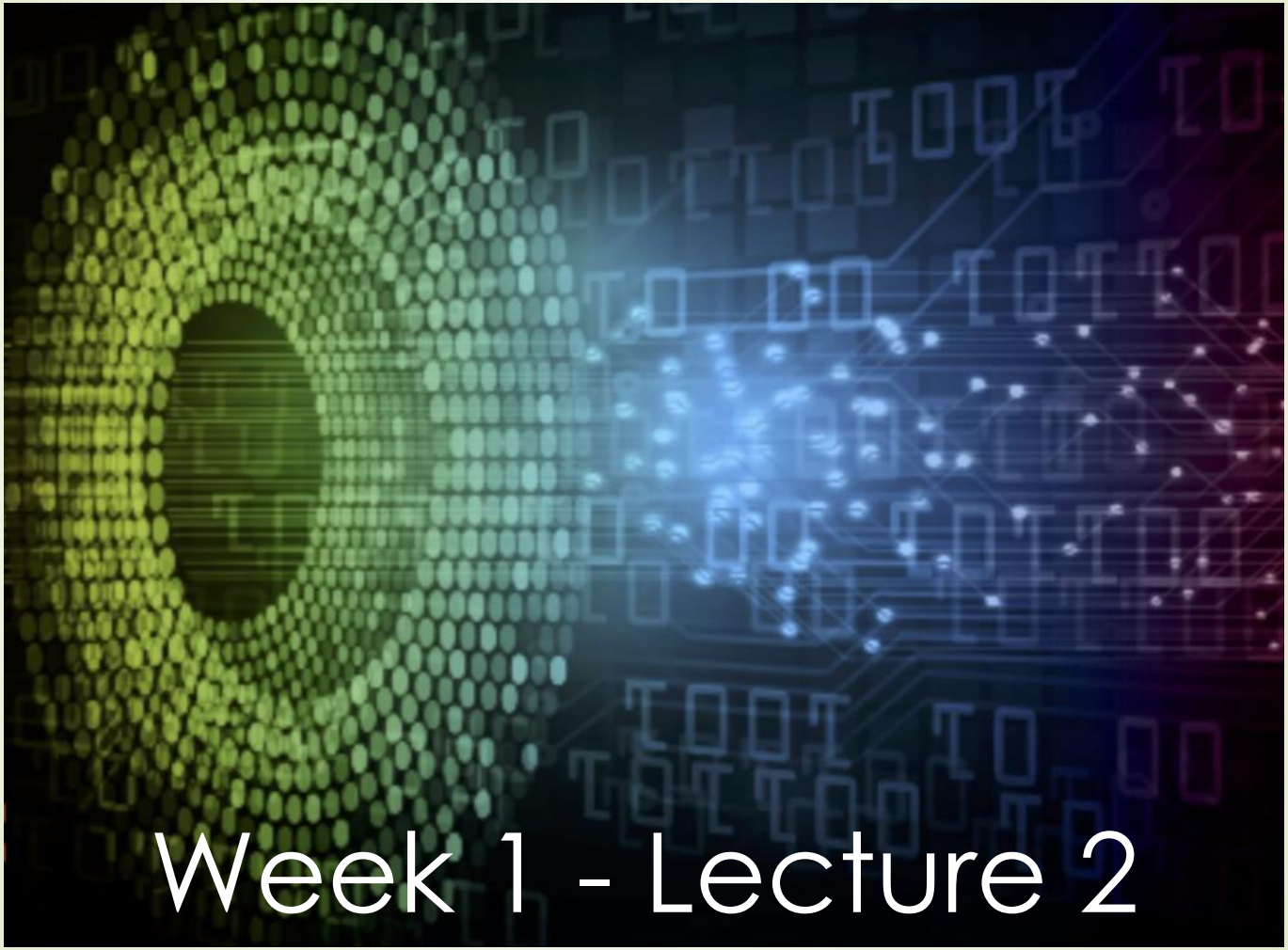
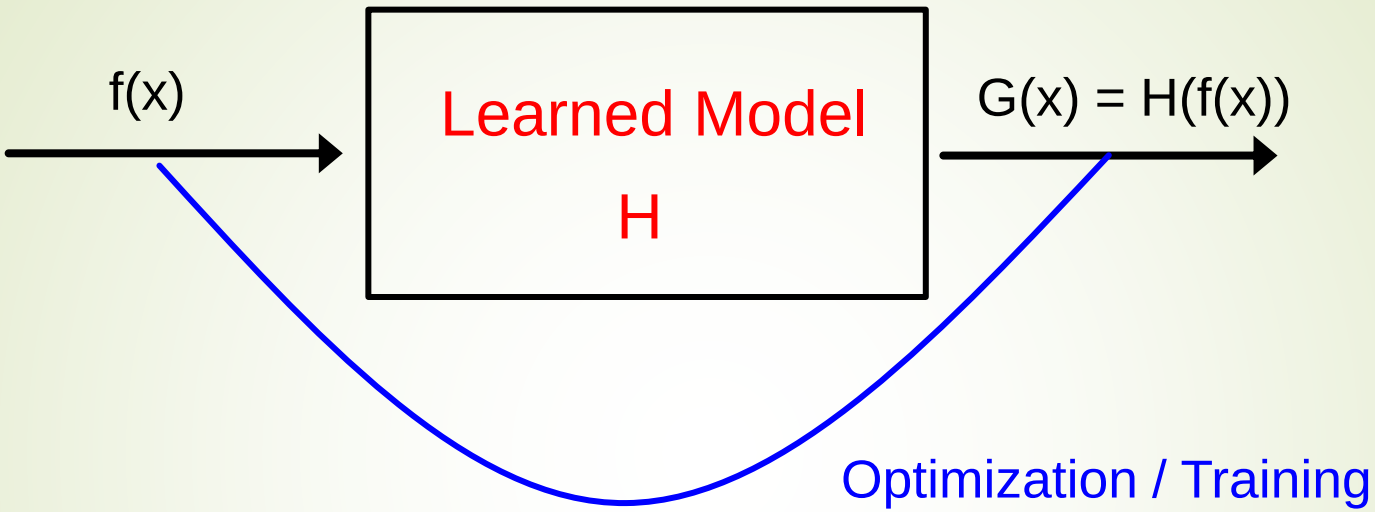
Neural Network Methods for Signals in Engineering and Physical Sciences



