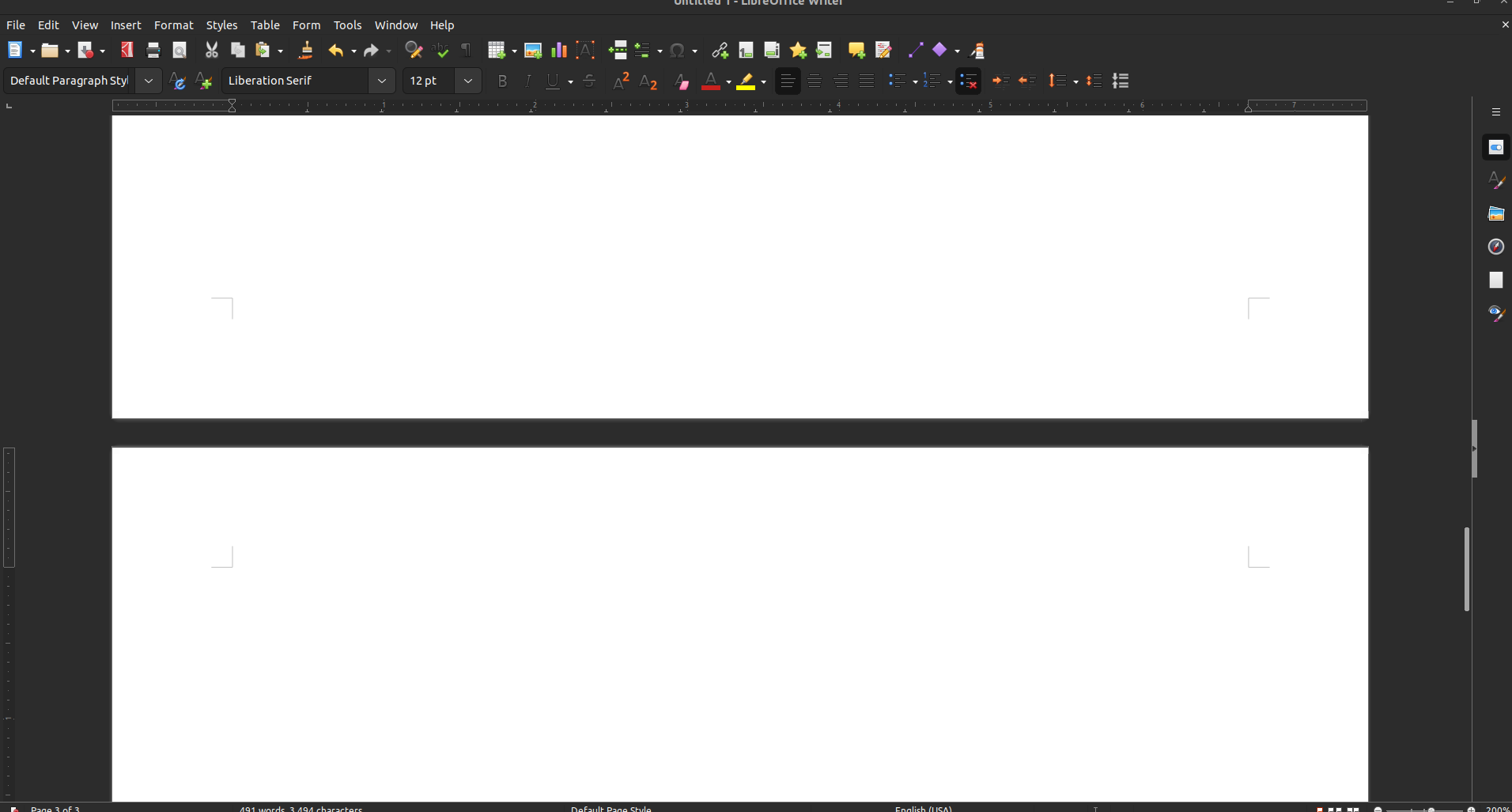
The term "artificial intelligence" had previously been used to describe machines that mimic and display "human" cognitive skills that are associated with the [human mind](https://en.wikipedia.org/wiki/Human_mind), such as "learning" and "problem-solving". This definition has since been rejected by major AI researchers who now describe AI in terms of [rationality](https://en.wikipedia.org/wiki/Rationality) and acting rationally, which does not limit how intelligence can be articulated.[[b]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-3)

