Welcome to the computational cognitive modelling workshop!

Part 2: Artificial neural networks

Part 2: **Artificial neural networks**

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Nick Sexton *Nicole Cruz De Echeverria Loebell*

What is a neural network?

A mathematical model

- Inspired by the nervous system
- A set of *units*, connected by *weights*
- The network *runs* by passing *activations* from the *input* (to the *hidden*) to the *output* units

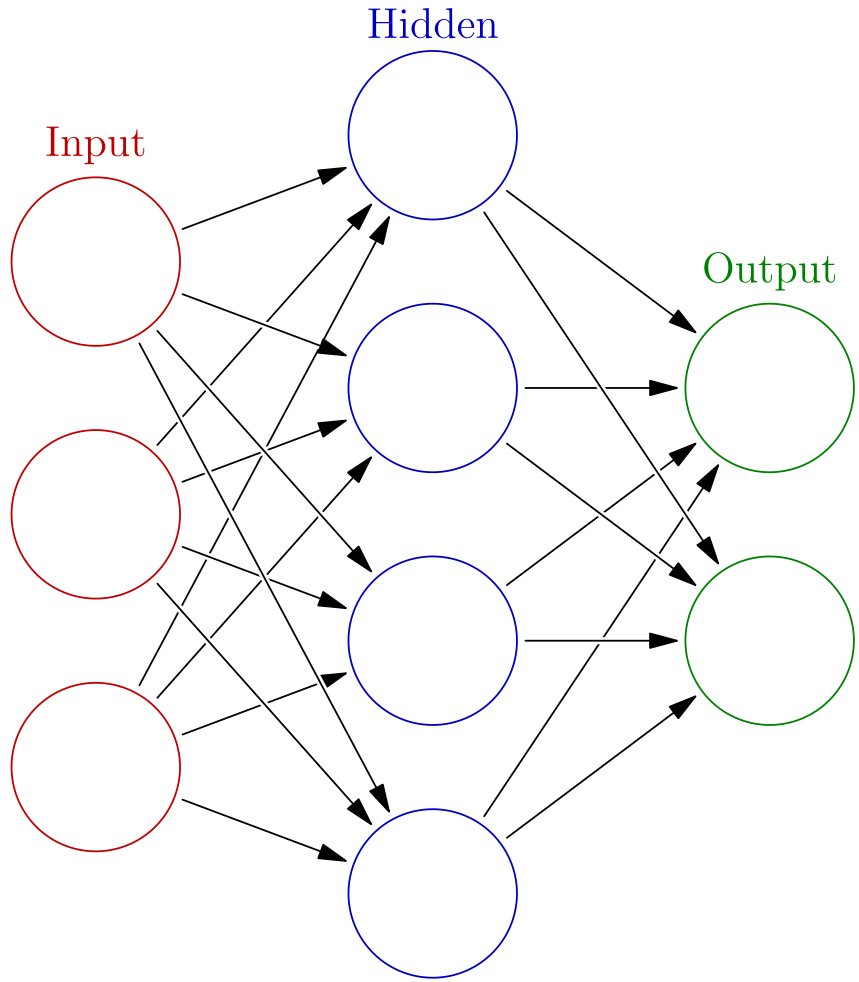


Figure: Glosser.ca / CC-BY-SA-3.0

Why use artificial neural networks for modelling?

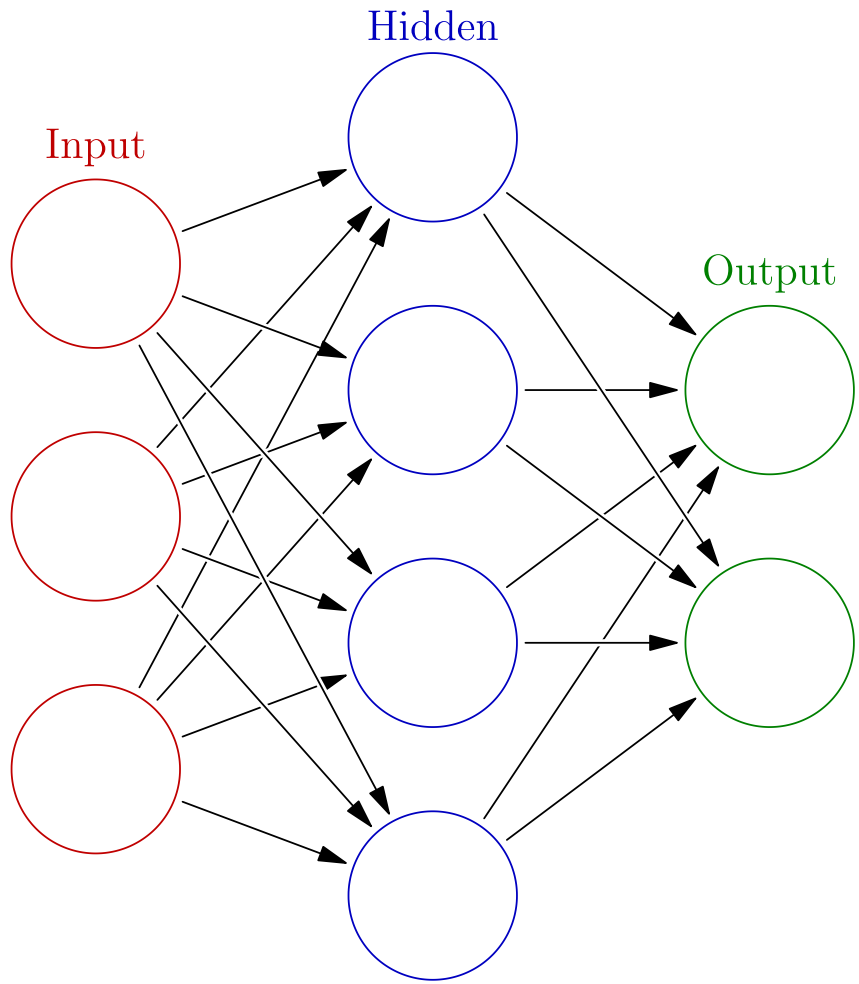
Some aspects of their behaviour are like their namesake!

- Learn pretty much any input-output data
- Uncover rules on their own about data
- Generalise from what they have learnt
- Cope with noise and damage

How does an artificial neural network run?

By using maths, predictably!

1. Input units are set to a *pattern*



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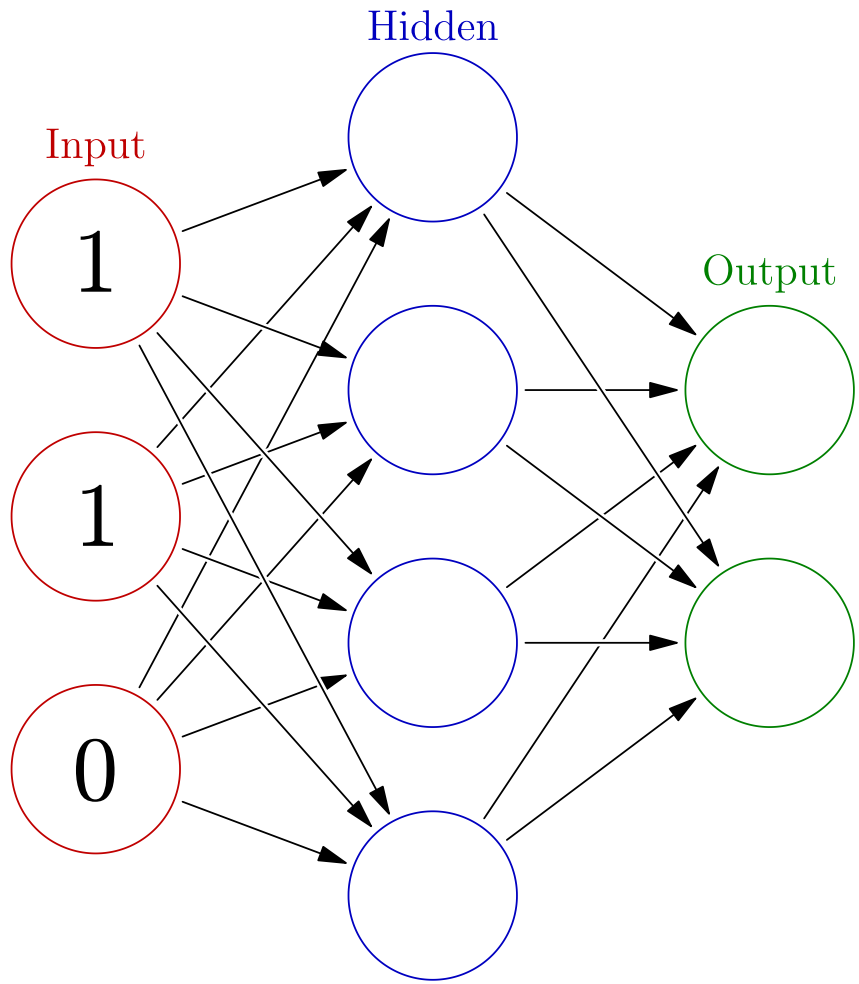

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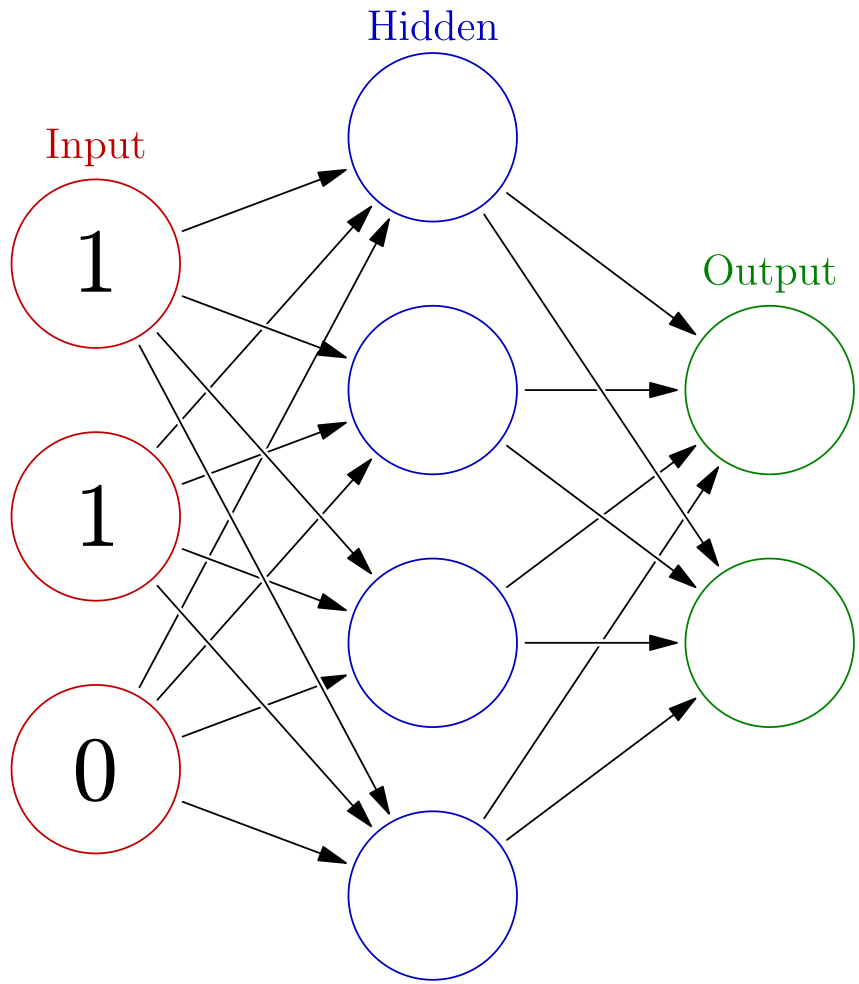
2. Calculate hidden units' states