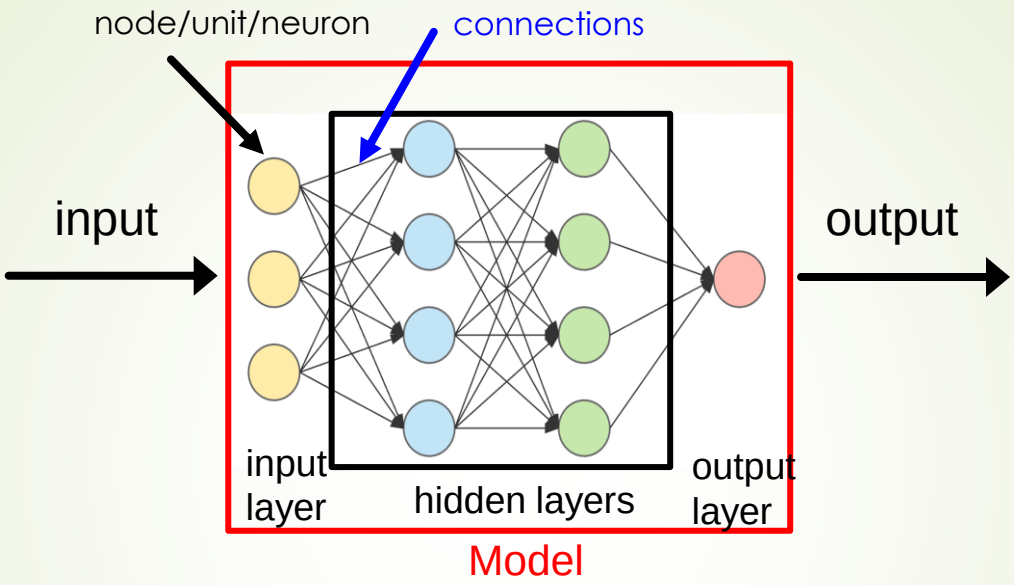
Previous Lecture: Neural Networks / DL

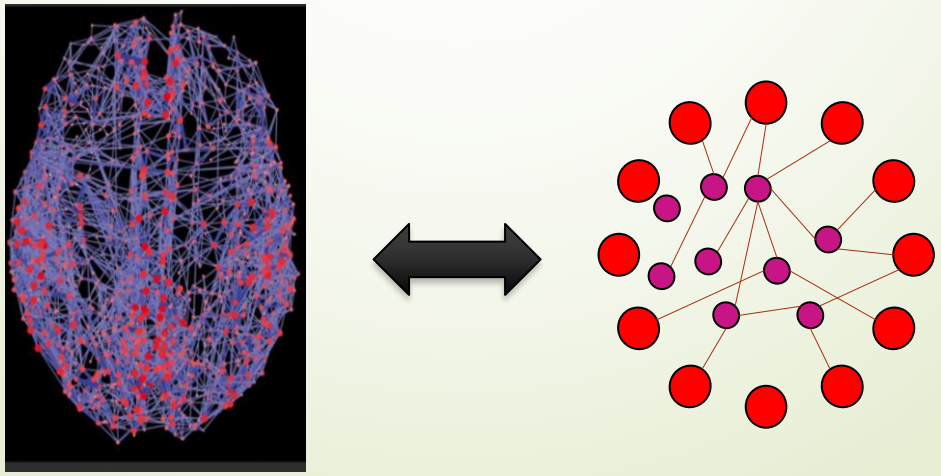


"Deep Learning is the new electricity"

