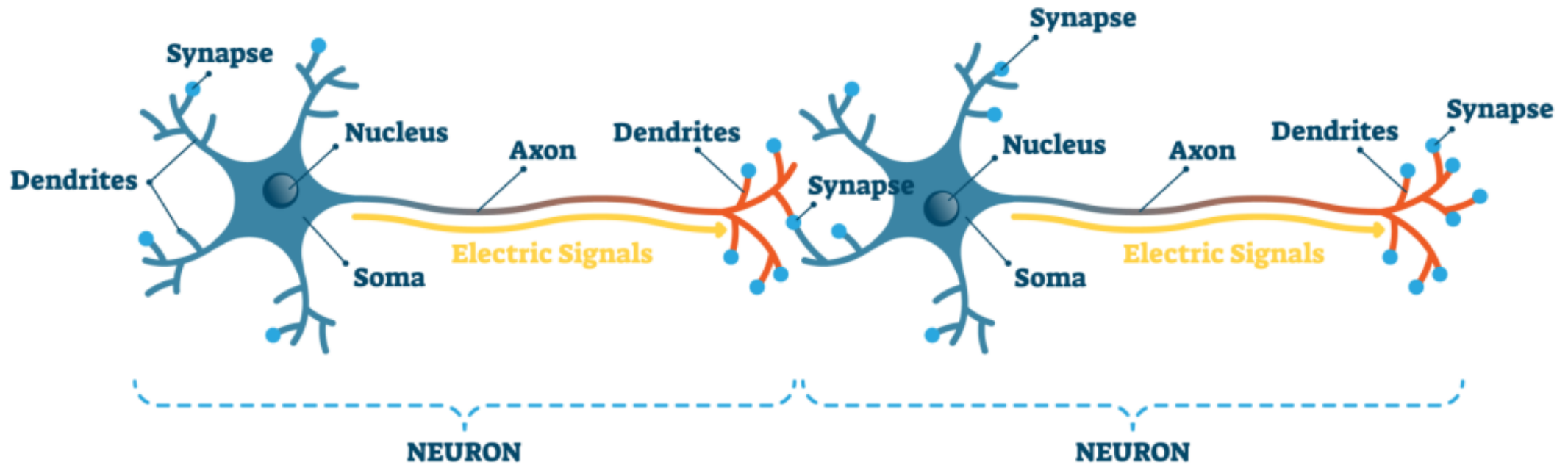


Neural networks: Introduction and history

Brief history

- There is a longstanding idea that one way to achieve an intelligent system is to get inspired from the human brain
- In particular to model and reconstitute neurons, which are the cells principally involved in animals in the functioning of the nervous system.
- The idea of calling certain components neurons might have a **branding value**.
 - Very often had been used as part of a narrative for company positioning.

Biological neurons and synapses



"Neural networks" vs biological neurons

- Current neural networks are **not** inspired from human brains, they don't work like biological neurons, and no feedback from neuroscientists had been used to develop them.
- There are things that we know that **animal brains don't do**:
 - Matrix multiplications (requires full connectivity)
 - Backpropagation (requires connections both directions, and biological neurons only go one way)
 - Represent values as activation strength (biological neurons operate in spikes)

Neuromorphic or biomimetic computing

- There are certain things that we know that **animal brains do**:
 - convolutions (eg. in the retina, possibly other places)
- There is a research area called **neuromorphic computing** or **biomimetic computing** which aims to create systems that (more) closely model the way neurons work
 - Sometimes the goal is to understand the human brain
 - Usually performance considerations are secondary
 - But there is the tacit implication that if implemented well, human equivalent computation can be achieved
- We don't really understand the mechanisms / algorithms through which the human brain achieves certain things

Brief history (1940-1970)

- **Perceptrons** the architecture, introduced by McCullough, Pitts, later described by Rosenblatt (1943...)
 - Essentially, a linear classifier with a threshold output, and a peculiar learning algorithm
 - Extensive hype follows
- **Perceptrons** the book by Marvin Minsky and Seymour Pappert 1969
 - Emphasizes that a linear perceptron cannot learn non-linear functions.
 - Kills funding for the field.

Brief history (1980s)

- **Neural networks with a hidden layer**
 - Become popular cca 1986 due to work of Rumelhart, Hinton and Williams.
 - New ideas:
 - train by "backpropagating errors"
 - have a non-linearity between layers (allows representation of arbitrary functions)
 - New hype cycle
 - Disputes in AI and psychology between "connectionist models" and "symbolic" and/or "computational" models

Brief history (1990s-2000s)

- **Slow progress, disappointment**

- Misunderstood theorem about representation ability of network with a single hidden layer discourages research in more layers
- Mathematical preference for the smoothly differentiable sigmoid function chooses one of the least well converging nonlinearities

- **But also continuing progress**

- Convolutional neural networks (CNN) invented (**LeNet** by Yann LeCun and Leon Bottou), but live in the shadow of current fashions of computer vision
- Max pooling invented
- **Long short term memory** invented (Sepp Hochreiter and Jürgen Schmidhuber), but does not appear a practical application
- Various techniques tried out for training multi-layer neural networks.

Brief history (2010s-2020s)

- **Deep learning explosion**

- 2012: **AlexNet** and its CNN successors obsolete away everything previously done in computer vision
- 2014: Seq2seq with LSTM obsoletes away everything previously done in computer translation
- 2016: AlphaGo, a system using CNN and deep RL beats Go world champion
- 2017: Introduction of transformers, obsolete away LSTM in NLP
- 2018: BERT: first transformer based large language model LLM making a massive step in human text understanding
- 2022: GPT 3.5: first LLM broadly available to the general public

The hidden history

- The landmarks of the deep learning history had been sometimes misunderstood
- Algorithms had been reinvented several times over
- Some of the algorithms had been named after people being prominent at the beginning of the hype cycle, not the original inventors
- For instance, there was nothing to invent in gradient descent
 - It is from the 1850's (at least), but probably Newton would have come up with it in 5 minutes if faced with the problem.

What are we going to study

- We will look at neural networks according to our **current understanding** and the algorithms we use today.
- We will try to stick to the notations and thought process of the 2020s.