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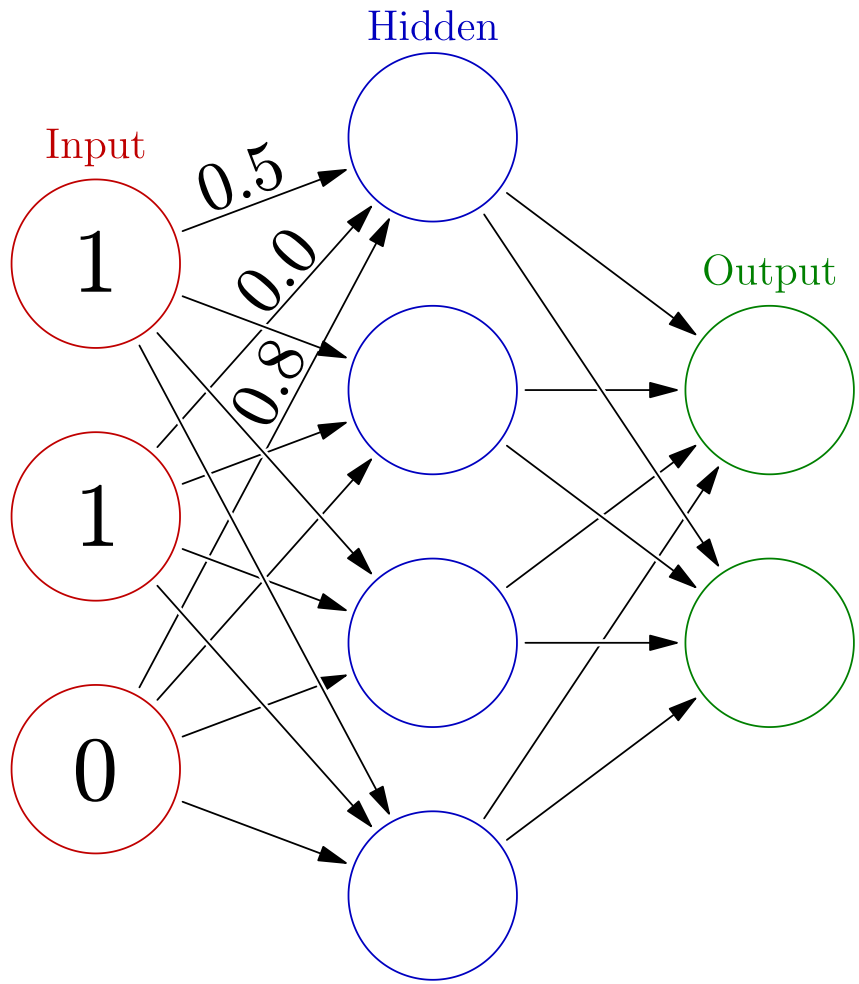

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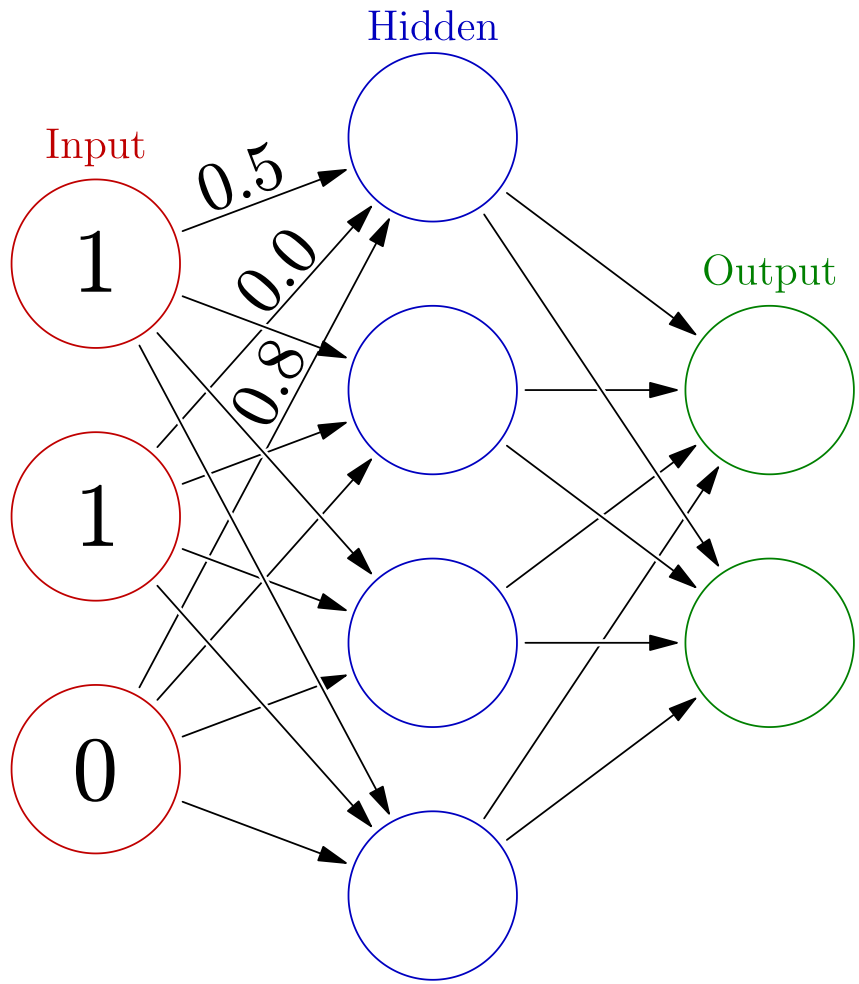
$$1 \times 0.5 = 0.5$$



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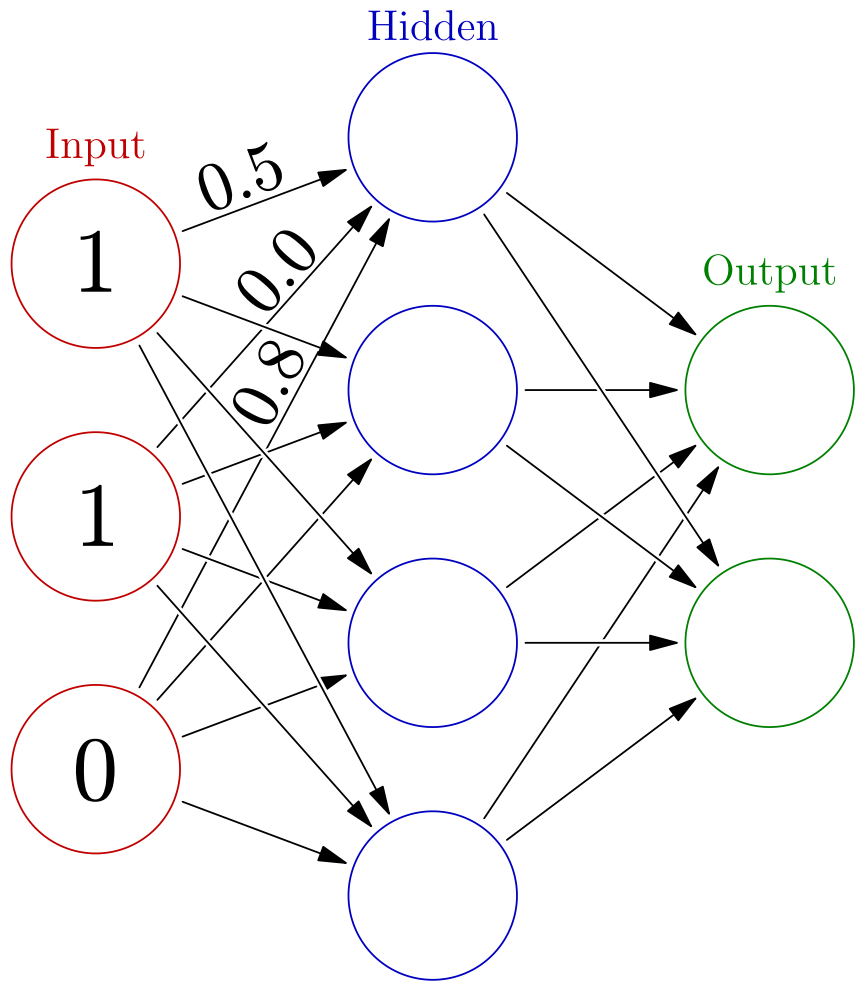