Andrew Ng

This Lecture: Neural Networks



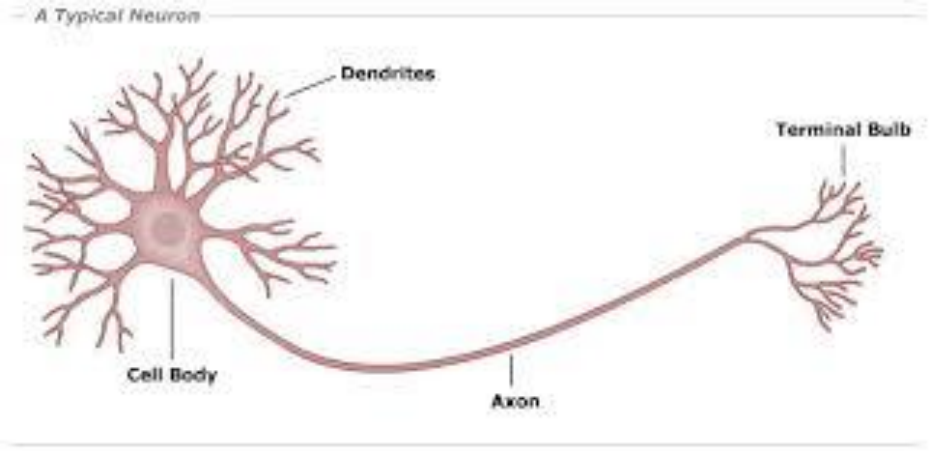


Neuron

Fundamental Unit

Brain Neuronal Networks

- **Neurons in the brain are cells**



Brain Neuronal Networks

Spike train

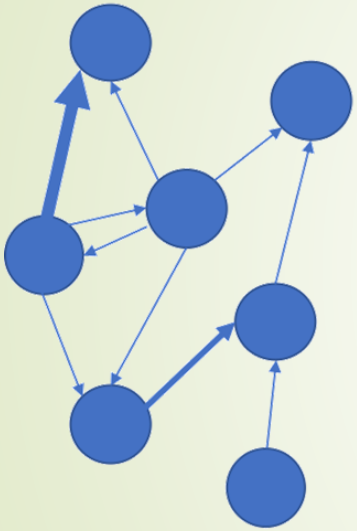
Binary

0	1	0	0	1	1	1	1	1	0						

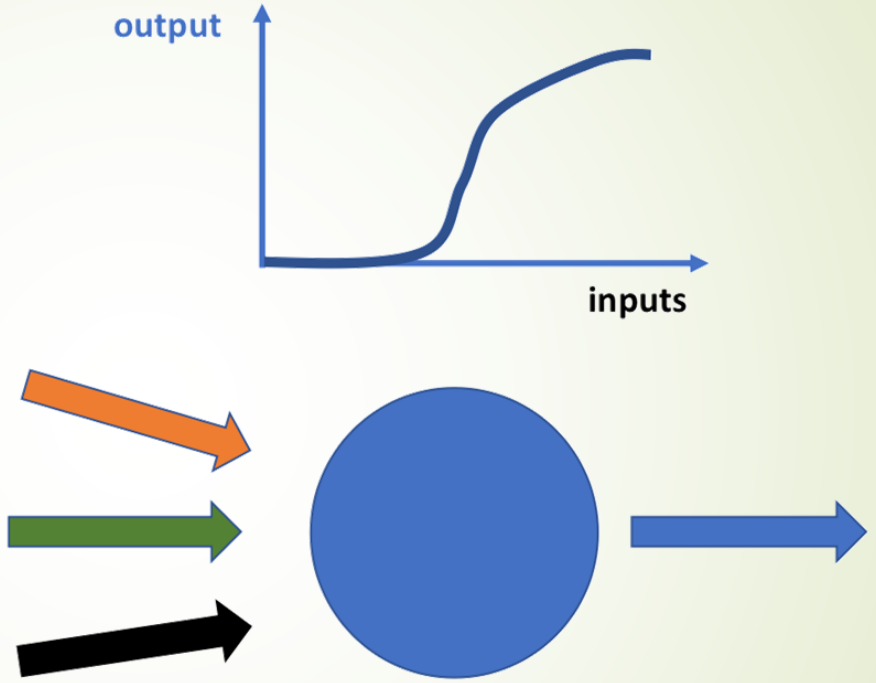
Firing rate

$$df/dt = -f + \tanh(x(t))$$

Firing rate units



Firing-rate model

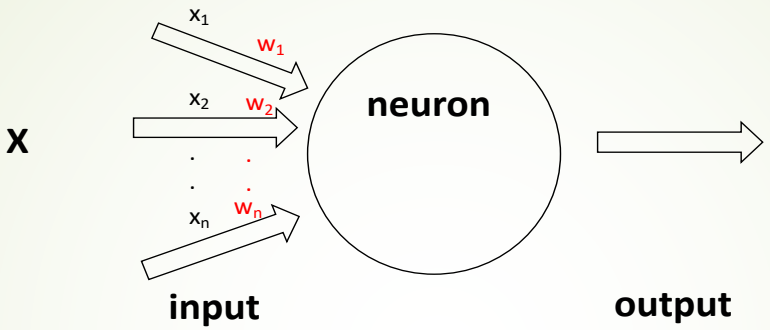


inputs (synapses):
from other units

neuron:
firing-rate unit

output:
to other units

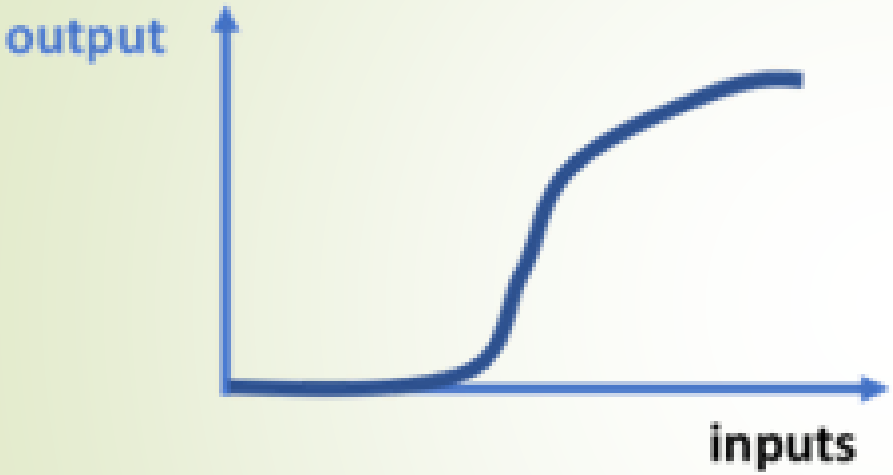
Neuron – Computational Unit

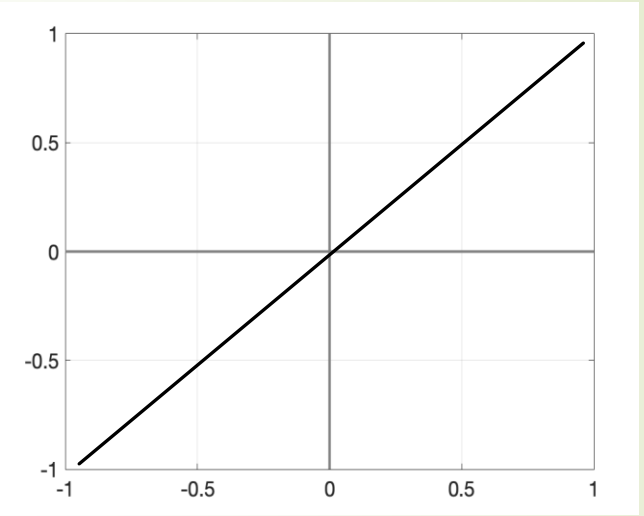


integration	activation	input to other neurons
$I = x_1 * w_1 + \ldots + x_n * w_n$	$f(I)$	$x = f(I)$

$$\sum_{i=1}^{n} x_i w_i + b \qquad f(\sum_{i=1}^{n} x_i w_i + b) \qquad y = f(\sum_{i=1}^{n} x_i w_i + b)$$

