**Artificial intelligence** (**AI**) is the [intelligence](https://en.wikipedia.org/wiki/Intelligence) of machines or software, as opposed to the intelligence of human beings or animals. [AI applications](https://en.wikipedia.org/wiki/AI_applications) include advanced [web search](https://en.wikipedia.org/wiki/Web_search) engines (e.g., [Google Search](https://en.wikipedia.org/wiki/Google_Search)), [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., [Waymo](https://en.wikipedia.org/wiki/Waymo)), [generative](https://en.wikipedia.org/wiki/Generative_artificial_intelligence) or [creative](https://en.wikipedia.org/wiki/Computational_creativity) tools ([ChatGPT](https://en.wikipedia.org/wiki/ChatGPT) and [AI art](https://en.wikipedia.org/wiki/AI_art)), and competing at the highest level in [strategic games](https://en.wikipedia.org/wiki/Strategic_game) (such as [chess](https://en.wikipedia.org/wiki/Chess) and [Go](https://en.wikipedia.org/wiki/Go_(game))).[[1]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-FOOTNOTEGoogle2016-1)

Artificial intelligence was founded as an academic discipline in 1956.[[2]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-Dartmouth_workshop-2) The field went through multiple cycles of optimism[[3]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-AI_in_the_60s-3)[[4]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-AI_in_the_80s-4) followed by disappointment and loss of funding,[[5]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-First_AI_winter-5)[[6]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-Second_AI_winter-6) but after 2012, when [deep learning](https://en.wikipedia.org/wiki/Deep_learning) surpassed all previous AI techniques,[[7]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-Deep_learning_revolution-7) there was a vast increase in funding and interest.

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 support for [robotics](https://en.wikipedia.org/wiki/Robotic).[[a]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-Problems_of_AI-8) [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.[[8]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-AGI-9) 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).[[b]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-Tools_of_AI-10) AI also draws upon [psychology](https://en.wikipedia.org/wiki/Psychology), [linguistics](https://en.wikipedia.org/wiki/Linguistics), [philosophy](https://en.wikipedia.org/wiki/Philosophy), [neuroscience](https://en.wikipedia.org/wiki/Neuroscience) and many other fields.[[9]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-AI_influences-11)

Goals

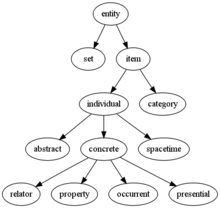
The general problem of simulating (or creating) intelligence has been broken down into sub-problems. These consist of particular traits or capabilities that researchers expect an intelligent system to display. The traits described below have received the most attention and cover the scope of AI research.[[a]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-Problems_of_AI-8)

**Reasoning, problem-solving**

Early researchers developed algorithms that imitated step-by-step reasoning that humans use when they solve puzzles or make logical deductions.[[10]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-12) By the late 1980s and 1990s, methods were developed for dealing with [uncertain](https://en.wikipedia.org/wiki/Uncertainty) or incomplete information, employing concepts from [probability](https://en.wikipedia.org/wiki/Probability) and [economics](https://en.wikipedia.org/wiki/Economics).[[11]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-13)

Many of these algorithms are insufficient for solving large reasoning problems because they experience a "combinatorial explosion": they became exponentially slower as the problems grew larger.[[12]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-Intractability-14) Even humans rarely use the step-by-step deduction that early AI research could model. They solve most of their problems using fast, intuitive judgments.[[13]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-Psychological_evidence_of_sub-symbolic_reasoning-15) Accurate and efficient reasoning is an unsolved problem.

**Knowledge representation**

[](https://en.wikipedia.org/wiki/File:GFO_taxonomy_tree.png)An ontology represents knowledge as a set of concepts within a domain and the relationships between those concepts.