AI applications include advanced [web search](https://en.wikipedia.org/wiki/Web_search) engines (e.g., [Google](https://en.wikipedia.org/wiki/Google)), [recommendation systems](https://en.wikipedia.org/wiki/Recommender_system) (used by [YouTube](https://en.wikipedia.org/wiki/YouTube), [Amazon](https://en.wikipedia.org/wiki/Amazon_(company)) and [Netflix](https://en.wikipedia.org/wiki/Netflix)), [understanding human speech](https://en.wikipedia.org/wiki/Natural-language_understanding) (such as [Siri](https://en.wikipedia.org/wiki/Siri) and [Alexa](https://en.wikipedia.org/wiki/Amazon_Alexa)), [self-driving cars](https://en.wikipedia.org/wiki/Self-driving_car) (e.g., [Tesla](https://en.wikipedia.org/wiki/Tesla,_Inc.)), [automated decision-making](https://en.wikipedia.org/wiki/Automated_decision-making) and competing at the highest level in [strategic game](https://en.wikipedia.org/wiki/Strategic_game) systems (such as [chess](https://en.wikipedia.org/wiki/Chess) and [Go](https://en.wikipedia.org/wiki/Go_(game))).[[2]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTEGoogle2016-4)[[*citation needed*](https://en.wikipedia.org/wiki/Wikipedia:Citation_needed)] As machines become increasingly capable, tasks considered to require "intelligence" are often removed from the definition of AI, a phenomenon known as the [AI effect](https://en.wikipedia.org/wiki/AI_effect).[[3]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTEMcCorduck2004204-5) For instance, [optical character recognition](https://en.wikipedia.org/wiki/Optical_character_recognition) is frequently excluded from things considered to be AI,[[4]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTEAshok832019-6) having become a routine technology.[[5]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTESchank199138-7)

Artificial intelligence was founded as an academic discipline in 1956, and in the years since has experienced several waves of optimism,[[6]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTECrevier1993109-8)[[7]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-AI_in_the_80s-9) followed by disappointment and the loss of funding (known as an "[AI winter](https://en.wikipedia.org/wiki/AI_winter)"),[[8]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-First_AI_winter-10)[[9]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-Second_AI_winter-11) followed by new approaches, success and renewed funding.[[7]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-AI_in_the_80s-9)[[10]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTEClark2015b-12) AI research has tried and discarded many different approaches since its founding, including simulating the brain, [modeling human problem solving](https://en.wikipedia.org/wiki/Symbolic_AI" \l "Cognitive_simulation), [formal logic](https://en.wikipedia.org/wiki/Symbolic_AI" \l "Logic-based), [large databases of knowledge](https://en.wikipedia.org/wiki/Symbolic_AI" \l "Knowledge-based) and imitating animal behavior. In the first decades of the 21st century, highly mathematical-statistical [machine learning](https://en.wikipedia.org/wiki/Machine_learning) has dominated the field, and this technique has proved highly successful, helping to solve many challenging problems throughout industry and academia.[[11]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-AI_widely_used_1990s-13)[[10]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTEClark2015b-12)

The various sub-fields of AI research are centered around particular goals and the use of particular tools. The traditional goals of AI research include [reasoning](https://en.wikipedia.org/wiki/Automated_reasoning), [knowledge representation](https://en.wikipedia.org/wiki/Knowledge_representation), [planning](https://en.wikipedia.org/wiki/Automated_planning_and_scheduling), [learning](https://en.wikipedia.org/wiki/Machine_learning), [natural language processing](https://en.wikipedia.org/wiki/Natural_language_processing), [perception](https://en.wikipedia.org/wiki/Machine_perception), and the ability to move and manipulate objects.[[c]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-Problems_of_AI-14) [General intelligence](https://en.wikipedia.org/wiki/Artificial_general_intelligence) (the ability to solve an arbitrary problem) is among the field's long-term goals.[[12]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-Artificial_General_Intelligence-15) To solve these problems, AI researchers have adapted and integrated a wide range of problem-solving techniques—including search and mathematical optimization, formal logic, [artificial neural networks](https://en.wikipedia.org/wiki/Artificial_neural_network), and methods based on [statistics](https://en.wikipedia.org/wiki/Statistics), [probability](https://en.wikipedia.org/wiki/Probability) and [economics](https://en.wikipedia.org/wiki/Economics). AI also draws upon [computer science](https://en.wikipedia.org/wiki/Computer_science), [psychology](https://en.wikipedia.org/wiki/Psychology), [linguistics](https://en.wikipedia.org/wiki/Linguistics), [philosophy](https://en.wikipedia.org/wiki/Philosophy), and many other fields.