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0 \times 0.8 &= 0.0
\end{aligned}
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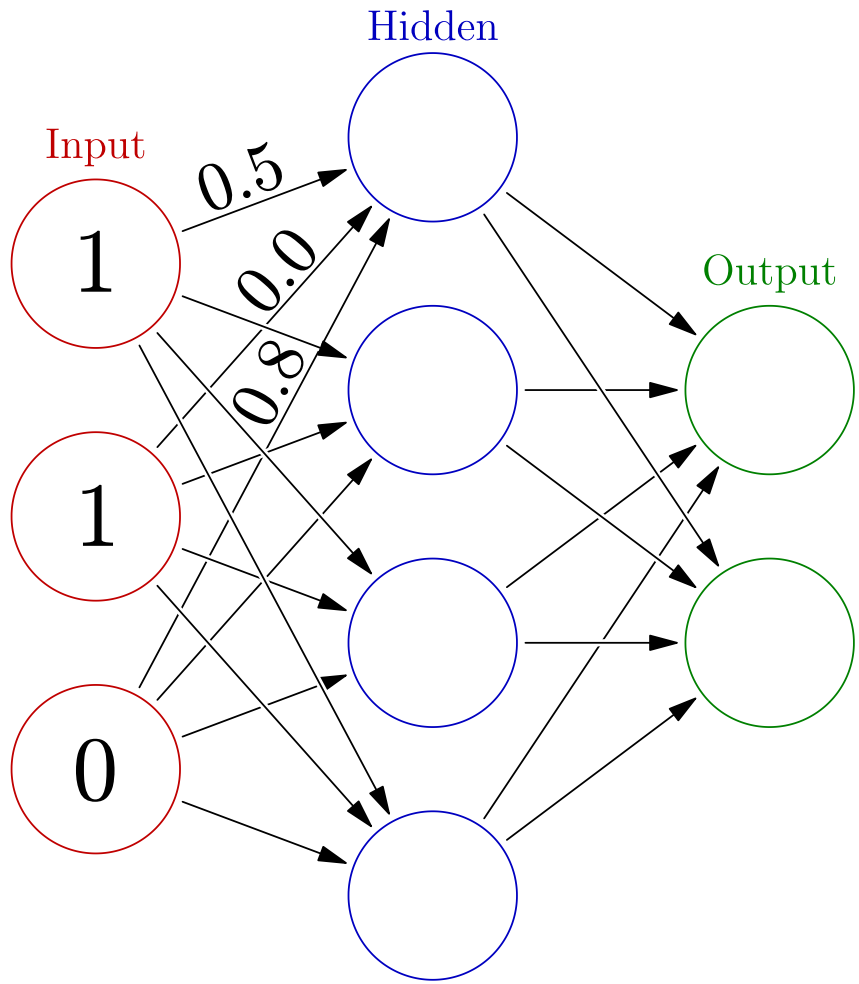

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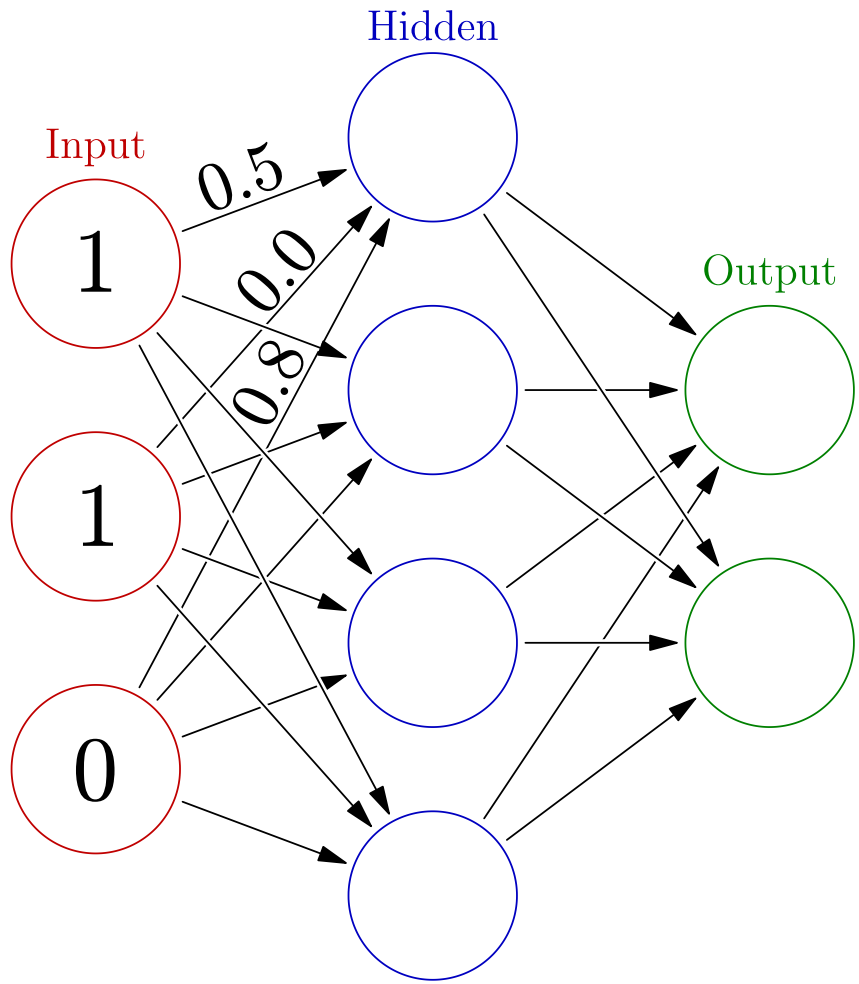

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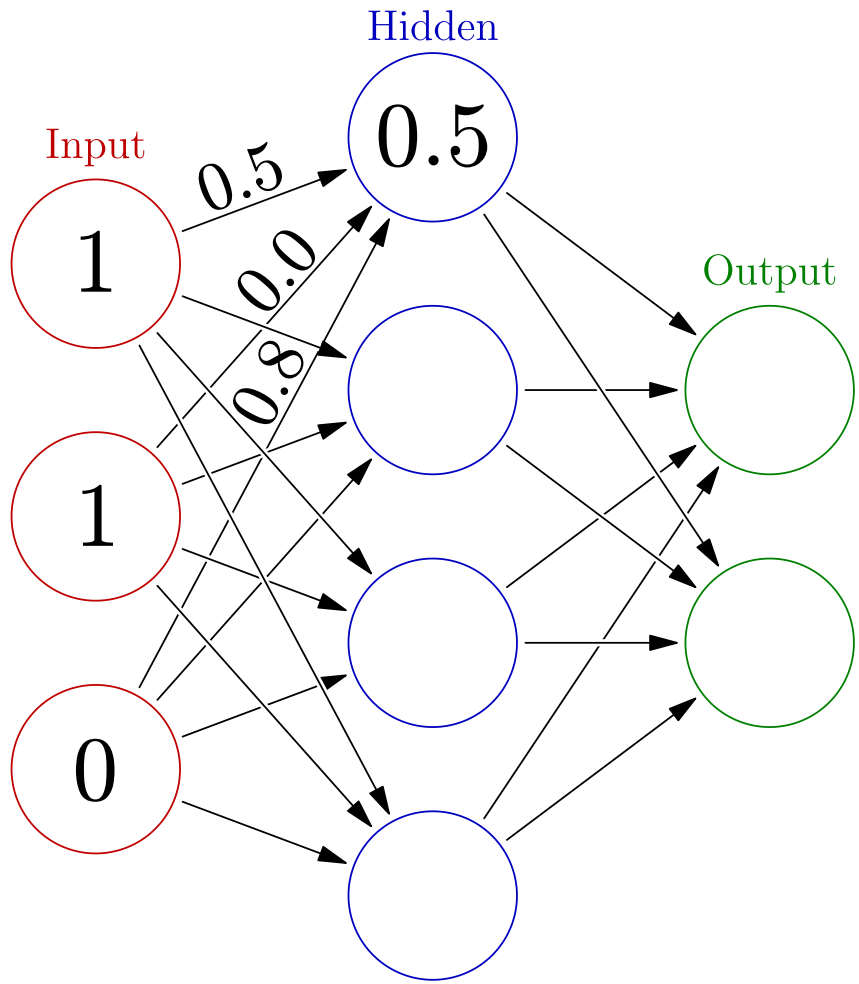

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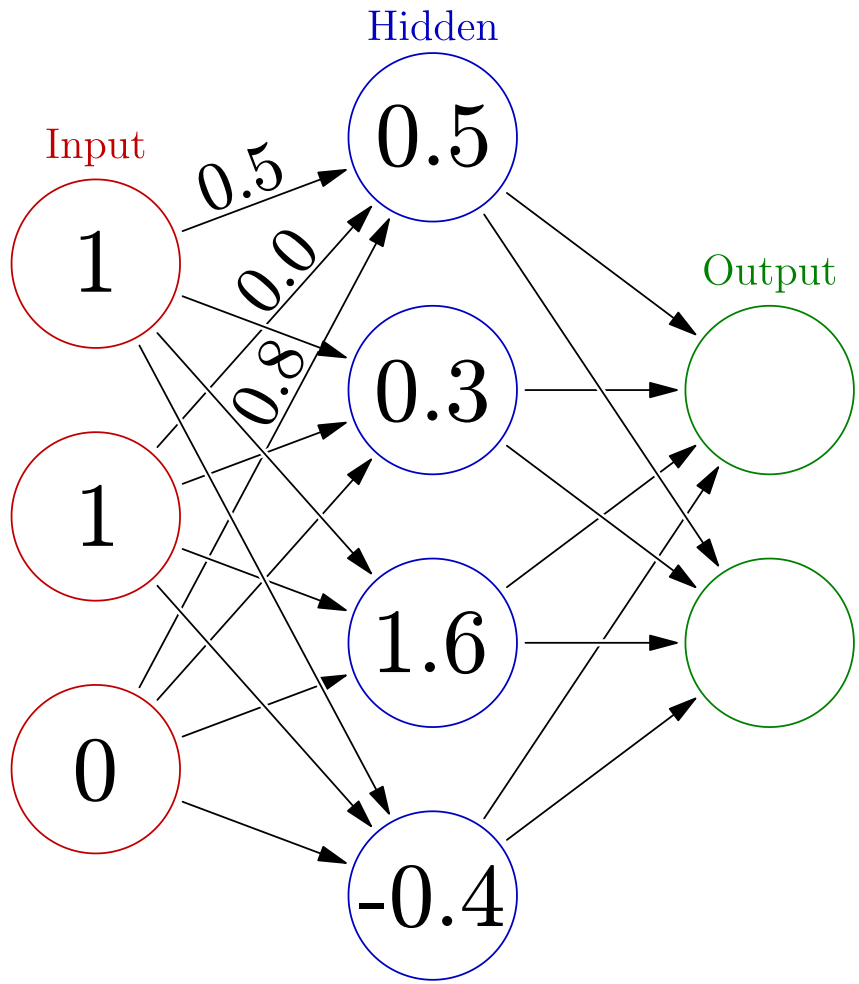

