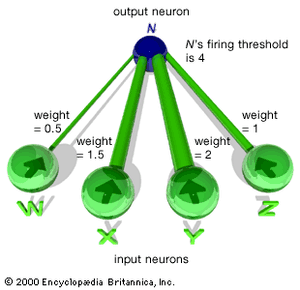
**[Connectionism](https://www.britannica.com/technology/connectionism-artificial-intelligence)**

Connectionism, or neuronlike computing, developed out of attempts to understand how the human [brain](https://www.britannica.com/science/brain) works at the neural level and, in particular, how people learn and remember. In 1943 the neurophysiologist Warren McCulloch of the [University of Illinois](https://www.britannica.com/topic/University-of-Illinois) and the mathematician Walter Pitts of the [University of Chicago](https://www.britannica.com/topic/University-of-Chicago) published an influential [treatise](https://www.merriam-webster.com/dictionary/treatise) on [neural nets and automatons](https://www.britannica.com/topic/automata-theory/Neural-nets-and-automata#ref21498), according to which each [neuron](https://www.britannica.com/science/neuron) in the brain is a simple digital processor and the brain as a whole is a form of computing [machine](https://www.britannica.com/technology/machine). As McCulloch put it subsequently, “What we thought we were doing (and I think we succeeded fairly well) was treating the brain as a [Turing machine](https://www.britannica.com/technology/Turing-machine).”

**Creating an artificial**[**neural network**](https://www.britannica.com/technology/neural-network)

It was not until 1954, however, that Belmont Farley and Wesley Clark of [MIT](https://www.britannica.com/topic/Massachusetts-Institute-of-Technology) succeeded in running the first artificial [neural network](https://www.britannica.com/technology/neural-network)—albeit limited by [computer memory](https://www.britannica.com/technology/computer-memory) to no more than 128 [neurons](https://www.britannica.com/science/neuron). They were able to train their networks to [recognize simple patterns](https://www.britannica.com/technology/pattern-recognition-computer-science). In addition, they discovered that the random destruction of up to 10 percent of the neurons in a trained network did not affect the network’s performance—a feature that is [reminiscent](https://www.britannica.com/dictionary/reminiscent) of the brain’s ability to tolerate limited damage inflicted by surgery, accident, or disease.

[](https://cdn.britannica.com/65/65065-004-55E954C2/weight-section-network-figure-input-strength-size.jpg)

[section of an artificial neural network](https://cdn.britannica.com/65/65065-004-55E954C2/weight-section-network-figure-input-strength-size.jpg)

The simple neural network depicted in the figure illustrates the central ideas of connectionism. Four of the network’s five neurons are for input, and the fifth—to which each of the others is connected—is for output. Each of the neurons is either firing (1) or not firing (0). Each connection leading to *N*, the output neuron, has a “weight.” What is called the total weighted input into *N* is calculated by adding up the weights of all the connections leading to *N* from neurons that are firing. For example, suppose that only two of the input neurons, *X* and *Y*, are firing. Since the weight of the connection from *X* to *N* is 1.5 and the weight of the connection from *Y* to *N* is 2, it follows that the total weighted input to *N* is 3.5. As shown in the figure, *N* has a firing [threshold](https://www.merriam-webster.com/dictionary/threshold) of 4. That is to say, if *N*’s total weighted input equals or exceeds 4, then *N* fires; otherwise, *N* does not fire. So, for example, *N* does not fire if the only input neurons to fire are *X* and *Y*, but *N* does fire if *X*, *Y*, and *Z* all fire.

Training the network involves two steps. First, the external agent inputs a pattern and observes the behaviour of *N*. Second, the agent adjusts the connection weights in accordance with the rules:

1. If the actual output is 0 and the desired output is 1, increase by a small fixed amount the weight of each connection leading to *N* from neurons that are firing (thus making it more likely that *N* will fire the next time the network is given the same pattern);
2. If the actual output is 1 and the desired output is 0, decrease by that same small amount the weight of each connection leading to the output neuron from neurons that are firing (thus making it less likely that the output neuron will fire the next time the network is given that pattern as input).

The external agent—actually a computer program—goes through this two-step procedure with each pattern in a training sample, which is then repeated a number of times. During these many repetitions, a pattern of connection weights is forged that enables the network to respond correctly to each pattern. The striking thing is that the [learning](https://www.britannica.com/science/learning) process is entirely mechanical and requires no human intervention or adjustment. The connection weights are increased or decreased automatically by a constant amount, and exactly the same learning procedure applies to different tasks.