[Knowledge representation](https://en.wikipedia.org/wiki/Knowledge_representation) and [knowledge engineering](https://en.wikipedia.org/wiki/Knowledge_engineering)[[14]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-16) allow AI programs to answer questions intelligently and make deductions about real-world facts. Formal knowledge representations are used in content-based indexing and retrieval,[[15]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-FOOTNOTESmoliarZhang1994-17) scene interpretation,[[16]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-FOOTNOTENeumannM%C3%B6ller2008-18) clinical decision support,[[17]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-FOOTNOTEKupermanReichleyBailey2006-19) knowledge discovery (mining "interesting" and actionable inferences from large databases),[[18]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-FOOTNOTEMcGarry2005-20) and other areas.[[19]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-FOOTNOTEBertiniDel_BimboTorniai2006-21)

A [knowledge base](https://en.wikipedia.org/wiki/Knowledge_base) is a body of knowledge represented in a form that can be used by a program. An [ontology](https://en.wikipedia.org/wiki/Ontology_(information_science)) is the set of objects, relations, concepts, and properties used by domain of knowledge.[[20]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-FOOTNOTERussellNorvig2021272-22) The most general ontologies are called [upper ontologies](https://en.wikipedia.org/wiki/Upper_ontology), which attempt to provide a foundation for all other knowledge and act as mediators between [domain ontologies](https://en.wikipedia.org/wiki/Domain_ontology) that cover specific knowledge about a particular [domain](https://en.wikipedia.org/wiki/Domain_ontology) (field of interest or area of concern).

Knowledge bases need to represent things such as: objects, properties, categories and relations between objects; [[21]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-Representing_categories_and_relations-23) situations, events, states and time;[[22]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-Representing_time-24) causes and effects;[[23]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-Representing_causation-25) knowledge about knowledge (what we know about what other people know);[[24]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-Representing_knowledge_about_knowledge-26) [default reasoning](https://en.wikipedia.org/wiki/Default_reasoning) (things that humans assume are true until they are told differently and will remain true even when other facts are changing);[[25]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-Default_reasoning_and_non-monotonic_logic-27) and many other aspects and domains of knowledge.

Among the most difficult problems in KR are: the breadth of commonsense knowledge (the set of atomic facts that the average person knows) is enormous;[[26]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-Breadth_of_commonsense_knowledge-28) the difficulty of [knowledge acquisition](https://en.wikipedia.org/wiki/Knowledge_acquisition) and the sub-symbolic form of most commonsense knowledge (much of what people know is not represented as "facts" or "statements" that they could express verbally).[[13]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-Psychological_evidence_of_sub-symbolic_reasoning-15)

**Planning and decision making**

|  |  |
| --- | --- |
| [[icon]](https://en.wikipedia.org/wiki/File:Wiki_letter_w_cropped.svg) | This section **needs expansion**. You can help by [adding to it](https://en.wikipedia.org/w/index.php?title=Artificial_intelligence&action=edit&section=). *(July 2023)* |

[Automated planning](https://en.wikipedia.org/wiki/Automated_planning)[[27]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-29) and [automated decision making](https://en.wikipedia.org/wiki/Automated_decision_making)[[28]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-30) are part of AI.

**Learning**

[Machine learning](https://en.wikipedia.org/wiki/Machine_learning) is the study of programs that can improve their performance on a given task automatically.[[29]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-machine_learning-31) It has been a part of AI from the beginning.[[c]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-34)

There are several kinds of machine learning. [Unsupervised learning](https://en.wikipedia.org/wiki/Unsupervised_learning) analyzes a stream of data and finds patterns and makes predictions without any other guidance.[[32]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-35) [Supervised learning](https://en.wikipedia.org/wiki/Supervised_learning) requires a human to label the input data first, and comes in two main varieties: [classification](https://en.wikipedia.org/wiki/Statistical_classification) (where the program must learn to predict what category the input belongs in) and [regression](https://en.wikipedia.org/wiki/Regression_analysis) (where the program must deduce a numeric function based on numeric input).[[33]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-Supervised_learning-36) In [reinforcement learning](https://en.wikipedia.org/wiki/Reinforcement_learning) the agent is rewarded for good responses and punished for bad ones. The agent learns to choose responses that are classified as "good".[[34]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-37) [Transfer learning](https://en.wikipedia.org/wiki/Transfer_learning) is when the knowledge gained from one problem is applied to a new problem.[[35]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-38) [Deep learning](https://en.wikipedia.org/wiki/Deep_learning) uses [artificial neural networks](https://en.wikipedia.org/wiki/Artificial_neural_networks) for all of these types of learning.