The field was founded on the assumption that human intelligence "can be so precisely described that a machine can be made to simulate it".[[d]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-17) This raised philosophical arguments about the mind and the ethical consequences of creating artificial beings endowed with human-like intelligence; these issues have previously been explored by [myth](https://en.wikipedia.org/wiki/History_of_artificial_intelligence" \l "Precursors), [fiction](https://en.wikipedia.org/wiki/Artificial_intelligence_in_fiction) and [philosophy](https://en.wikipedia.org/wiki/Philosophy_of_artificial_intelligence) since antiquity.[[14]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTENewquist199445–53-18) [Science fiction](https://en.wikipedia.org/wiki/Science_fiction) writers and [futurologists](https://en.wikipedia.org/wiki/Futures_studies) have since suggested that AI may become an [existential risk](https://en.wikipedia.org/wiki/Existential_risk) to humanity if its rational capacities are not overseen.[[15]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTESpadafora2016-19)[[16]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTELombardoBoehmNairz2020-20)



[Artificial beings](https://en.wikipedia.org/wiki/Artificial_being) with intelligence appeared as [storytelling devices](https://en.wikipedia.org/wiki/Storytelling_device) in antiquity,[[17]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-AI_in_myth-21) and have been common in fiction, as in [Mary Shelley](https://en.wikipedia.org/wiki/Mary_Shelley)'s [*Frankenstein*](https://en.wikipedia.org/wiki/Frankenstein) or [Karel Čapek](https://en.wikipedia.org/wiki/Karel_Čapek)'s [*R.U.R.*](https://en.wikipedia.org/wiki/R.U.R.)[[18]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTEMcCorduck200417–25-22) These characters and their fates raised many of the same issues now discussed in the [ethics of artificial intelligence](https://en.wikipedia.org/wiki/Ethics_of_artificial_intelligence).[[19]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTEMcCorduck2004340–400-23)

The study of mechanical or ["formal" reasoning](https://en.wikipedia.org/wiki/Formal_reasoning) began with [philosophers](https://en.wikipedia.org/wiki/Philosopher) and mathematicians in antiquity. The study of mathematical logic led directly to [Alan Turing](https://en.wikipedia.org/wiki/Alan_Turing)'s [theory of computation](https://en.wikipedia.org/wiki/Theory_of_computation), which suggested that a machine, by shuffling symbols as simple as "0" and "1", could simulate any conceivable act of mathematical deduction. This insight that digital computers can simulate any process of formal reasoning is known as the [Church–Turing thesis](https://en.wikipedia.org/wiki/Church–Turing_thesis).[[20]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTEBerlinski2000-24)

The Church-Turing thesis, along with concurrent discoveries in [neurobiology](https://en.wikipedia.org/wiki/Neuroscience), [information theory](https://en.wikipedia.org/wiki/Information_theory) and [cybernetics](https://en.wikipedia.org/wiki/Cybernetics), led researchers to consider the possibility of building an electronic brain.[[21]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-25) The first work that is now generally recognized as AI was [McCullouch](https://en.wikipedia.org/wiki/Warren_McCullouch) and [Pitts](https://en.wikipedia.org/wiki/Walter_Pitts)' 1943 formal design for [Turing-complete](https://en.wikipedia.org/wiki/Turing-complete) "artificial neurons".[[22]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTERussellNorvig200916-26)