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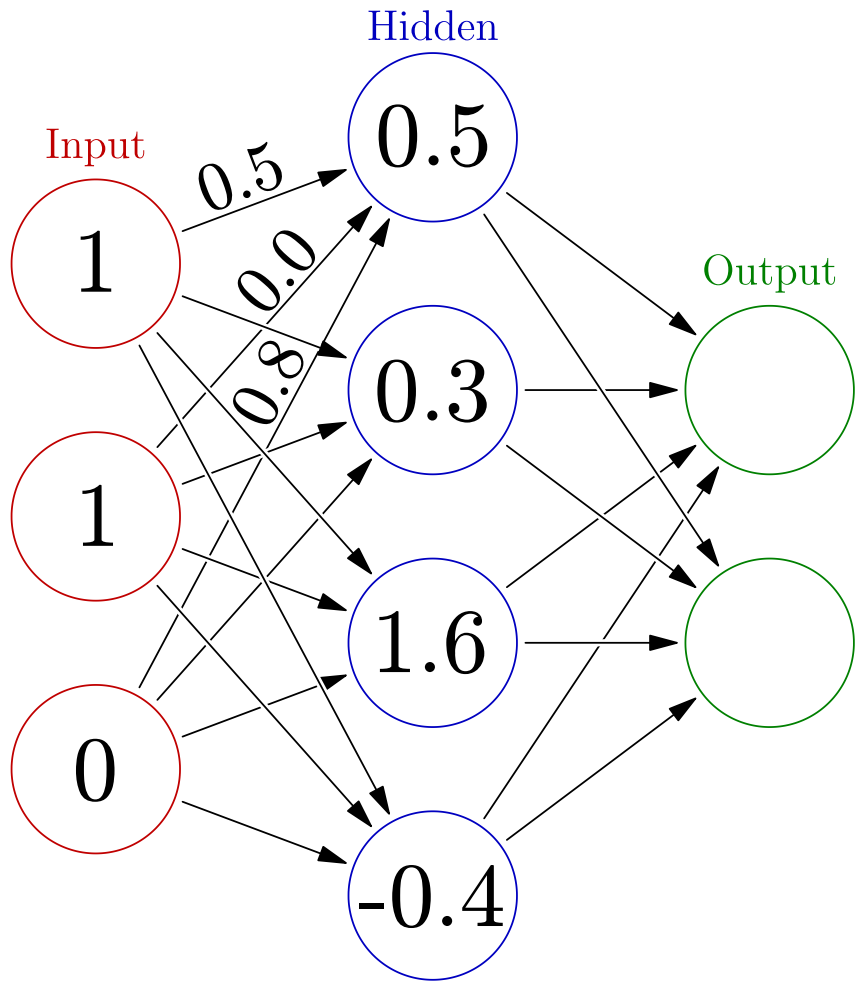
3. Same for output units



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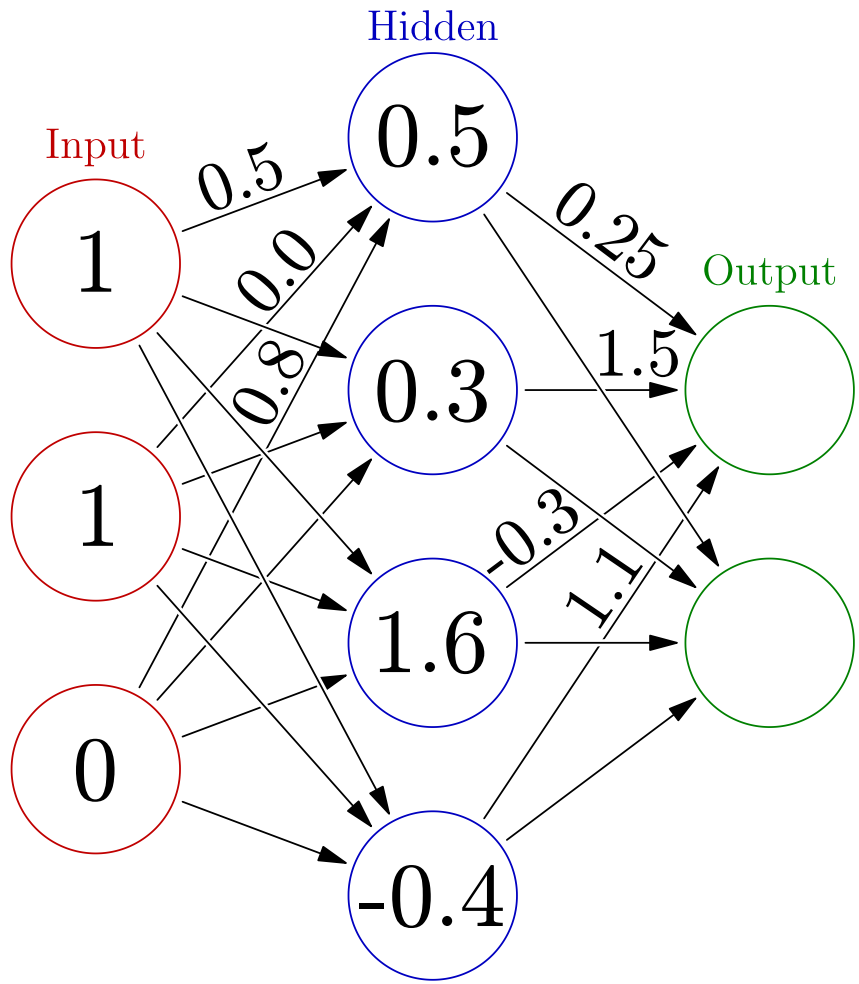

How does an artificial neural network run?

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1. Input units are set to a *pattern*
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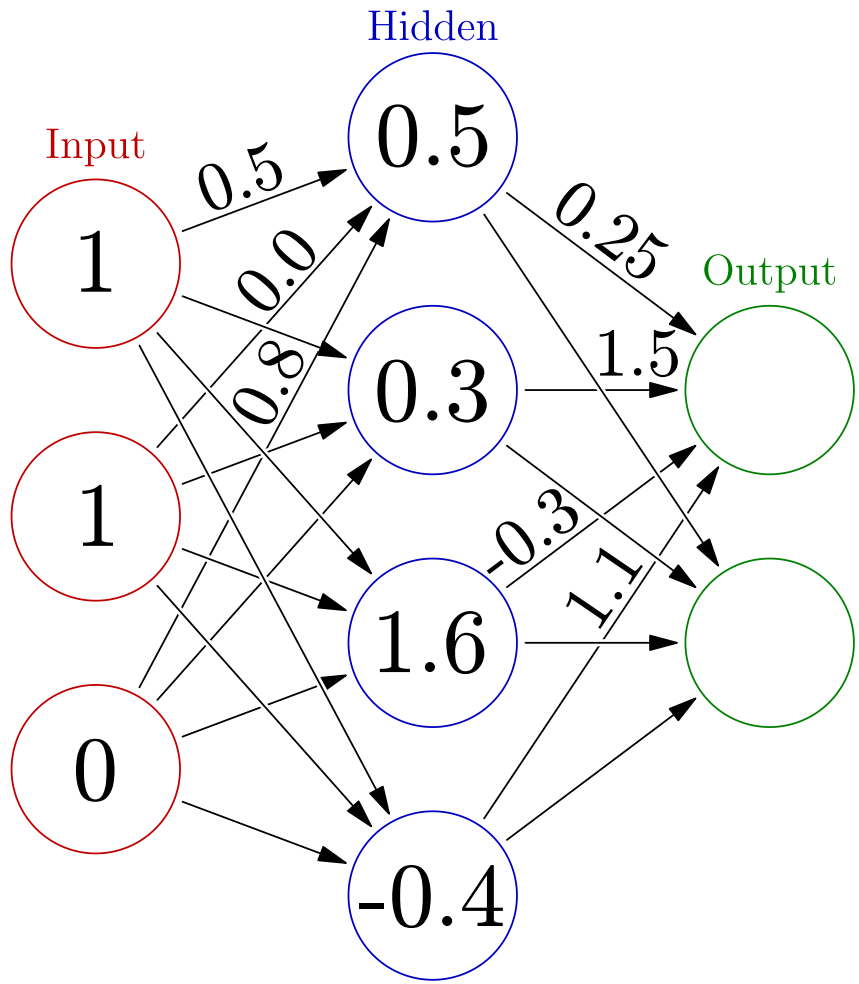
3. Same for output units:

$$0.5 \times 0.25 = 0.125$$



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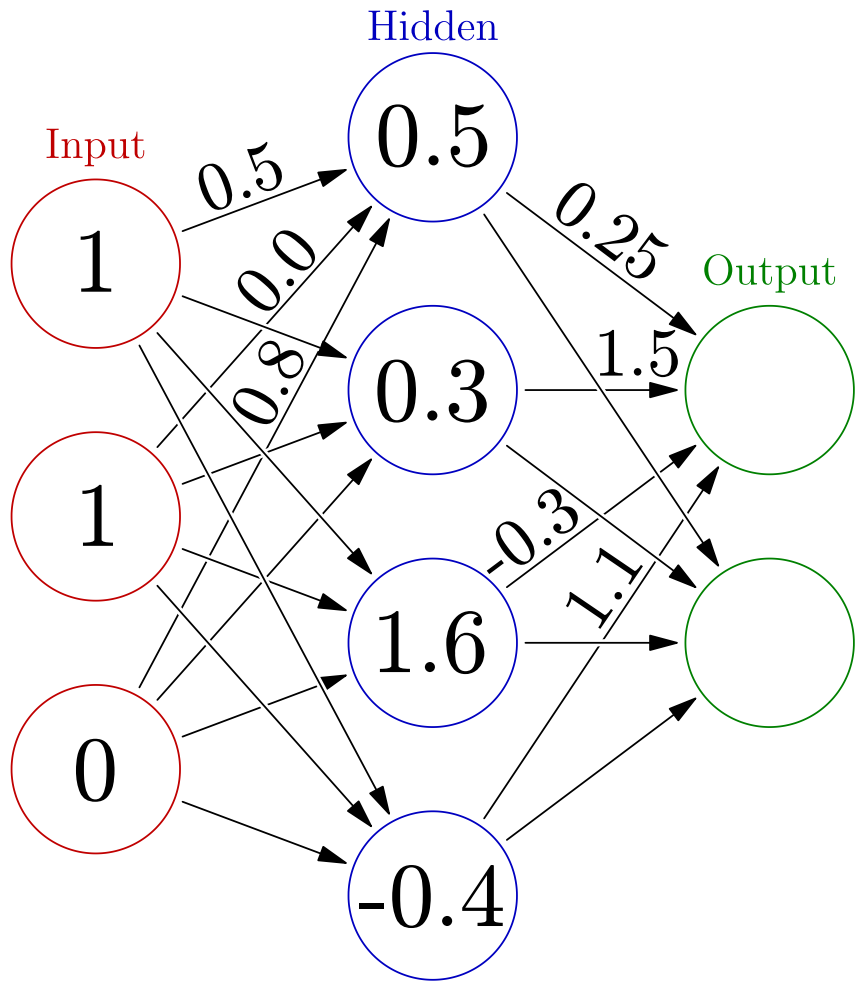
$$\begin{aligned} 0.5 \times 0.25 &= 0.125 \\ 0.3 \times 1.5 &= 0.45 \end{aligned}$$



