

# Deep learning

**Deep learning** is the subset of machine learning methods based on artificial neural networks (ANNs) with representation learning. The adjective "deep" refers to the use of multiple layers in the network. Methods used can be either supervised, semi-supervised or unsupervised.<sup>[2]</sup>

Deep-learning architectures such as deep neural networks, deep belief networks, recurrent neural networks, convolutional neural networks and transformers have been applied to fields including computer vision, speech recognition, natural language processing, machine translation, bioinformatics, drug design, medical image analysis, climate science, material inspection and board game programs, where they have produced results comparable to and in some cases surpassing human expert performance.<sup>[3][4][5]</sup>

Artificial neural networks were inspired by information processing and distributed communication nodes in biological systems. ANNs have various differences from biological brains. Specifically, artificial neural networks tend to be static and symbolic, while the biological brain of most living organisms is dynamic (plastic) and analog.<sup>[6][7]</sup> ANNs are generally seen as low quality models for brain function.<sup>[8]</sup>

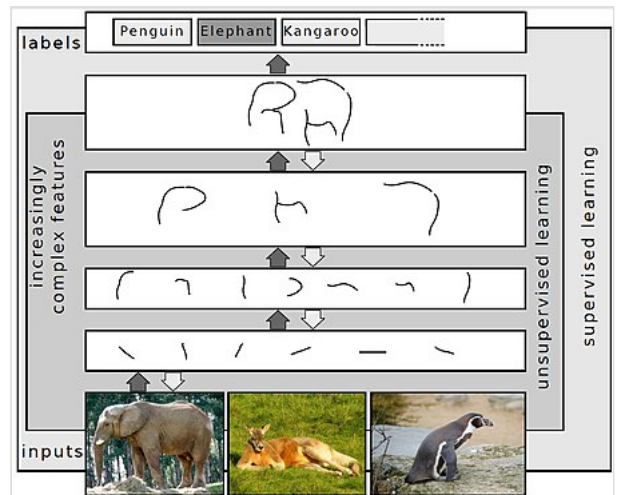
## Definition

Deep learning is a class of machine learning algorithms that<sup>[9]:199–200</sup> uses multiple layers to progressively extract higher-level features from the raw input. For example, in image processing, lower layers may identify edges, while higher layers may identify the concepts relevant to a human such as digits or letters or faces.

From another angle to view deep learning, deep learning refers to "computer-simulate" or "automate" human learning processes from a source (e.g., an image of dogs) to a learned object (dogs). Therefore, a notion coined as "deeper" learning or "deepest" learning<sup>[10]</sup> makes sense. The deepest learning refers to the fully automatic learning from a source to a final learned object. A deeper learning thus refers to a mixed learning process: a human learning process from a source to a learned semi-object, followed by a computer learning process from the human learned semi-object to a final learned object.

## Overview

Most modern deep learning models are based on multi-layered artificial neural networks such as convolutional neural networks and transformers, although they can also include propositional formulas or latent variables organized layer-wise in deep generative models such as the nodes in deep belief networks and deep Boltzmann machines.<sup>[11]</sup>



Representing images on multiple layers of abstraction in deep learning<sup>[1]</sup>