Neuron – Computational Unit

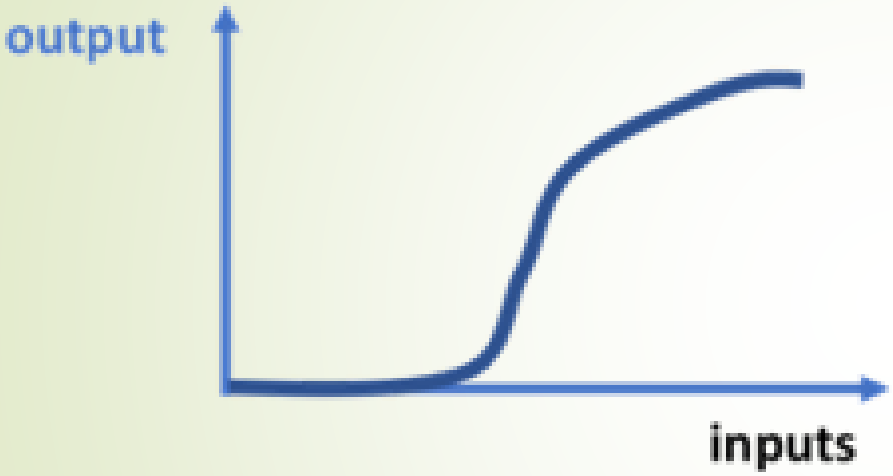


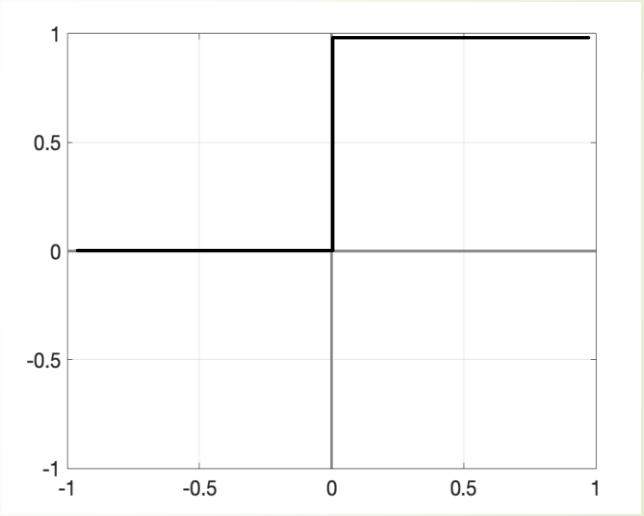


Linear

$$f = x$$

Neuron – Computational Unit

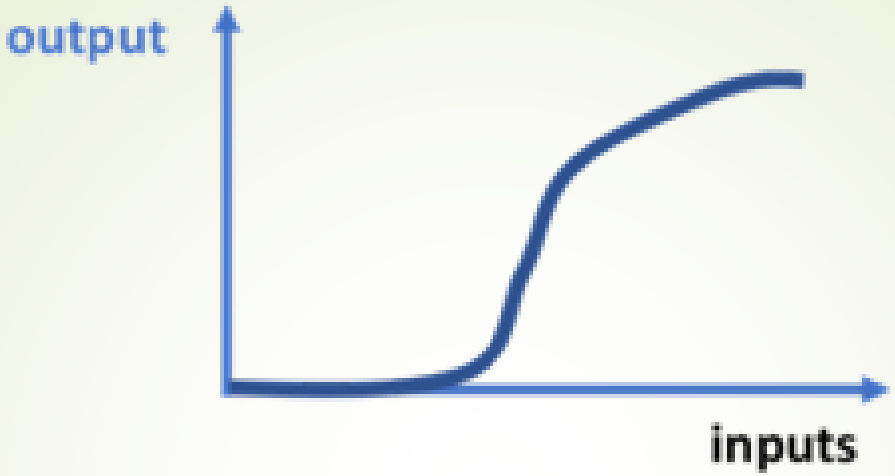


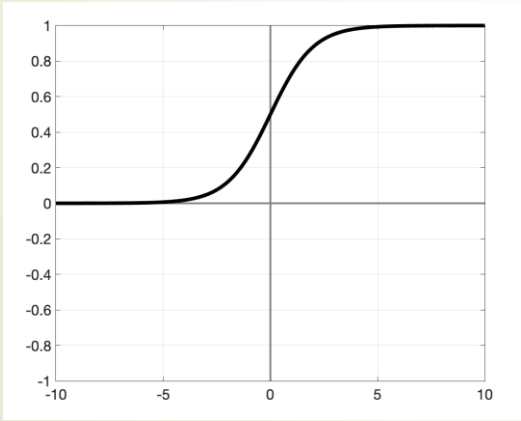


Step

$$f(n) = \begin{cases} 1 & x > 0 \\ 0 & \text{otherwise} \end{cases}$$

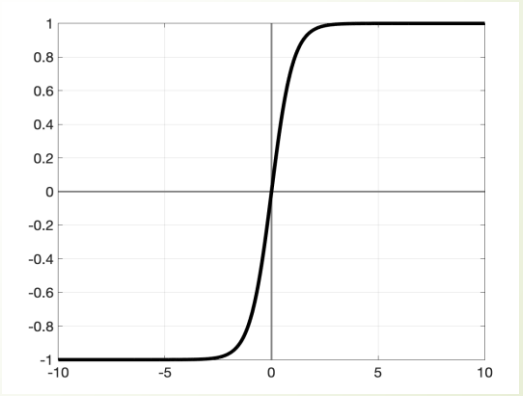
Neuron – Computational Unit





Sigmoid

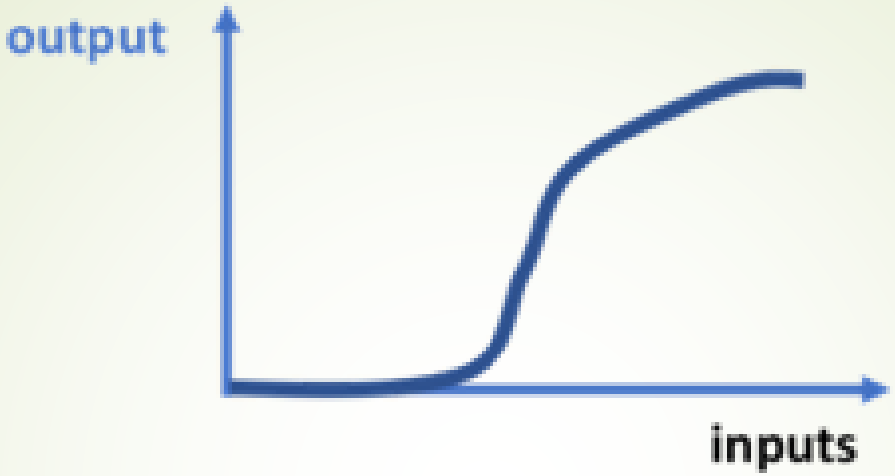
$$f = \frac{1}{1 + e^{-x}}$$

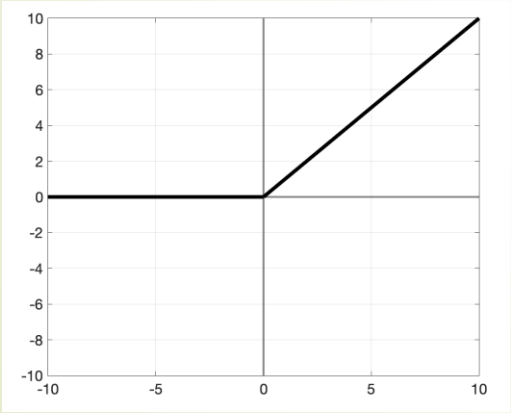


Tanh

$$f = \tanh(x)$$

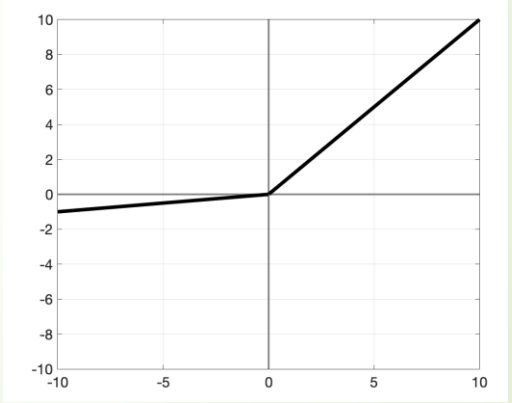
Neuron – Computational Unit