By the 1950s, two visions for how to achieve machine intelligence emerged. One vision, known [Symbolic AI](https://en.wikipedia.org/wiki/Symbolic_AI) or [GOFAI](https://en.wikipedia.org/wiki/GOFAI), was to use computers to create a symbolic representation of the world and systems that could reason about the world. Proponents included [Allen Newell](https://en.wikipedia.org/wiki/Allen_Newell), [Herbert A. Simon](https://en.wikipedia.org/wiki/Herbert_A._Simon), and [Marvin Minsky](https://en.wikipedia.org/wiki/Marvin_Minsky). Closely associated with this approach was the ["heuristic search"](https://en.wikipedia.org/wiki/Heuristic_(computer_science)) approach, which likened intelligence to a problem of exploring a space of possibilities for answers. The second vision, known as the [connectionist approach](https://en.wikipedia.org/wiki/Connectionism), sought to achieve intelligence through learning. Proponents of this approach, most prominently [Frank Rosenblatt](https://en.wikipedia.org/wiki/Frank_Rosenblatt), sought to connect [Perceptron](https://en.wikipedia.org/wiki/Perceptrons) in ways inspired by connections of neurons.[[23]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTEManyika20229-27) [James Manyika](https://en.wikipedia.org/wiki/James_Manyika) and others have compared the two approaches to the mind (Symbolic AI) and the brain (connectionist). Manyika argues that symbolic approaches dominated the push for artificial intelligence in this period, due in part to its connection to intellectual traditions of [Descarte](https://en.wikipedia.org/wiki/Descarte), [Boole](https://en.wikipedia.org/wiki/Boole), [Gottlob Frege](https://en.wikipedia.org/wiki/Gottlob_Frege), [Bertrand Russell](https://en.wikipedia.org/wiki/Bertrand_Russell), and others. Connectionist approaches based on [cybernetics](https://en.wikipedia.org/wiki/Cybernetics) or [artificial neural networks](https://en.wikipedia.org/wiki/Artificial_neural_network) were pushed to the background but have gained new prominence in recent decades.[[24]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTEManyika202210-28)

The field of AI research was born at [a workshop](https://en.wikipedia.org/wiki/Dartmouth_workshop) at [Dartmouth College](https://en.wikipedia.org/wiki/Dartmouth_College) in 1956.[[e]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-31)[[27]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-32) The attendees became the founders and leaders of AI research.[[f]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-33) They and their students produced programs that the press described as "astonishing":[[g]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-35) computers were learning [checkers](https://en.wikipedia.org/wiki/Draughts) strategies, solving word problems in algebra, proving [logical theorems](https://en.wikipedia.org/wiki/Theorem) and speaking English.[[h]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-36)[[29]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-37) By the middle of the 1960s, research in the U.S. was heavily funded by the [Department of Defense](https://en.wikipedia.org/wiki/DARPA)[[30]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-38) and laboratories had been established around the world.[[31]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTEHowe1994-39)

Researchers in the 1960s and the 1970s were convinced that symbolic approaches would eventually succeed in creating a machine with [artificial general intelligence](https://en.wikipedia.org/wiki/Artificial_general_intelligence) and considered this the goal of their field.[[32]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTENewquist199486–86-40) [Herbert Simon](https://en.wikipedia.org/wiki/Herbert_A._Simon) predicted, "machines will be capable, within twenty years, of doing any work a man can do".[[33]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-41) [Marvin Minsky](https://en.wikipedia.org/wiki/Marvin_Minsky) agreed, writing, "within a generation ... the problem of creating 'artificial intelligence' will substantially be solved".[[34]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-42)

They failed to recognize the difficulty of some of the remaining tasks. Progress slowed and in 1974, in response to the [criticism](https://en.wikipedia.org/wiki/Lighthill_report) of [Sir James Lighthill](https://en.wikipedia.org/wiki/Sir_James_Lighthill)[[35]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTELighthill1973-43) and ongoing pressure from the US Congress to [fund more productive projects](https://en.wikipedia.org/wiki/Mansfield_Amendment), both the U.S. and British governments cut off exploratory research in AI. The next few years would later be called an "[AI winter](https://en.wikipedia.org/wiki/AI_winter)", a period when obtaining funding for AI projects was difficult. [[8]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-First_AI_winter-10)

In the early 1980s, AI research was revived by the commercial success of [expert systems](https://en.wikipedia.org/wiki/Expert_system),[[36]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-44) a form of AI program that simulated the knowledge and analytical skills of human experts. By 1985, the market for AI had reached over a billion dollars. At the same time, Japan's [fifth generation computer](https://en.wikipedia.org/wiki/Fifth_generation_computer) project inspired the U.S and British governments to restore funding for [academic research](https://en.wikipedia.org/wiki/Academic_research).[[7]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-AI_in_the_80s-9) However, beginning with the collapse of the [Lisp Machine](https://en.wikipedia.org/wiki/Lisp_Machine) market in 1987, AI once again fell into disrepute, and a second, longer-lasting winter began.[[9]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-Second_AI_winter-11)