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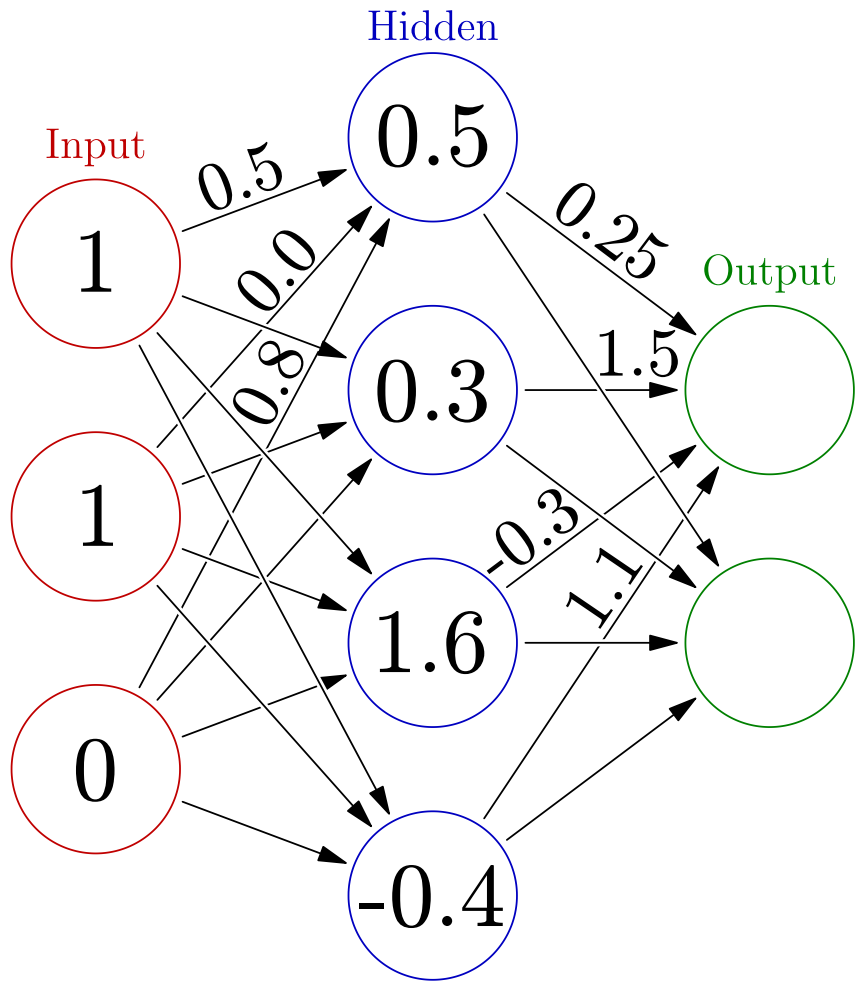
$$\begin{aligned} 0.5 \times 0.25 &= 0.125 \\ 0.3 \times 1.5 &= 0.45 \\ 1.6 \times -0.3 &= -0.48 \end{aligned}$$



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-0.4 \times 1.1 &= -0.44
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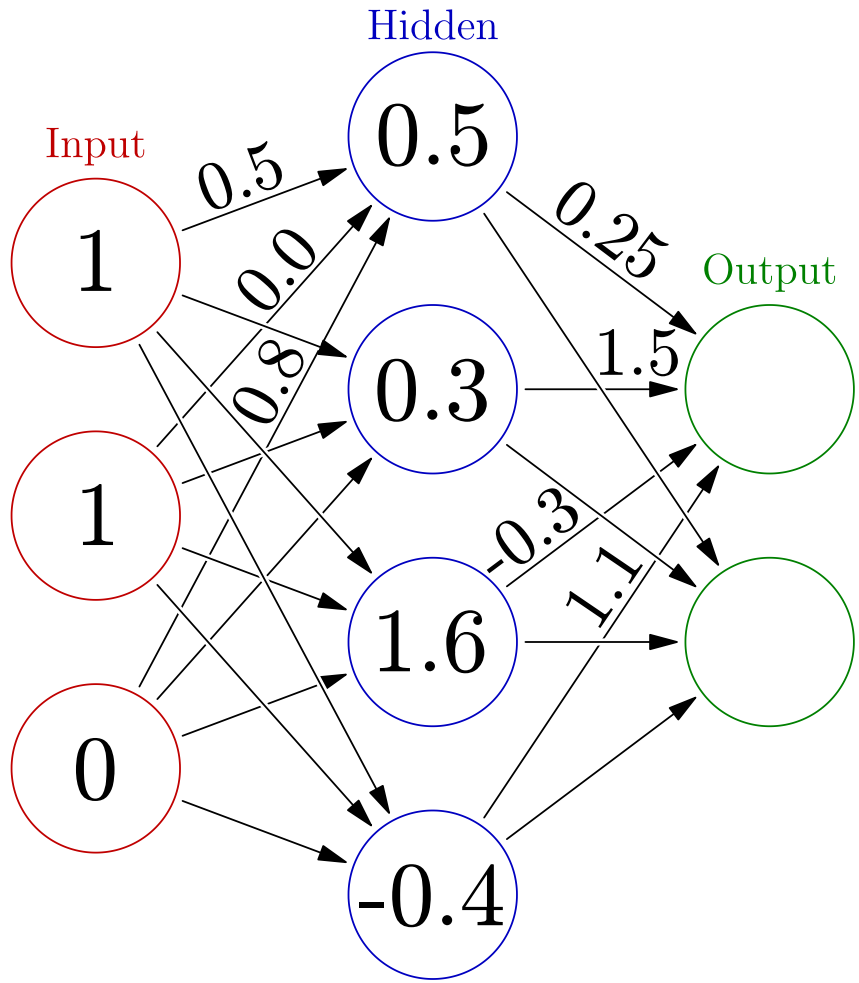

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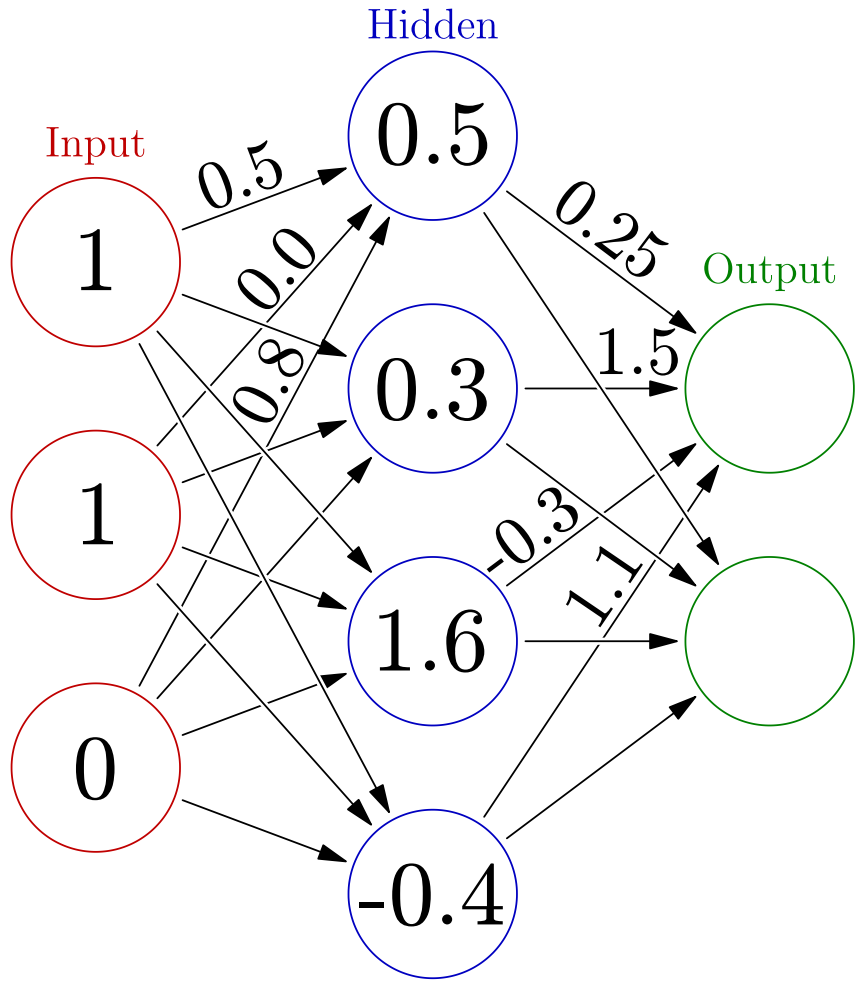

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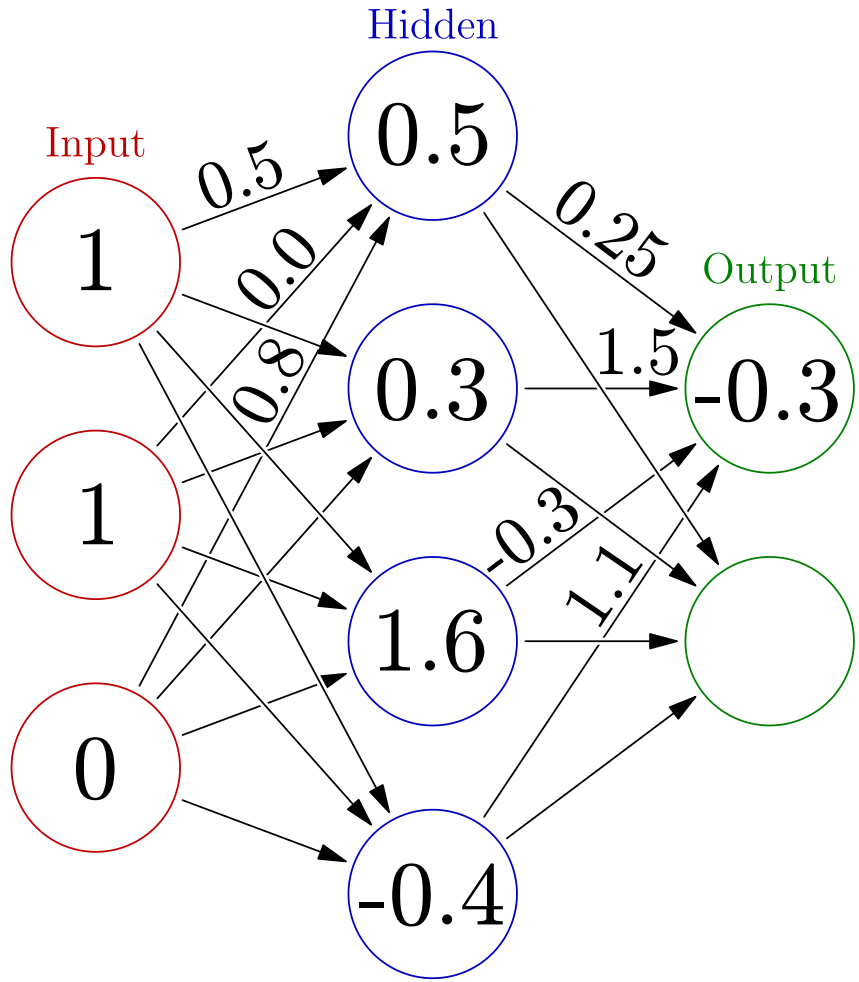