ReLU: Rectified Linear Unit

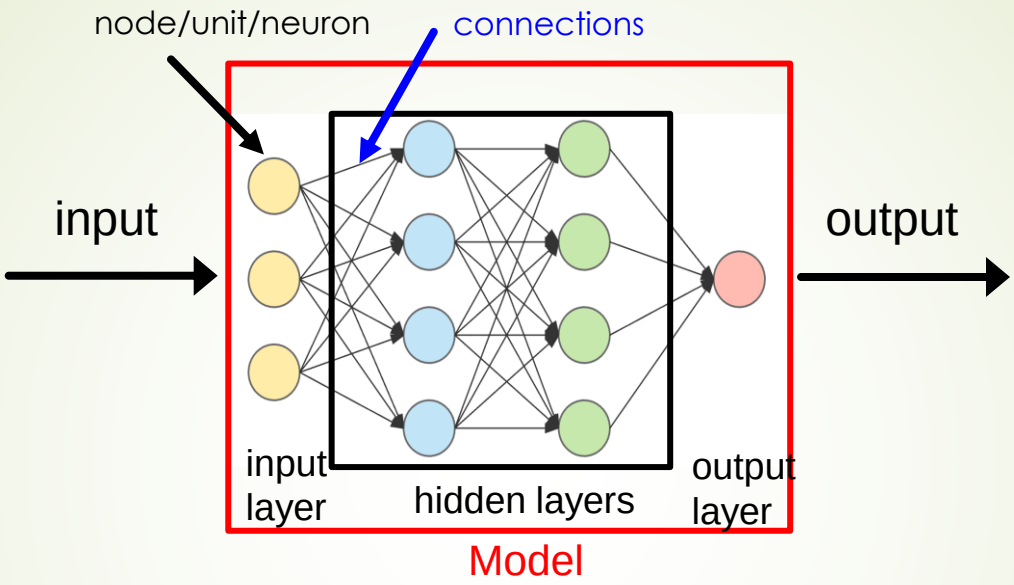
$$f = \max(x, 0)$$



Leaky (parametric) ReLU

$$f = \max(x, ax)$$

Neuron – Computational Unit



$$y = f(\sum_{i=1}^{n} x_i w_i + b)$$

Connecting Neurons

Neural Networks Architectures

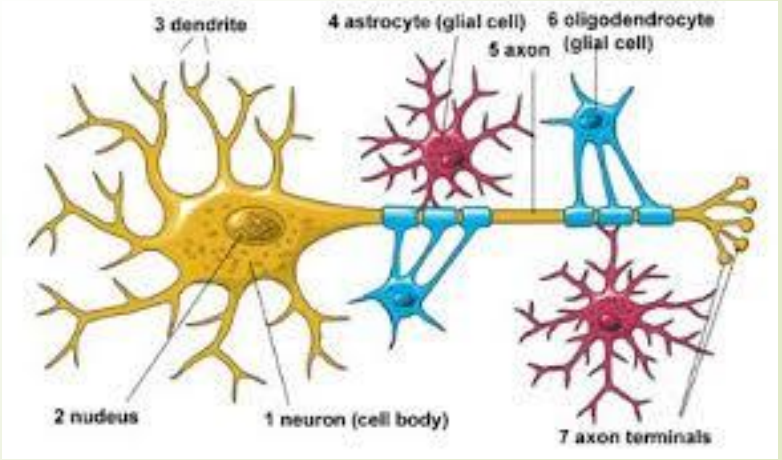
Neuronal Networks

- **Neurons in the brain are abundant and well connected**

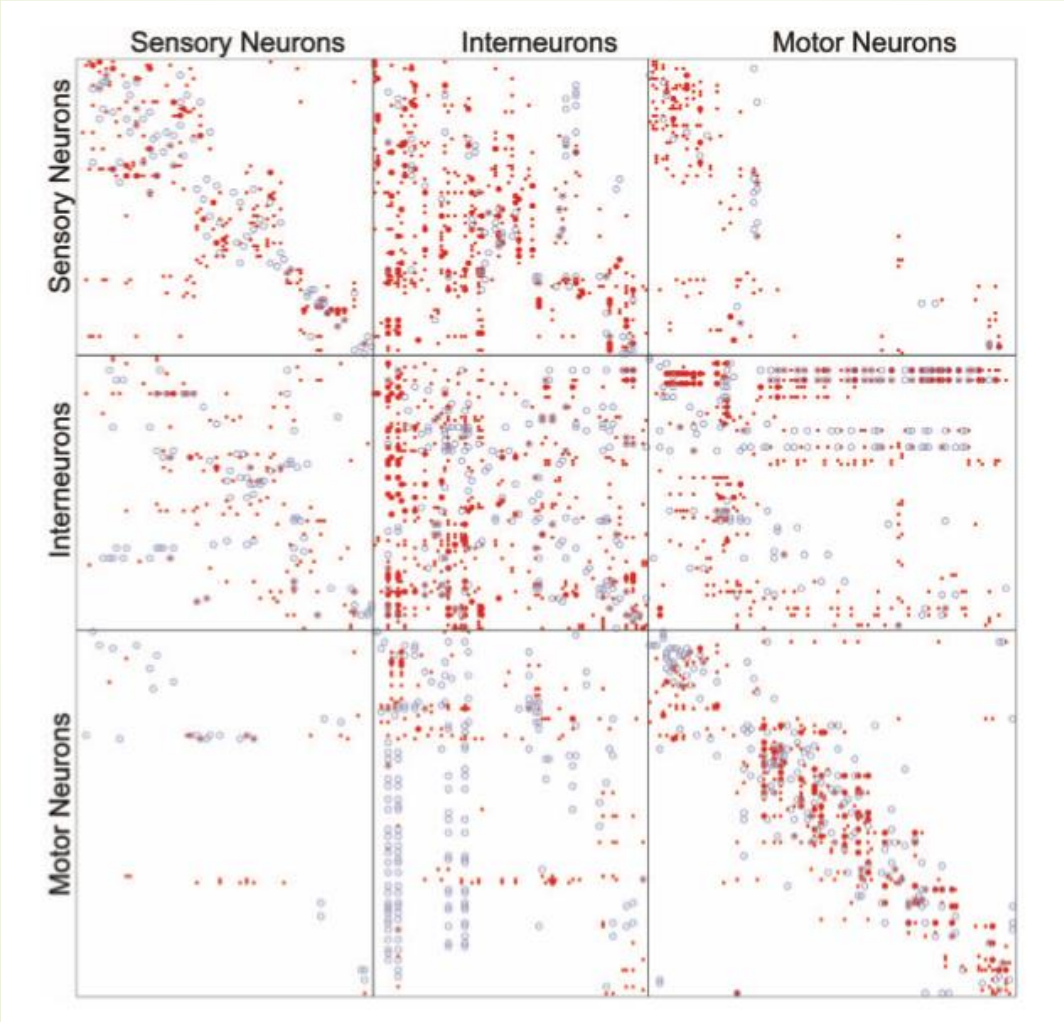
  Human Brain

  10^{11} neurons

  10^{14} connections (**synapses**)

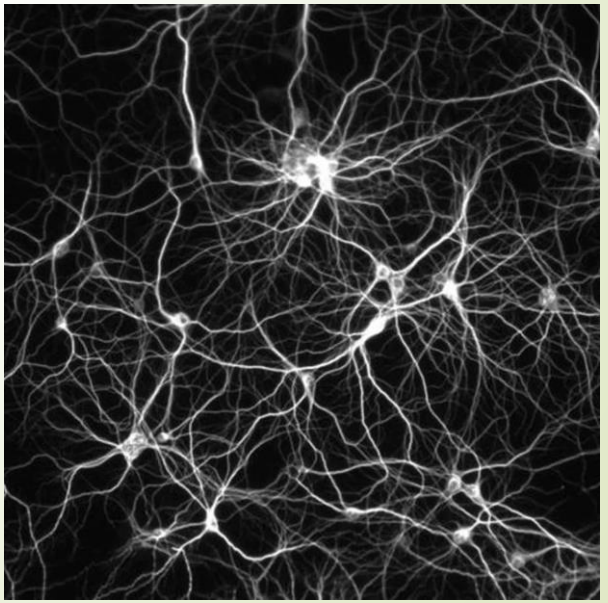


Connectome


Sensory Neurons
Interneurons
Motor Neurons
Sensory Neurons
Interneurons
Motor Neurons