[Computational learning theory](https://en.wikipedia.org/wiki/Computational_learning_theory) can assess learners by [computational complexity](https://en.wikipedia.org/wiki/Computational_complexity), by [sample complexity](https://en.wikipedia.org/wiki/Sample_complexity) (how much data is required), or by other notions of [optimization](https://en.wikipedia.org/wiki/Optimization_theory).[[36]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-39)

**Natural language processing**

[Natural language processing](https://en.wikipedia.org/wiki/Natural_language_processing) (NLP)[[37]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-40) allows programs to read, write and communicate in human languages such as [English](https://en.wikipedia.org/wiki/English_(language)). Specific problems include [speech recognition](https://en.wikipedia.org/wiki/Speech_recognition), [speech synthesis](https://en.wikipedia.org/wiki/Speech_synthesis), [machine translation](https://en.wikipedia.org/wiki/Machine_translation), [information extraction](https://en.wikipedia.org/wiki/Information_extraction), [information retrieval](https://en.wikipedia.org/wiki/Information_retrieval) and [question answering](https://en.wikipedia.org/wiki/Question_answering).[[38]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-41)

Early work, based on [Noam Chomsky](https://en.wikipedia.org/wiki/Noam_Chomsky)'s [generative grammar](https://en.wikipedia.org/wiki/Generative_grammar), had difficulty with [word-sense disambiguation](https://en.wikipedia.org/wiki/Word-sense_disambiguation)[[d]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-42) unless restricted to small domains called "[micro-worlds](https://en.wikipedia.org/wiki/Blocks_world)" (due to the common sense knowledge problem[[26]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-Breadth_of_commonsense_knowledge-28)).

Modern [deep learning](https://en.wikipedia.org/wiki/Deep_learning) techniques for NLP include [word embedding](https://en.wikipedia.org/wiki/Word_embedding) (how often one word appears near another),[[39]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-FOOTNOTERussellNorvig2021856%E2%80%93858-43) [transformers](https://en.wikipedia.org/wiki/Transformer_(machine_learning_model)) (which finds patterns in text),[[40]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-FOOTNOTERussellNorvig2021868%E2%80%93871-44) and others.[[41]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-45) In 2019, [generative pre-trained transformer](https://en.wikipedia.org/wiki/Generative_pre-trained_transformer) (or "GPT") language models began to generate coherent text,[[42]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-FOOTNOTEVincent2019-46)[[43]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-FOOTNOTERussellNorvig2021875%E2%80%93878-47) and by 2023 these models were able to get human-level scores on the [bar exam](https://en.wikipedia.org/wiki/Bar_exam), [SAT](https://en.wikipedia.org/wiki/Scholastic_aptitude_test), [GRE](https://en.wikipedia.org/wiki/Graduate_Record_Examinations), and many other real-world applications.[[44]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-FOOTNOTEBushwick2023-48)

**Perception**

[](https://en.wikipedia.org/wiki/File:%C3%84%C3%A4retuvastuse_n%C3%A4ide.png)[Feature detection](https://en.wikipedia.org/wiki/Feature_detection_(computer_vision)) (pictured: [edge detection](https://en.wikipedia.org/wiki/Edge_detection)) helps AI compose informative abstract structures out of raw data.

[Machine perception](https://en.wikipedia.org/wiki/Machine_perception) is the ability to use input from sensors (such as cameras, microphones, wireless signals, active [lidar](https://en.wikipedia.org/wiki/Lidar), sonar, radar, and [tactile sensors](https://en.wikipedia.org/wiki/Tactile_sensor)) to deduce aspects of the world. [Computer vision](https://en.wikipedia.org/wiki/Computer_vision) is the ability to analyze visual input.[[45]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-49) The field includes [speech recognition](https://en.wikipedia.org/wiki/Speech_recognition),[[46]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-FOOTNOTERussellNorvig2021849%E2%80%93850-50) [image classification](https://en.wikipedia.org/wiki/Image_classification),[[47]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-FOOTNOTERussellNorvig2021895%E2%80%93899-51) [facial recognition](https://en.wikipedia.org/wiki/Facial_recognition_system), [object recognition](https://en.wikipedia.org/wiki/Object_recognition),[[48]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-FOOTNOTERussellNorvig2021899%E2%80%93901-52) and [robotic perception](https://en.wikipedia.org/wiki/Robotic_sensing).[[49]](https://en.wikipedia.org/wiki/Artificial_intelligence#cite_note-FOOTNOTERussellNorvig2021931%E2%80%93938-53)