[**Perceptrons**](https://www.britannica.com/technology/perceptrons)

In 1957 [Frank Rosenblatt](https://www.britannica.com/biography/Frank-Rosenblatt) of the Cornell Aeronautical Laboratory at [Cornell University](https://www.britannica.com/topic/Cornell-University) in Ithaca, [New York](https://www.britannica.com/place/New-York-state), began investigating artificial neural networks that he called perceptrons. He made major contributions to the field of AI, both through experimental investigations of the properties of neural networks (using computer simulations) and through detailed mathematical analysis. Rosenblatt was a [charismatic](https://www.merriam-webster.com/dictionary/charismatic) communicator, and there were soon many research groups in the [United States](https://www.britannica.com/place/United-States) studying perceptrons. Rosenblatt and his followers called their approach connectionist to emphasize the importance in learning of the creation and modification of connections between neurons. Modern researchers have adopted this term.

One of Rosenblatt’s contributions was to generalize the training procedure that Farley and Clark had applied to only two-layer networks so that the procedure could be applied to multilayer networks. Rosenblatt used the phrase “back-propagating error correction” to describe his method. The method, with substantial improvements and [extensions](https://www.britannica.com/dictionary/extensions) by numerous scientists, and the term [*back-propagation*](https://www.britannica.com/technology/back-propagation-algorithm) are now in everyday use in connectionism.

**Conjugating**[**verbs**](https://www.britannica.com/topic/verb)

In one famous connectionist experiment conducted at the University of California at San Diego (published in 1986), David Rumelhart and James McClelland trained a network of 920 artificial neurons, arranged in two layers of 460 neurons, to form the past tenses of English verbs. Root forms of verbs—such as *come*, *look*, and *sleep*—were presented to one layer of neurons, the input layer. A supervisory [computer program](https://www.britannica.com/technology/computer-program) observed the difference between the actual response at the layer of output neurons and the desired response—*came*, say—and then mechanically adjusted the connections throughout the network in accordance with the procedure described above to give the network a slight push in the direction of the correct response. About 400 different verbs were presented one by one to the network, and the connections were adjusted after each presentation. This whole procedure was repeated about 200 times using the same verbs, after which the network could correctly form the past tense of many unfamiliar verbs as well as of the original verbs. For example, when presented for the first time with *guard*, the network responded *guarded*; with *weep*, *wept*; with *cling*, *clung*; and with *drip*, *dripped* (complete with double *p*). This is a striking example of learning involving generalization. (Sometimes, though, the peculiarities of English were too much for the network, and it formed *squawked* from *squat*, *shipped* from *shape*, and *membled* from *mail*.)

Another name for connectionism is [*parallel distributed processing*](https://www.britannica.com/science/parallel-distributed-processing)*,* which [emphasizes](https://www.britannica.com/dictionary/emphasizes) two important features. First, a large number of relatively simple processors—the neurons—operate in parallel. Second, neural networks store information in a distributed fashion, with each individual connection participating in the storage of many different items of information. The know-how that enabled the past-tense network to form *wept* from *weep*, for example, was not stored in one specific location in the network but was spread throughout the entire pattern of connection weights that was forged during training. The human brain also appears to store information in a distributed fashion, and connectionist research is contributing to attempts to understand how it does so.

**Other neural networks**

Other work on neuronlike computing includes the following:

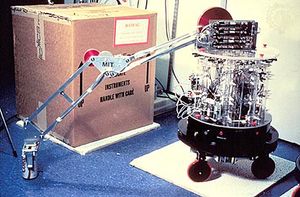
* *Visual perception*. Networks can recognize faces and other objects from visual [data](https://www.britannica.com/dictionary/data). A neural network designed by John Hummel and Irving Biederman at the [University of Minnesota](https://www.britannica.com/topic/University-of-Minnesota) can identify about 10 objects from simple line drawings. The network is able to recognize the objects—which include a mug and a frying pan—even when they are drawn from different angles. Networks investigated by Tomaso Poggio of MIT are able to recognize bent-wire shapes drawn from different angles, faces photographed from different angles and showing different expressions, and objects from cartoon drawings with gray-scale shading indicating depth and orientation.
* *Language processing*. Neural networks are able to convert handwritten and typewritten material to electronic text. The U.S. Internal Revenue Service has commissioned a neuronlike system that will automatically read tax returns and correspondence. Neural networks also convert speech to printed text and printed text to speech.
* *Financial analysis*. Neural networks are being used increasingly for loan risk [assessment](https://www.merriam-webster.com/dictionary/assessment), real estate valuation, bankruptcy prediction, share price prediction, and other business applications.
* *Medicine*. Medical applications include detecting [lung](https://www.britannica.com/science/lung) nodules and [heart](https://www.britannica.com/science/heart) [arrhythmias](https://www.britannica.com/science/arrhythmia) and predicting adverse drug reactions.
* *Telecommunications*. [Telecommunications](https://www.britannica.com/technology/telecommunications-network) applications of neural networks include [control](https://www.britannica.com/technology/control-system) of [telephone](https://www.britannica.com/technology/telephone) switching networks and echo cancellation in [modems](https://www.britannica.com/technology/modem) and on [satellite](https://www.britannica.com/science/satellite) links.

[**Nouvelle AI**](https://www.britannica.com/technology/nouvelle-artificial-intelligence)

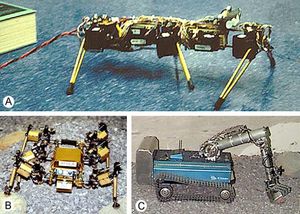
**New foundations**

The approach now known as nouvelle AI was pioneered at the MIT AI Laboratory by the Australian [Rodney Brooks](https://www.britannica.com/biography/Rodney-Allen-Brooks) during the latter half of the 1980s. Nouvelle AI distances itself from strong AI, with its emphasis on human-level performance, in favour of the relatively modest aim of [insect](https://www.britannica.com/animal/insect)-level performance. At a very fundamental level, nouvelle AI rejects symbolic AI’s reliance upon constructing internal models of reality, such as those described in the section [Microworld programs](https://www.britannica.com/technology/artificial-intelligence/Evolutionary-computing" \l "ref219097). Practitioners of nouvelle AI assert that true intelligence involves the ability to function in a real-world [environment](https://www.merriam-webster.com/dictionary/environment).

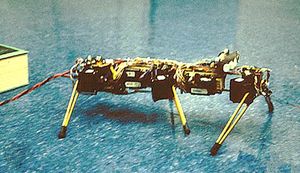
A central [idea](https://www.britannica.com/topic/idea) of nouvelle AI is that intelligence, as expressed by complex behaviour, “emerges” from the interaction of a few simple behaviours. For example, a [robot](https://www.britannica.com/technology/robot-technology) whose simple behaviours include collision avoidance and motion toward a moving object will appear to stalk the object, pausing whenever it gets too close.

[](https://cdn.britannica.com/56/65356-004-2DB7470F/Herbert-Simon-robot-compass-laser-scanner-sensors-1987.jpg)

[Herbert the robot](https://cdn.britannica.com/56/65356-004-2DB7470F/Herbert-Simon-robot-compass-laser-scanner-sensors-1987.jpg)

[](https://cdn.britannica.com/74/65774-004-6505892A/Mars-Rover-Research-Project-Three-stages-robot.jpg)

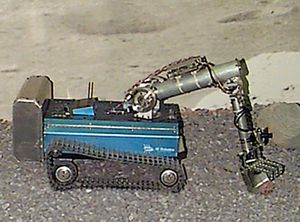
[three stages of mobile robot development for the Mars Rover Research Project](https://cdn.britannica.com/74/65774-004-6505892A/Mars-Rover-Research-Project-Three-stages-robot.jpg)

[](https://cdn.britannica.com/76/65776-004-16019FEB/Genghis-robot-MIT-efficacy-robots-surface-Martian.jpg)

[Genghis the robot](https://cdn.britannica.com/76/65776-004-16019FEB/Genghis-robot-MIT-efficacy-robots-surface-Martian.jpg)

[](https://cdn.britannica.com/75/65775-004-28DCB46E/robot-Attila-Hannibal-robots-exploration-research-project.jpg)

[Attila the robot](https://cdn.britannica.com/75/65775-004-28DCB46E/robot-Attila-Hannibal-robots-exploration-research-project.jpg)