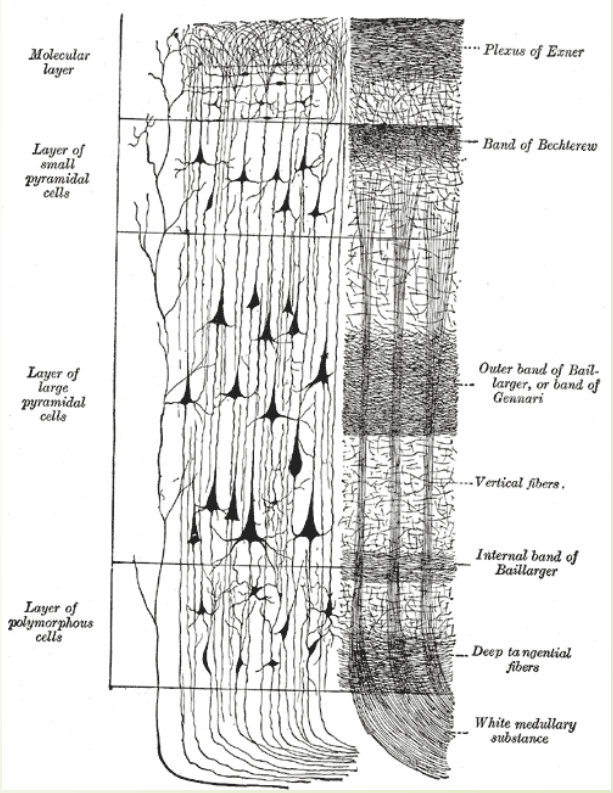
Neuronal Networks

- **Parallelism**
  - Computations done on various scales
  - Recurrences



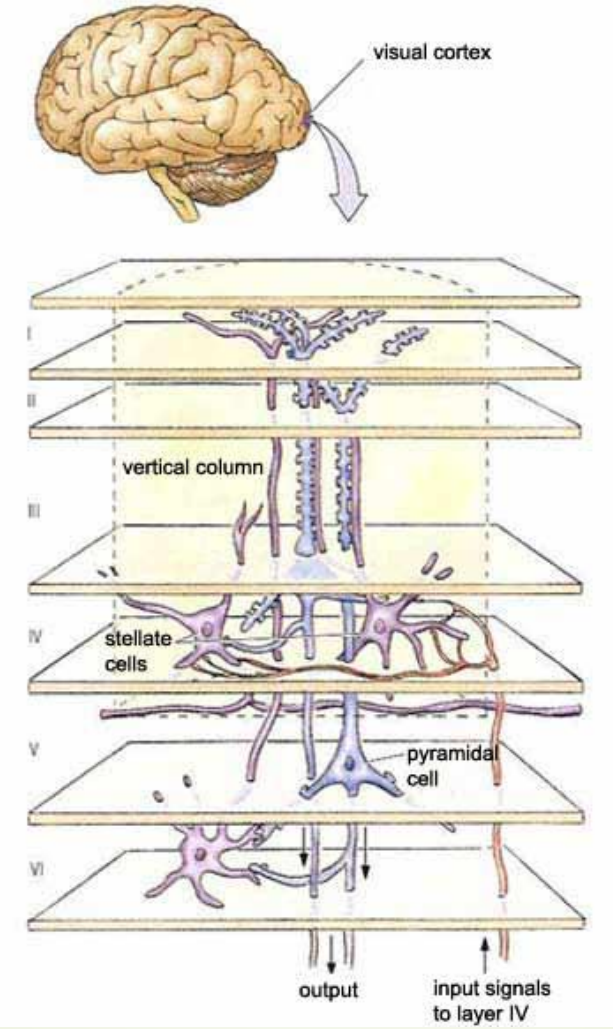
Hierarchical Layered Structure

- **Hierarchical Structure on System Level**
  - Layers
  - Columns
  - Defined Flow
  - Functional Organization
  - Feedback