Many researchers began to doubt that the [symbolic approach](https://en.wikipedia.org/wiki/Symbolic_AI) would be able to imitate all the processes of human cognition, especially [perception](https://en.wikipedia.org/wiki/Machine_perception), robotics, [learning](https://en.wikipedia.org/wiki/Machine_learning) and [pattern recognition](https://en.wikipedia.org/wiki/Pattern_recognition). A number of researchers began to look into "sub-symbolic" approaches to specific AI problems.[[37]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTENilsson19987-45) [Robotics](https://en.wikipedia.org/wiki/Robotics) researchers, such as [Rodney Brooks](https://en.wikipedia.org/wiki/Rodney_Brooks), rejected symbolic AI and focused on the basic engineering problems that would allow robots to move, survive, and learn their environment.[[i]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-50) Interest in [neural networks](https://en.wikipedia.org/wiki/Artificial_neural_network) and "[connectionism](https://en.wikipedia.org/wiki/Connectionism)" was revived by [Geoffrey Hinton](https://en.wikipedia.org/wiki/Geoffrey_Hinton), [David Rumelhart](https://en.wikipedia.org/wiki/David_Rumelhart) and others in the middle of the 1980s.[[42]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-51) [Soft computing](https://en.wikipedia.org/wiki/Soft_computing) tools were developed in the 80s, such as [neural networks](https://en.wikipedia.org/wiki/Artificial_neural_network), [fuzzy systems](https://en.wikipedia.org/wiki/Fuzzy_system), [Grey system theory](https://en.wikipedia.org/wiki/Grey_system_theory), [evolutionary computation](https://en.wikipedia.org/wiki/Evolutionary_computation) and many tools drawn from [statistics](https://en.wikipedia.org/wiki/Statistics) or [mathematical optimization](https://en.wikipedia.org/wiki/Mathematical_optimization).

AI gradually restored its reputation in the late 1990s and early 21st century by finding specific solutions to specific problems. The narrow focus allowed researchers to produce verifiable results, exploit more mathematical methods, and collaborate with other fields (such as [statistics](https://en.wikipedia.org/wiki/Statistics), [economics](https://en.wikipedia.org/wiki/Economics) and [mathematics](https://en.wikipedia.org/wiki/Mathematical_optimization)).[[43]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-AI_1990s-52) By 2000, solutions developed by AI researchers were being widely used, although in the 1990s they were rarely described as "artificial intelligence".[[11]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-AI_widely_used_1990s-13)

[Faster computers](https://en.wikipedia.org/wiki/Moore's_law), algorithmic improvements, and access to [large amounts of data](https://en.wikipedia.org/wiki/Big_data) enabled advances in [machine learning](https://en.wikipedia.org/wiki/Machine_learning) and perception; data-hungry [deep learning](https://en.wikipedia.org/wiki/Deep_learning) methods started to dominate accuracy benchmarks [around 2012](https://en.wikipedia.org/wiki/Deep_learning" \l "Deep_learning_revolution).[[44]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTEMcKinsey2018-53) According to [Bloomberg's](https://en.wikipedia.org/wiki/Bloomberg_News) Jack Clark, 2015 was a landmark year for artificial intelligence, with the number of software projects that use AI within [Google](https://en.wikipedia.org/wiki/Google) increased from a "sporadic usage" in 2012 to more than 2,700 projects.[[j]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-54) He attributes this to an increase in affordable [neural networks](https://en.wikipedia.org/wiki/Artificial_neural_network), due to a rise in cloud computing infrastructure and to an increase in research tools and datasets.[[10]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTEClark2015b-12) In a 2017 survey, one in five companies reported they had "incorporated AI in some offerings or processes".[[45]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-55) The amount of research into AI (measured by total publications) increased by 50% in the years 2015–2019.[[46]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-FOOTNOTEUNESCO2021-56)

Numerous academic researchers became concerned that AI was no longer pursuing the original goal of creating versatile, fully intelligent machines. Much of current research involves statistical AI, which is overwhelmingly used to solve specific problems, even highly successful techniques such as [deep learning](https://en.wikipedia.org/wiki/Deep_learning). This concern has led to the subfield of [artificial general intelligence](https://en.wikipedia.org/wiki/Artificial_general_intelligence) (or "AGI"), which had several well-funded institutions by the 2010s.[[12]](https://en.wikipedia.org/wiki/Artificial_intelligence" \l "cite_note-Artificial_General_Intelligence-15)