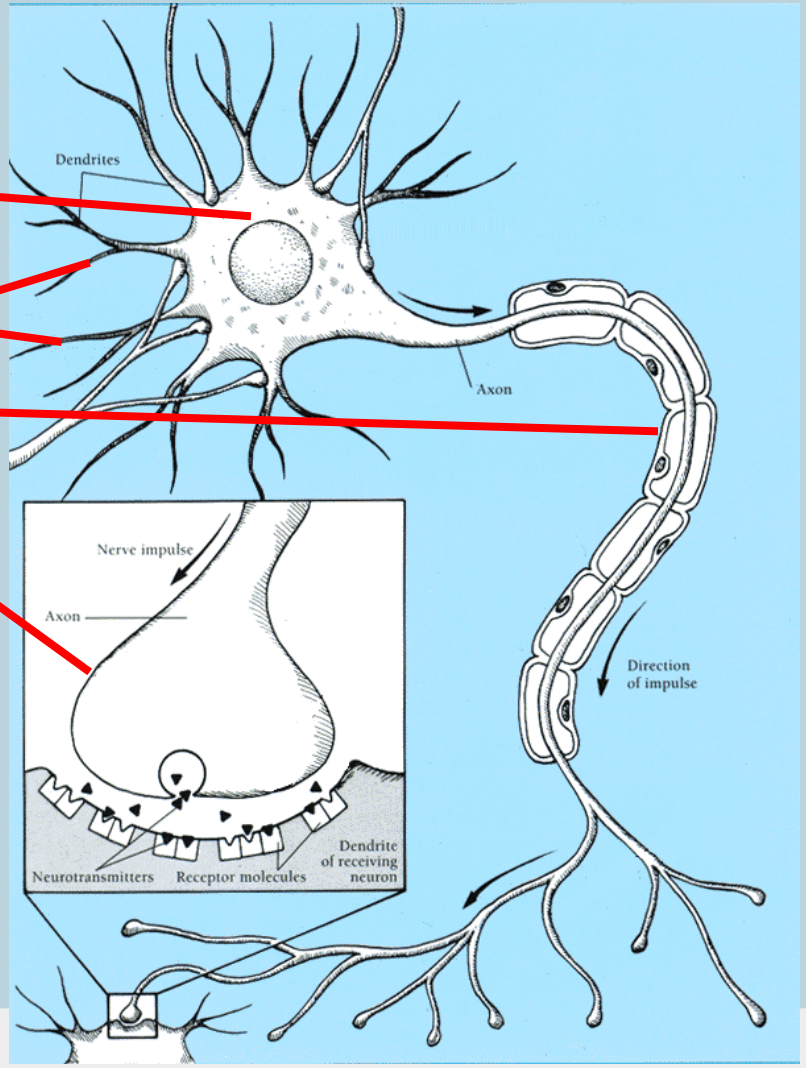
Connectionist / Neural Network

- Try to computationally model the processing and learning in neurobiological systems / brains.