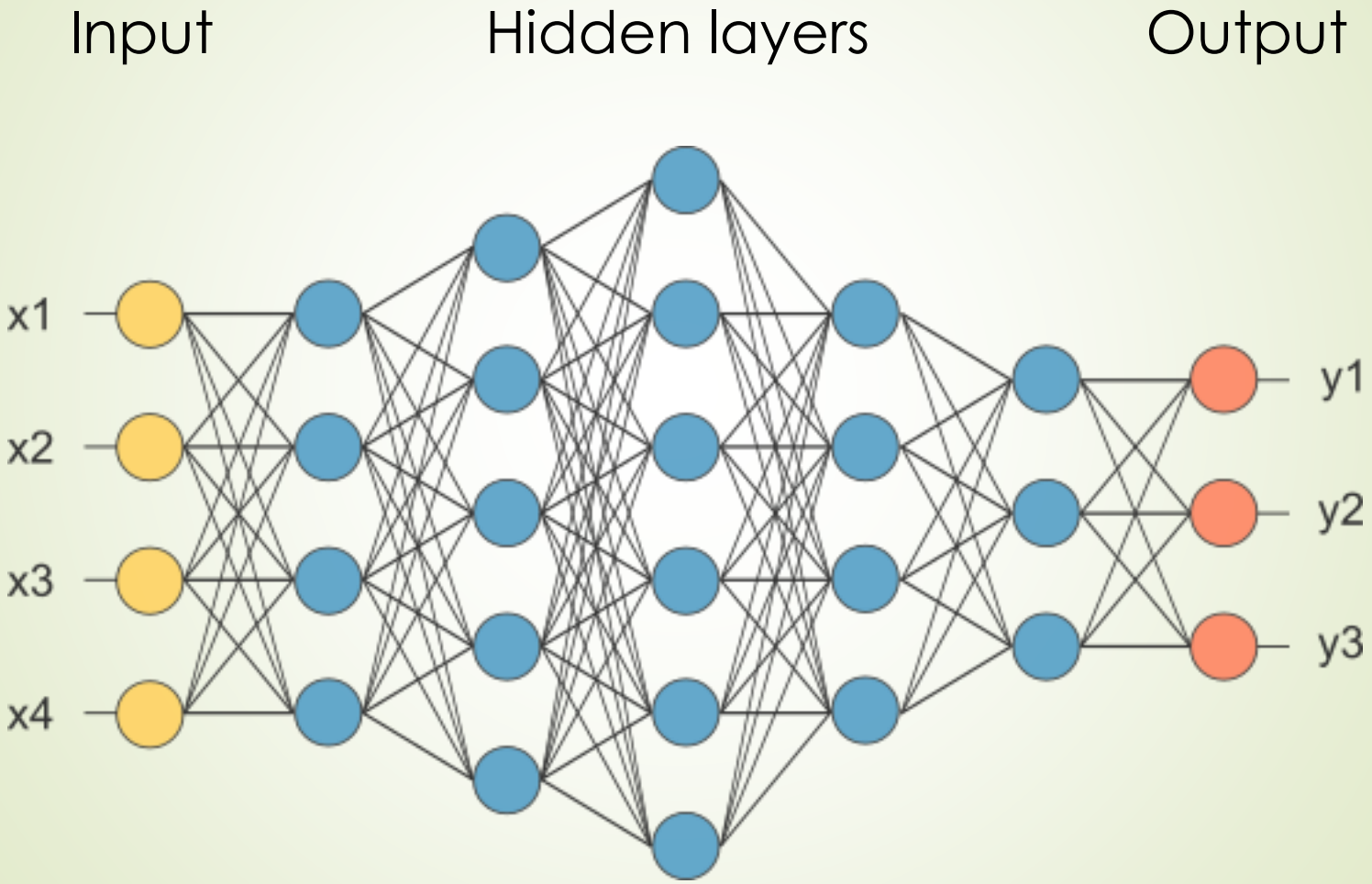
Cerebral cortex

The Visual Cortex

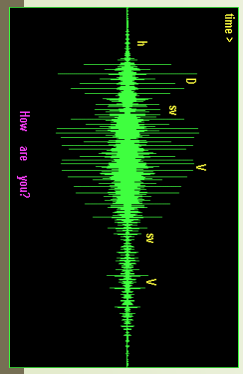


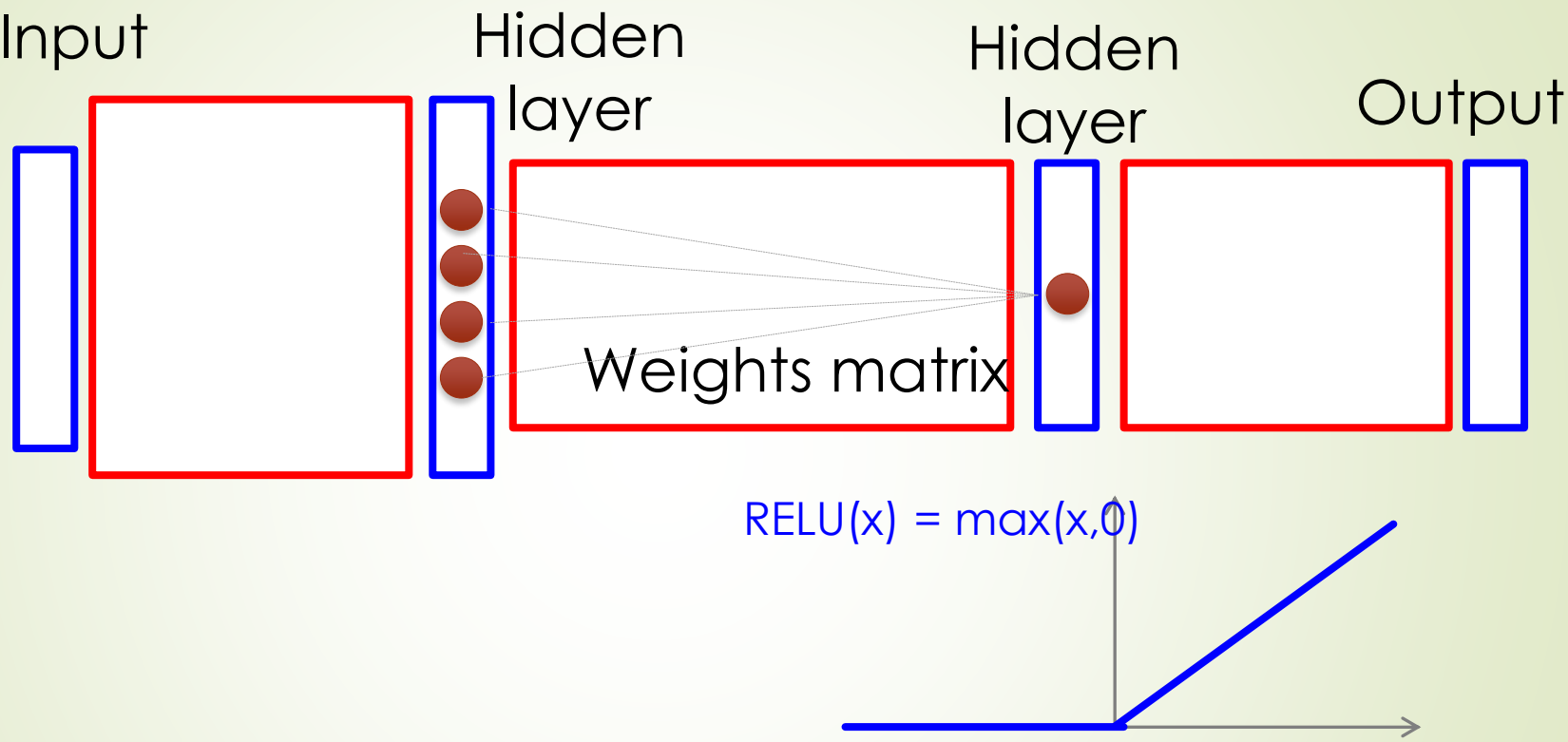
Visual cortex

Deep Neural Networks



Deep Neural Networks- Forward Propagation



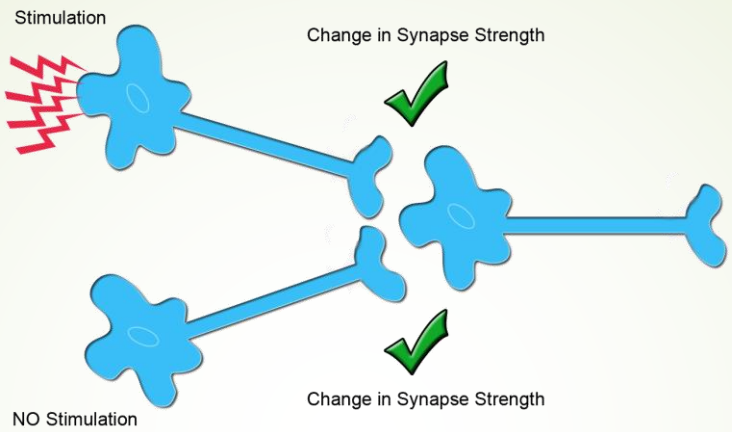


- Multiple layers of **simple units**
- Each unit computes **a weighted sum** of its inputs
- Weighted sum is passed through **a nonlinear** function