[](https://cdn.britannica.com/12/62112-050-27372350/Pebbles-robot-control-system-size-part-obstacles.jpg)

[Pebbles the robot](https://cdn.britannica.com/12/62112-050-27372350/Pebbles-robot-control-system-size-part-obstacles.jpg)

One famous example of nouvelle AI is Brooks’s robot [Herbert](https://www.britannica.com/topic/Herbert-robot) (named after [Herbert Simon](https://www.britannica.com/biography/Herbert-A-Simon)), whose environment is the busy offices of the MIT AI Laboratory. Herbert searches desks and tables for empty soda cans, which it picks up and carries away. The robot’s seemingly goal-directed behaviour emerges from the interaction of about 15 simple behaviours. More recently, Brooks has constructed [prototypes](https://www.merriam-webster.com/dictionary/prototypes) of mobile robots for exploring the surface of [Mars](https://www.britannica.com/place/Mars-planet). (*See* the photographs and an interview with Rodney Brooks.)

Nouvelle AI sidesteps the frame problem discussed in the section [The CYC project](https://www.britannica.com/technology/artificial-intelligence/Expert-systems#ref219102). Nouvelle systems do not contain a complicated symbolic model of their environment. Instead, information is left “out in the world” until such time as the system needs it. A nouvelle system refers continuously to its sensors rather than to an internal model of the world: it “reads off” the external world whatever information it needs at precisely the time it needs it. (As Brooks insisted, the world is its own best model—always exactly [up-to-date](https://www.britannica.com/dictionary/up-to-date) and complete in every detail.)

**The**[**situated approach**](https://www.britannica.com/technology/artificial-intelligence-situated-approach)

Traditional AI has by and large attempted to build disembodied intelligences whose only interaction with the world has been indirect (CYC, for example). Nouvelle AI, on the other hand, attempts to build embodied intelligences situated in the real world—a method that has come to be known as the situated approach. Brooks quoted approvingly from the brief sketches that [Turing](https://www.britannica.com/biography/Alan-Turing) gave in 1948 and 1950 of the situated approach. By equipping a [machine](https://www.britannica.com/technology/machine) “with the best sense organs that money can buy,” Turing wrote, the machine might be taught “to understand and speak English” by a process that would “follow the normal teaching of a child.” Turing contrasted this with the approach to AI that focuses on abstract activities, such as the playing of [chess](https://www.britannica.com/topic/chess). He advocated that both approaches be pursued, but until recently little attention has been paid to the situated approach.

The situated approach was also anticipated in the writings of the philosopher [Bert Dreyfus](https://www.britannica.com/biography/Bert-Dreyfus) of the [University of California](https://www.britannica.com/topic/University-of-California) at Berkeley. Beginning in the early 1960s, Dreyfus opposed the physical symbol system [hypothesis](https://www.merriam-webster.com/dictionary/hypothesis), arguing that intelligent behaviour cannot be completely captured by symbolic descriptions. As an [alternative](https://www.merriam-webster.com/dictionary/alternative), Dreyfus advocated a view of intelligence that stressed the need for a body that could move about, interacting directly with [tangible](https://www.merriam-webster.com/dictionary/tangible) physical objects. Once reviled by advocates of AI, Dreyfus is now regarded as a prophet of the situated approach.

Critics of nouvelle AI point out the failure to produce a system exhibiting anything like the complexity of behaviour found in real insects. Suggestions by researchers that their nouvelle systems may soon be conscious and possess language seem entirely premature.

