KUNGL. VETENSKAPS-AKADEMIEN
THE ROYAL SWEDISH ACADEMY OF SCIENCES

The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics 2024 to **John J. Hopfield** and **Geoffrey Hinton** "for foundational discoveries and inventions that enable machine learning with artificial neural networks".

The Nobel Prize 2024 **in Physics**

Tools from physics find patterns in information

This year's laureates used tools from physics to construct methods that helped lay the foundation for today's powerful machine learning. John Hopfield created a structure that can store and reconstruct information. Geoffrey Hinton invented a method that can independently find properties in data and which has become important for the large artificial neural networks used today.

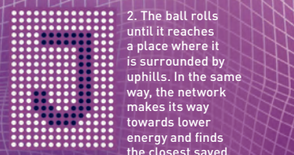
The development of machine learning has exploded in the last fifteen to twenty years, utilising a type of structure called an artificial neural network. Nowadays, when we talk about artificial intelligence – or AI – it is often this type of technology we mean.

Many people have seen how computers can translate between languages, interpret images and even conduct reasonable conversations. What is perhaps less well known is that this type of technology has long been important for research, including the sorting and analysis of large amounts of data.

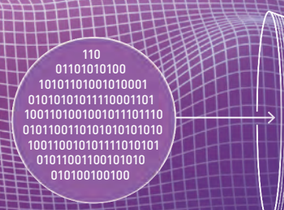
An artificial neural network processes information using the network structure in its entirety. This technology was originally inspired by the brain. Artificial neural networks mimic the brain's neurons through nodes that are given different values, and the synapses are represented by connections between nodes that can be made stronger or weaker. There are significant differences between the brain's network and artificial neural networks, but they can imitate some functions – such as memory and learning.

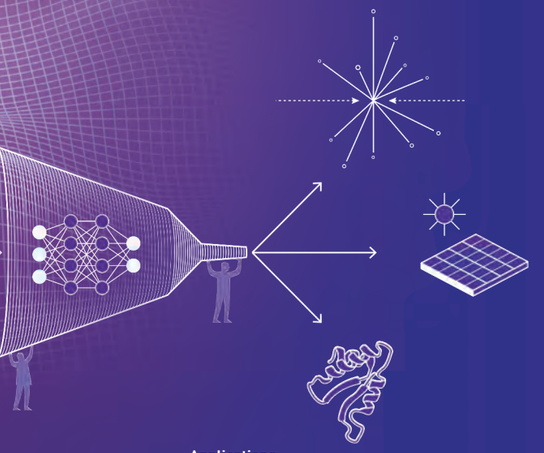
In their work from the 1980s and onward, John Hopfield and Geoffrey Hinton helped lay the foundation for the machine learning revolution we see today. They used techniques from physics and created tools that physics benefits from.

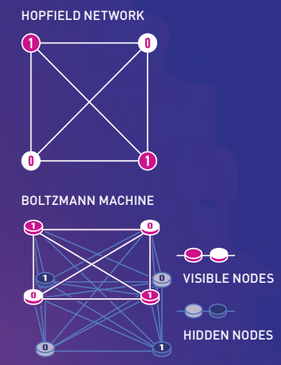
1. When the trained network is fed with a distorted or incomplete pattern, it can be likened to dropping a ball down a slope in this landscape.



2. The ball rolls until it reaches a place where it is surrounded by uphills. In the same way, the network makes its way towards lower energy and finds the closest saved pattern.





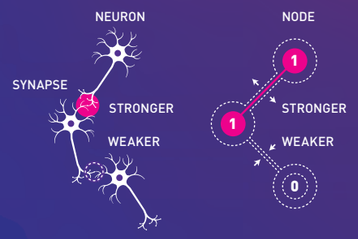


Geoffrey Hinton and the Boltzmann machine

Geoffrey Hinton used tools from statistical physics – the science of systems composed of many similar elements – and expanded the Hopfield network to build something he called the Boltzmann machine. The machine is trained in such a way that the examples it is fed with have a high probability of occurring when the machine is run. It can be used to classify information, or to generate new examples of the type of patterns it has been trained on.

John J. Hopfield
Born 1933 in Chicago, USA. Professor at Princeton University, USA.

Geoffrey Hinton
Born 1947 in London, UK. Professor at University of Toronto, Canada.



Neural networks
Artificial neural networks mimic, in a simplified way, how the brain's neural network functions. During learning, the connections between some neurons are strengthened while others are weakened. The artificial network has rules for strengthening or weakening the connections between nodes depending on their values.

The Hopfield Network
John Hopfield began his research career in solid state physics. He then used techniques and approaches from physics to tackle problems in biology. A research meeting on neuroscience sparked his interest in the dynamics of neural networks. He realised that he could use the physics that describes magnetic materials to produce a model network of nodes and their connections.

Memories are stored in a landscape
John Hopfield's associative memory from 1982 is based on the network storing information in a similar manner to shaping a landscape. The nodes' values are like pixels in a picture. When the network is trained, it creates a valley in a virtual energy landscape for every saved pattern.

Applications
Physics benefits greatly from artificial neural networks. Among other things, machine learning was used to sift through and process vast amounts of data in the search for the Higgs particle. Other applications include reducing noise in the measurements of gravitational waves from colliding black holes, or in the search for exoplanets – and much, much more.

Photo: Portrait of John J. Hopfield: Matthew Rasparin, Princeton University; Portrait of Geoffrey Hinton: Johnny Guatto

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More information about the Nobel Prize in Physics 2024 is available at *www.kva.se/nobelphysics2024* and *www.nobelprize.org*, with video and detailed information about the prize and the laureates.

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