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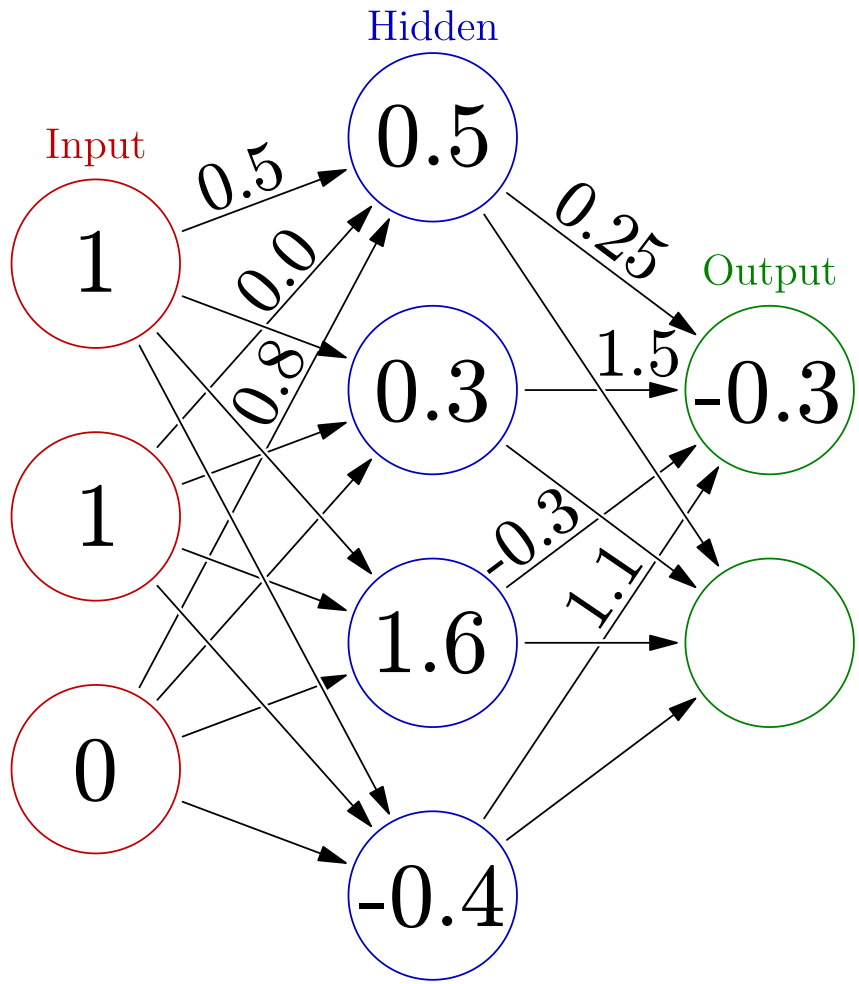


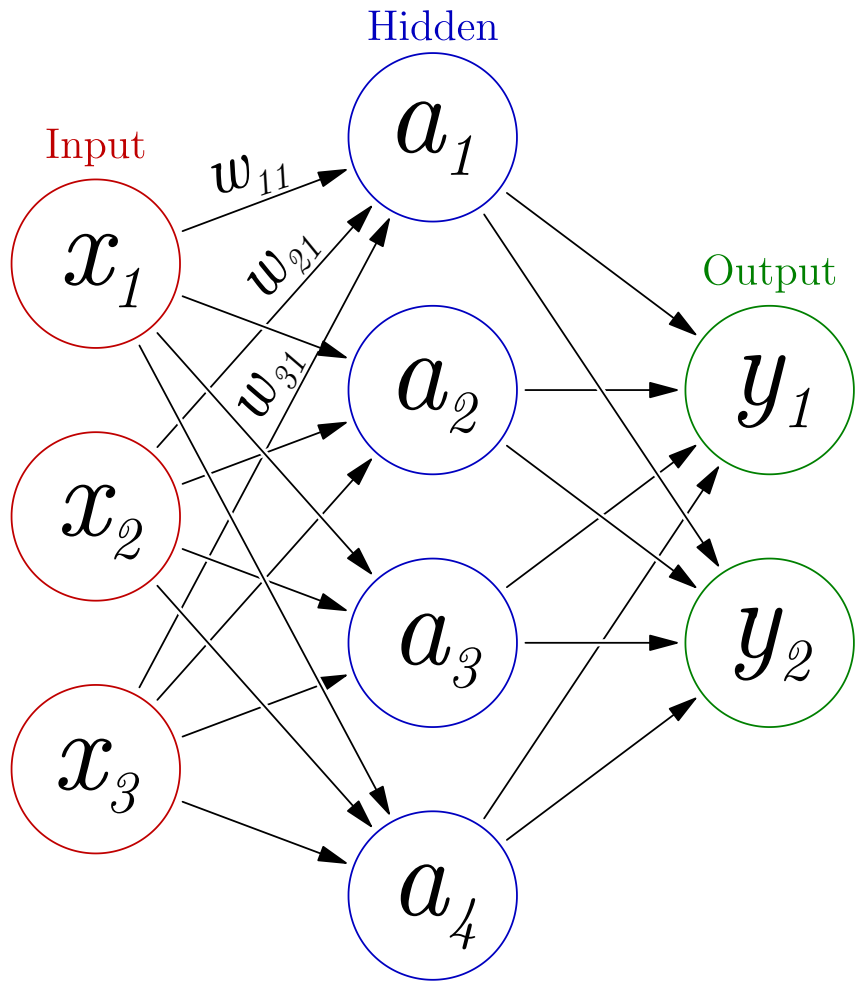
How does an artificial neural network run?

By using maths, predictably!

But we/programmers are lazy:

$$a_i = f\left(\sum_1^N x_j \times w_{ji}\right)$$

where a_i is the unit whose state we want to calculate, N are the units on the previous layer, w_{ji} is the weight on the connection between i and j, and f is a function that we will discuss later.



How do networks learn?

Cunning!

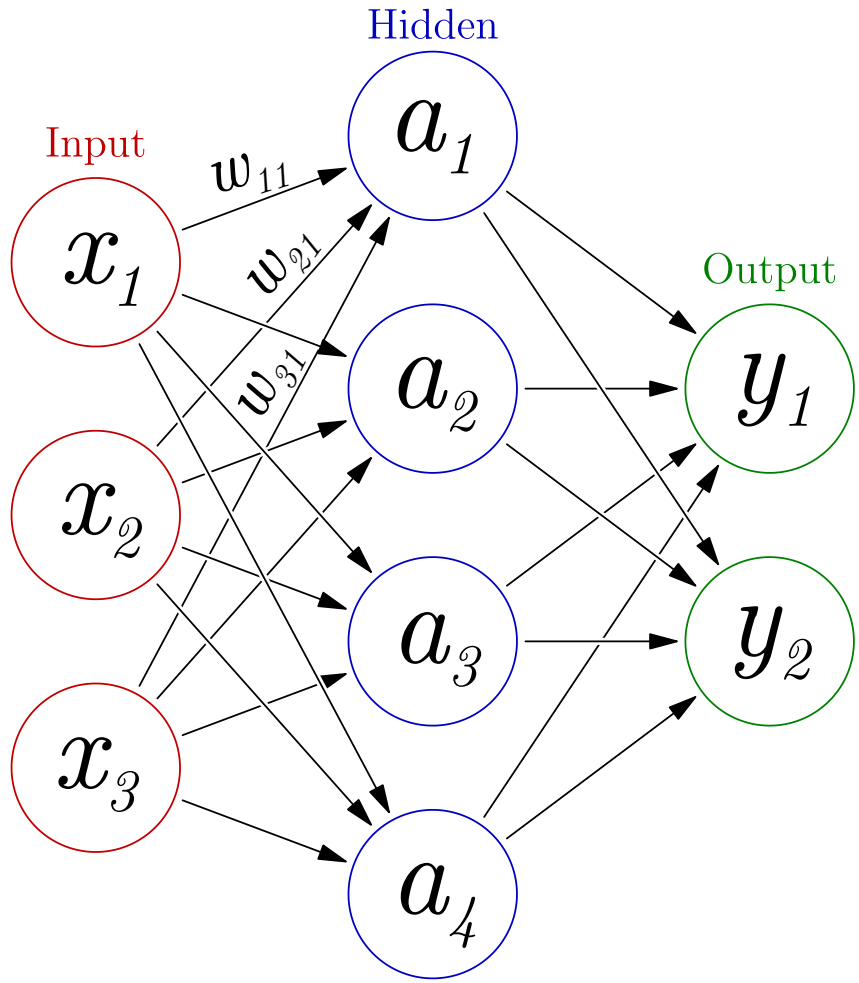
- Many options: Hebbian learning, back-propagation of error, Boltzmann machine learning, self-organising map algorithm, etc.
- All learning algorithms work by changing the connection weights
- Learning can be divided into *supervised*, *unsupervised*, and *reinforcement*

Hebbian learning

"Cells that fire together, wire together" — Carla Shatz

$$\Delta w_{ij} = \eta \sum_{i}^{N} x_i \times a_j$$

which means each weight, w_{ij} is changed by a small in/decrement



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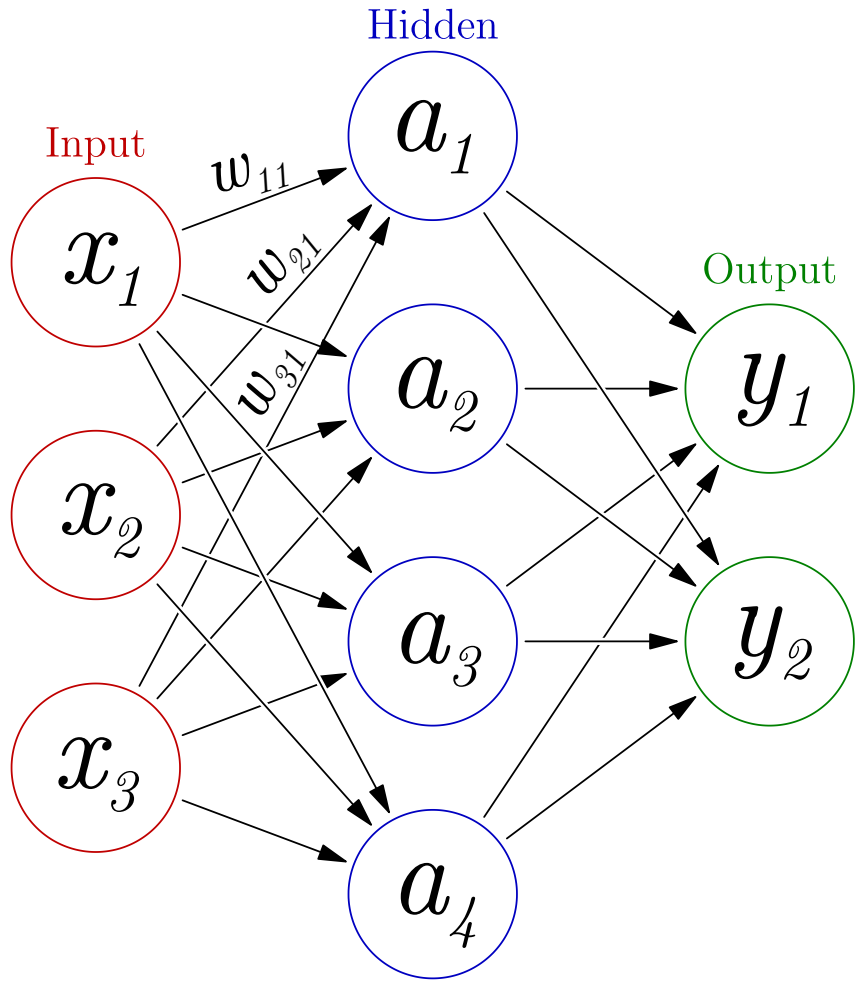
If x_i or a_j is on, then the other will also be on



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Hebb's rule is very simple but *very unstable*!