- The learning algorithm changes the **weights**

Properties of Brain Networks and Learning

1. Neurons: simple computational units
2. Well connected
3. Parallelism and Recurrence
4. Hierarchically structured
5. Learning

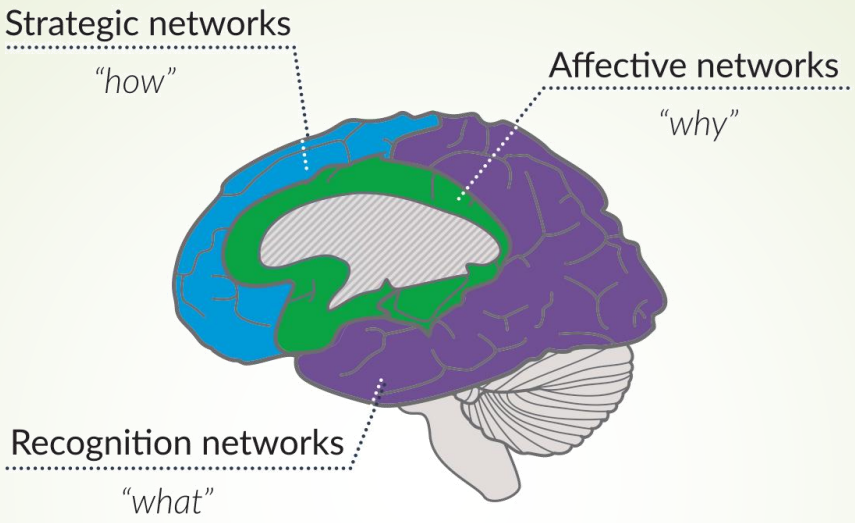
Learning



5.1 Synaptic Plasticity

- Adaptive connections
- The “strength” of synapses changes

Learning



5.2 Feature Extraction

- Classification/Recognition
- Regression Direct
- Regression Indirect