**Is**[**strong AI**](https://www.britannica.com/technology/strong-artificial-intelligence)**possible?**

The ongoing success of applied AI and of [cognitive](https://www.merriam-webster.com/dictionary/cognitive) simulation, as described in the preceding sections of this article, seems assured. However, strong AI—that is, artificial intelligence that aims to duplicate human [intellectual](https://www.merriam-webster.com/dictionary/intellectual) abilities—remains controversial. Exaggerated claims of success, in professional journals as well as the popular press, have damaged its reputation. At the present time even an embodied system displaying the overall intelligence of a [cockroach](https://www.britannica.com/animal/cockroach-insect) is proving [elusive](https://www.merriam-webster.com/dictionary/elusive), let alone a system that can rival a [human being](https://www.britannica.com/topic/human-being). The difficulty of scaling up AI’s modest achievements cannot be overstated. Five decades of research in symbolic AI have failed to produce any firm evidence that a symbol system can [manifest](https://www.merriam-webster.com/dictionary/manifest) human levels of general intelligence; connectionists are unable to model the nervous systems of even the simplest [invertebrates](https://www.britannica.com/animal/invertebrate); and critics of [nouvelle AI](https://www.britannica.com/technology/nouvelle-artificial-intelligence) regard as simply mystical the view that high-level behaviours involving language understanding, planning, and reasoning will somehow emerge from the interaction of basic behaviours such as obstacle avoidance, gaze [control](https://www.britannica.com/technology/control-system), and object manipulation.

However, this lack of substantial progress may simply be testimony to the difficulty of strong AI, not to its impossibility. Let us turn to the very [idea](https://www.britannica.com/topic/idea) of strong artificial intelligence. Can a computer possibly think? [Noam Chomsky](https://www.britannica.com/biography/Noam-Chomsky) suggests that debating this question is pointless, for it is an essentially [arbitrary](https://www.britannica.com/dictionary/arbitrary) decision whether to extend common usage of the word *think* to include machines. There is, Chomsky claims, no factual question as to whether any such decision is right or wrong—just as there is no question as to whether our decision to say that airplanes fly is right, or our decision not to say that ships swim is wrong. However, this seems to oversimplify matters. The important question is, Could it ever be appropriate to say that computers think, and, if so, what conditions must a computer satisfy in order to be so described?

Some authors offer the [Turing test](https://www.britannica.com/technology/Turing-test) as a definition of intelligence. However, Turing himself pointed out that a computer that ought to be described as intelligent might nevertheless fail his test if it were incapable of successfully imitating a human being. For example, why should an intelligent [robot](https://www.britannica.com/technology/robot-technology) designed to oversee mining on the [Moon](https://www.britannica.com/place/Moon) necessarily be able to pass itself off in conversation as a human being? If an intelligent [entity](https://www.britannica.com/dictionary/entity) can fail the test, then the test cannot function as a definition of intelligence. It is even questionable whether passing the test would actually show that a computer is intelligent, as the information theorist [Claude Shannon](https://www.britannica.com/biography/Claude-Shannon) and the AI pioneer [John McCarthy](https://www.britannica.com/biography/John-McCarthy) pointed out in 1956. Shannon and McCarthy argued that it is possible, in principle, to design a [machine](https://www.britannica.com/technology/machine) containing a complete set of canned responses to all the questions that an interrogator could possibly ask during the fixed time span of the test. Like Parry, this machine would produce answers to the interviewer’s questions by looking up appropriate responses in a giant table. This objection seems to show that in principle a system with no intelligence at all could pass the Turing test.

In fact, AI has no real definition of intelligence to offer, not even in the subhuman case. [Rats](https://www.britannica.com/animal/rat) are intelligent, but what exactly must an artificial intelligence achieve before researchers can claim this level of success? In the absence of a reasonably precise [criterion](https://www.merriam-webster.com/dictionary/criterion) for when an artificial system counts as intelligent, there is no objective way of telling whether an AI research program has succeeded or failed. One result of AI’s failure to produce a satisfactory criterion of intelligence is that, whenever researchers achieve one of AI’s goals—for example, a program that can summarize newspaper articles or beat the world [chess](https://www.britannica.com/topic/chess) champion—critics are able to say “*That’s* not intelligence!” [Marvin Minsky’s](https://www.britannica.com/biography/Marvin-Lee-Minsky) response to the problem of defining intelligence is to maintain—like Turing before him—that intelligence is simply our name for any problem-solving mental process that we do not [yet](https://www.britannica.com/dictionary/yet) understand. Minsky likens intelligence to the concept “unexplored regions of Africa”: it disappears as soon as we discover it.

Слова:

1. Treatise – трактат
2. albeit – хотя
3. adopted  - установленный / приемный
4. appears – проявлять
5. mug – кружка
6. frying pan –сковорода
7. emerges – всплывать
8. disembodied  - свободный
9. indirect  - косвенный
10. sketches – набросок
11. Exaggerated – преувеличенный
12. claims –заявления
13. cockroach –таракан
14. invertebrates – беспозвоночные
15. ought  - должен
16. incapable  - неспособный