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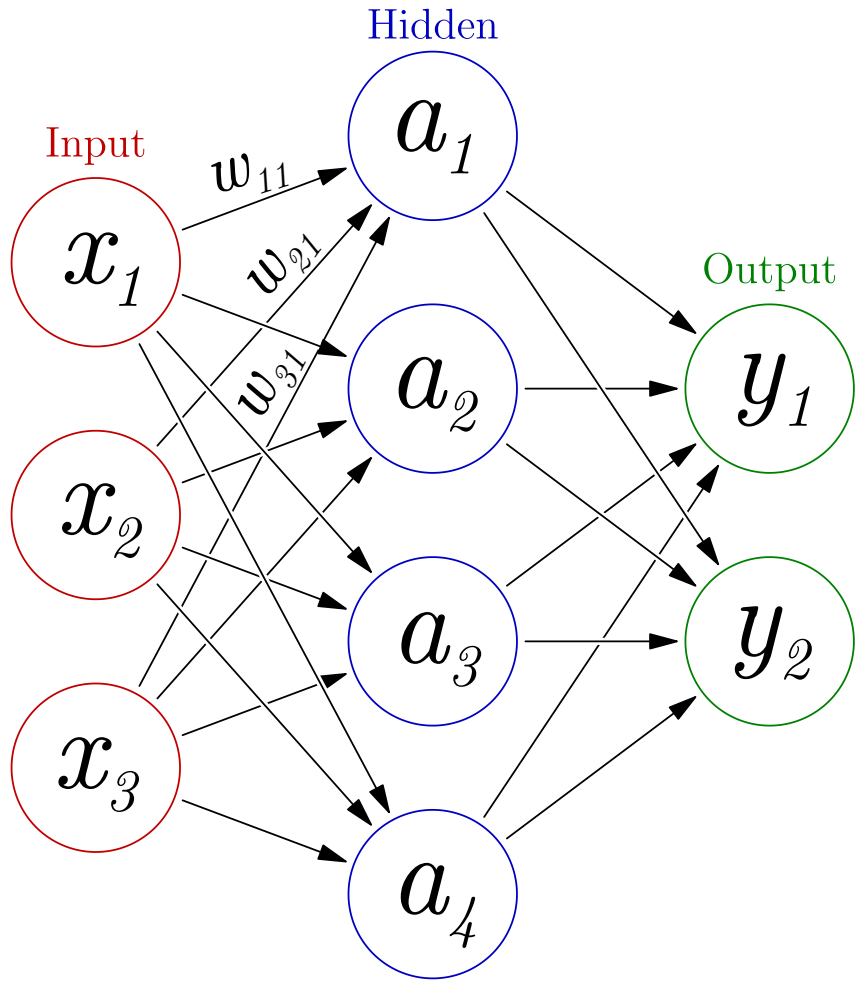
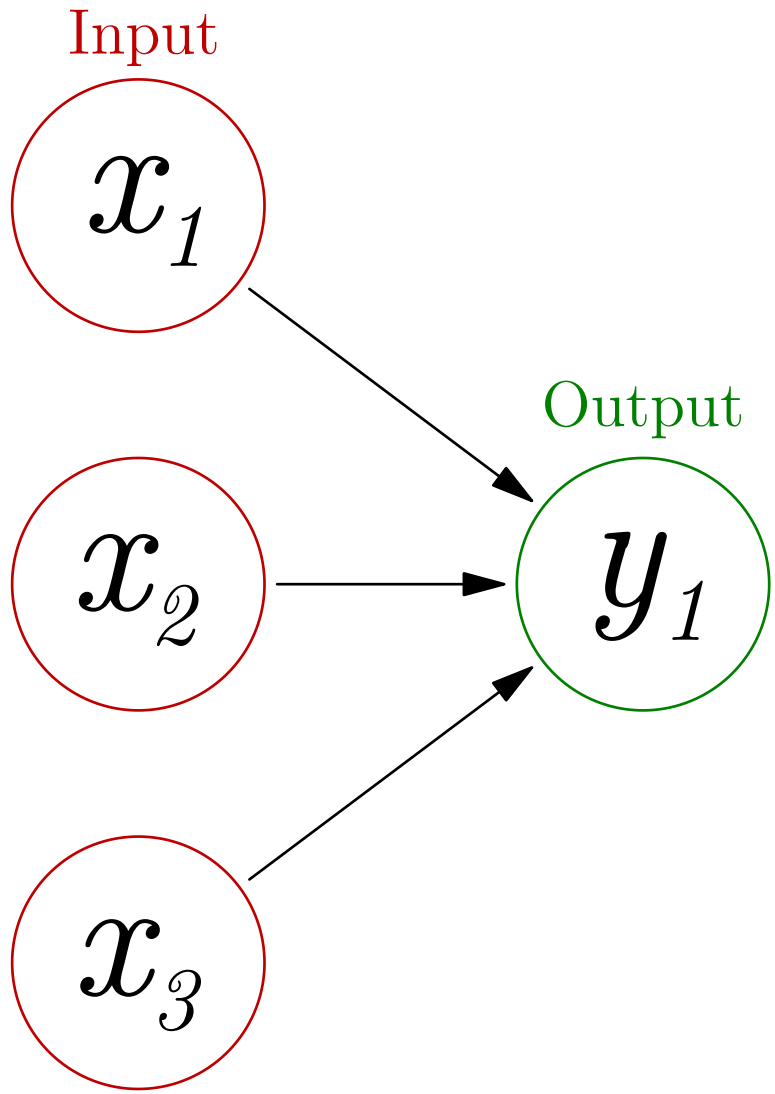


The perceptron

A simple classifier

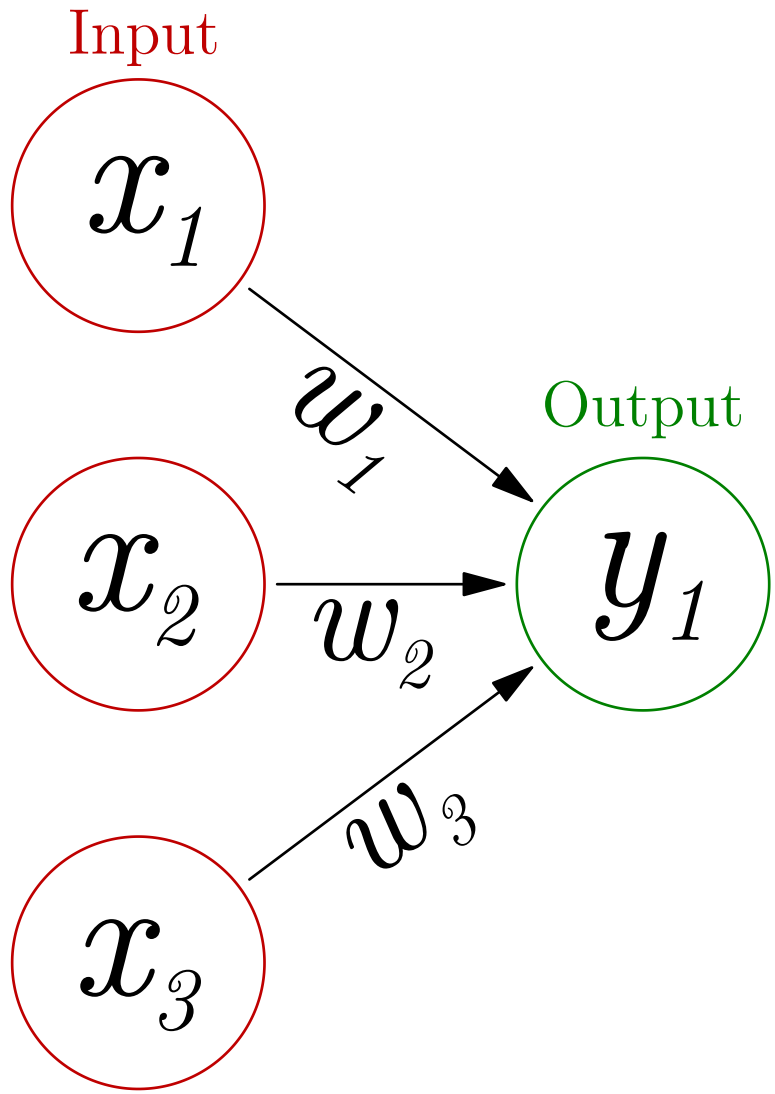
- Created in 1957 at the Cornell Aeronautical Laboratory by Frank Rosenblatt
- Linear classifier
- Simplest form of feedforward network



How does the perceptron learn?

Maths again!

1. Initialise weights



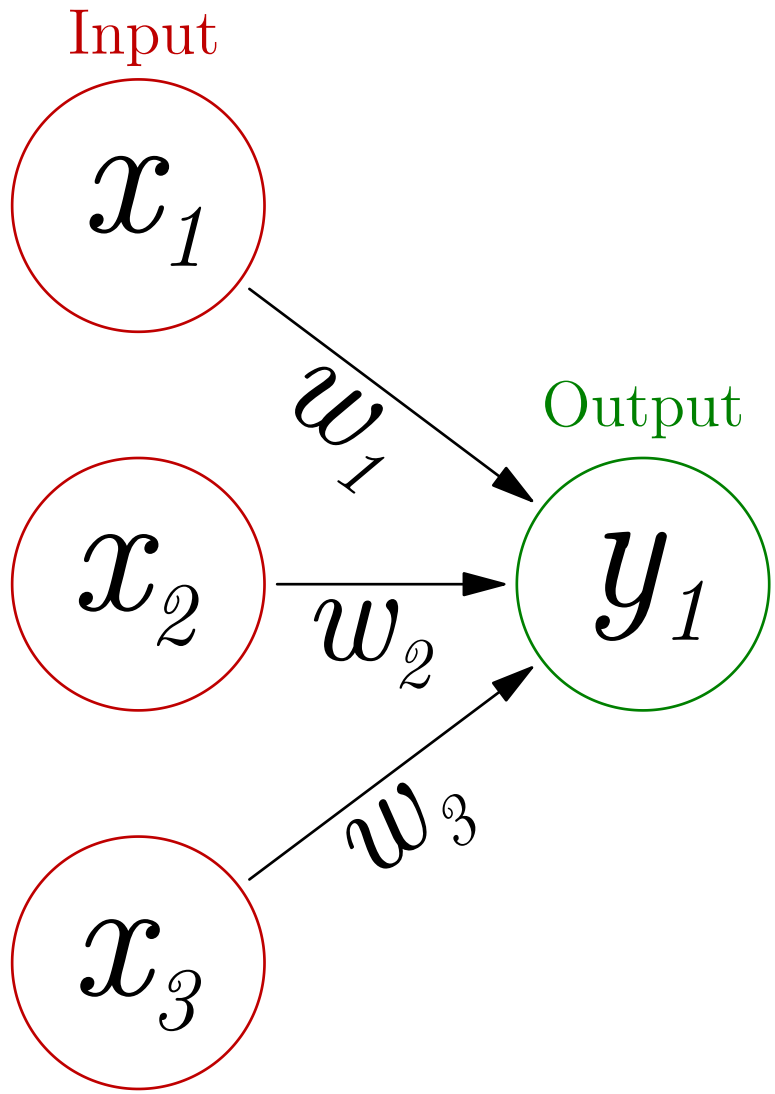
How does the perceptron learn?

Maths again!

1. Initialise weights
2. Run network using:

$$y_j = f\left(\sum_1^N w_i \times x_i\right)$$

same as always!



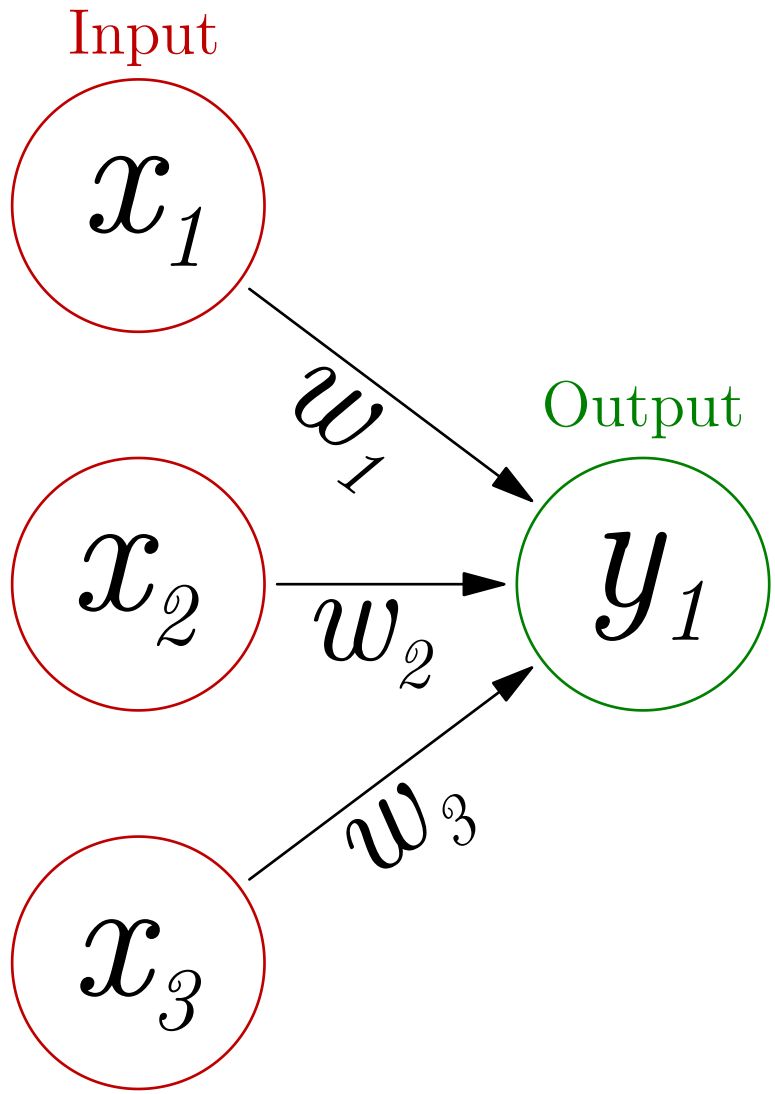
How does the perceptron learn?

Maths again!

1. Initialise weights
2. Run network
3. Update weights using:

$$\Delta w_i = \eta (d_j - y_j) \times x_i$$

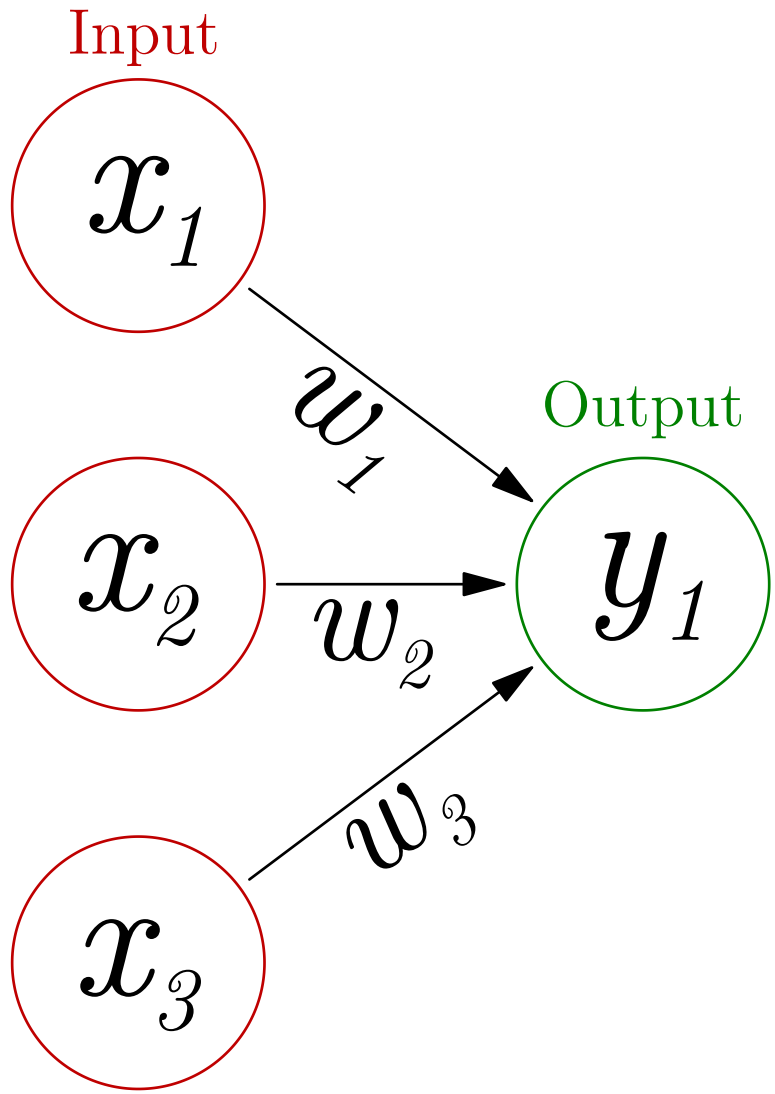
where d is what we want y to be given x_i, and η is the learning rate.



How does the perceptron learn?

Maths again!

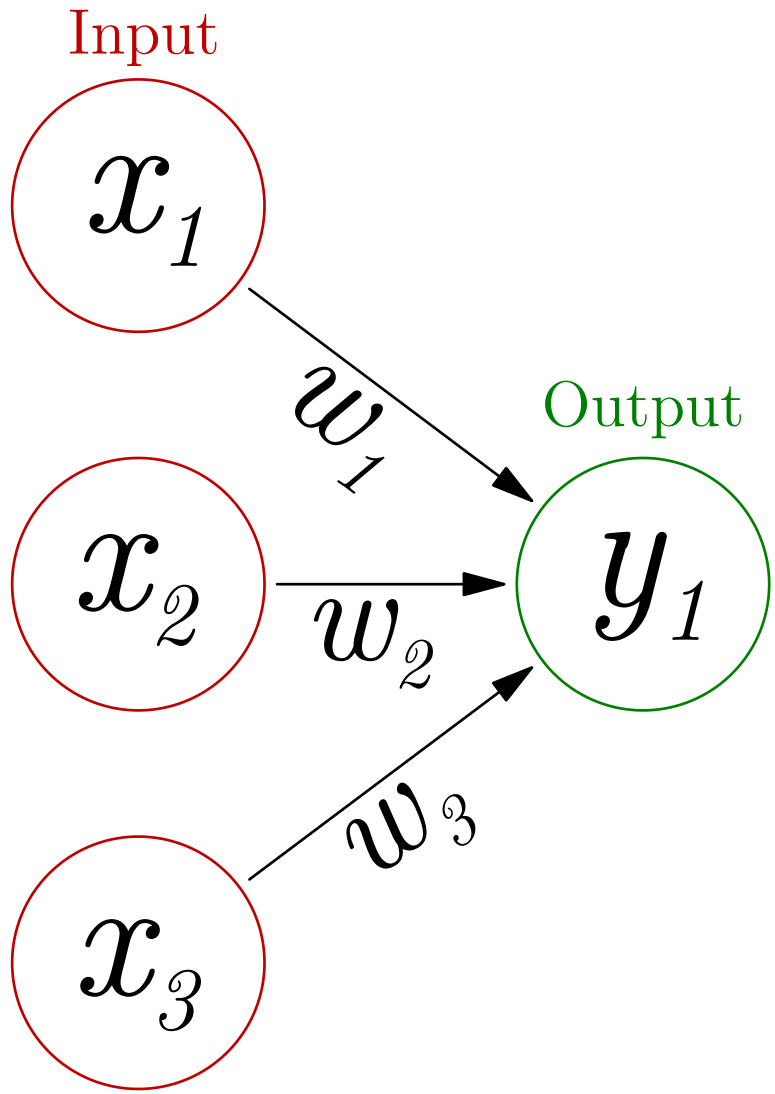
1. Initialise weights
2. Run network
3. Update weights
4. Repeat 2 and 3



How does the perceptron learn?

Maths again!

1. Initialise weights
2. Run network
3. Update weights
4. Repeat 2 and 3
5. When do we stop?



The end

Time to program a perceptron!