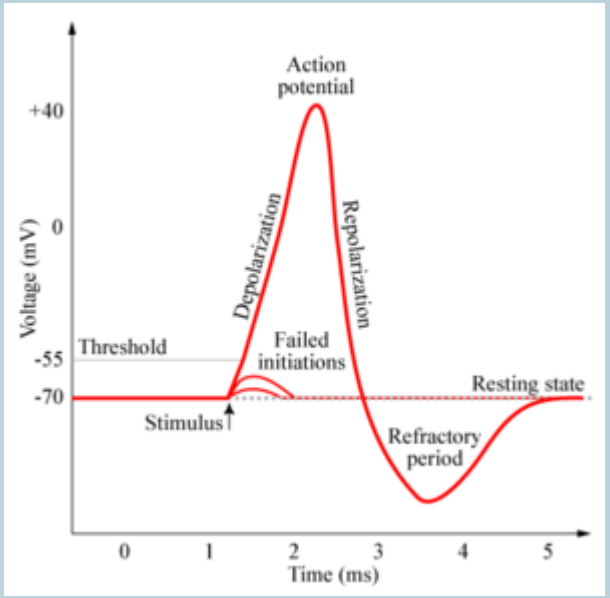
Real Neurons

- Cell structures
  - Cell body
  - Dendrites
  - Axon
  - Synaptic terminals



Neural Computation

- Electrical potential across cell membrane exhibits spikes called action potentials.
- Spike originates in cell body, travels down axon, and causes synaptic terminals to release neurotransmitters.
- Chemical diffuses across synapse to dendrites of other neurons.
- Neurotransmitters can be excititory or inhibitory.
- If net input of neurotransmitters to a neuron from other neurons is excititory and exceeds some threshold, it fires an action potential.



Real Neural Learning

- Synapses change size and strength with experience.
- Hebbian learning: When two connected neurons are firing at the same time, the strength of the synapse between them increases.
- "Neurons that fire together, wire together."

Artificial Neuron Model

- Model network as a graph with cells as nodes and synaptic connections as weighted edges from node *i* to node *j*, w_{ji}

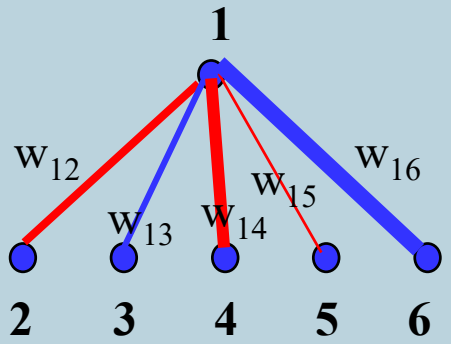
- Model net input to cell as

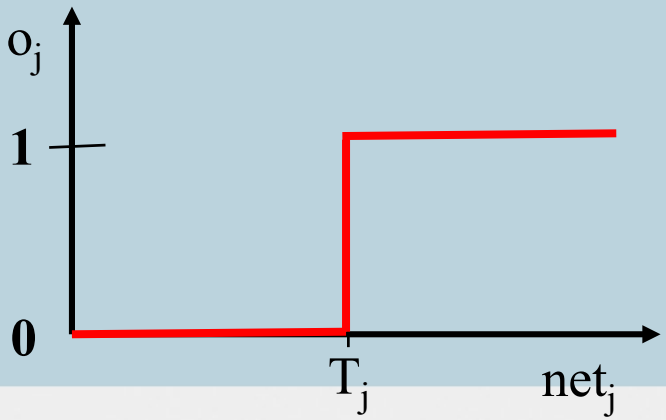
$$net_j = \sum_i w_{ji} o_i$$

- Cell output is:

$$o_j = \begin{cases} 0 \text{ if } net_j < T_j \\ 1 \text{ if } net_i \geq T_j \end{cases}$$

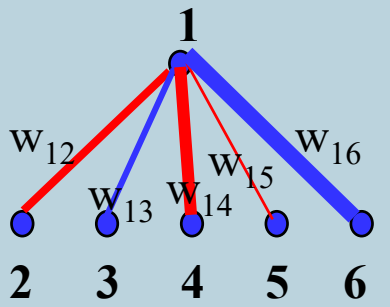
(T_j is threshold for unit j)

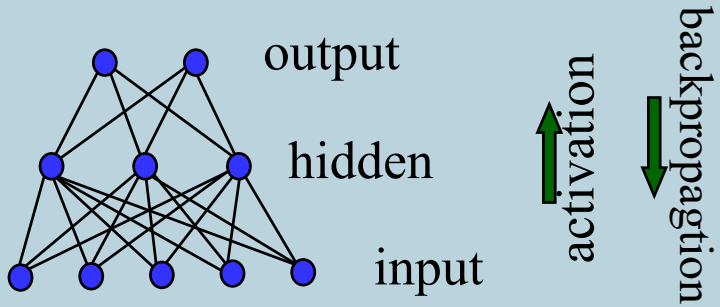


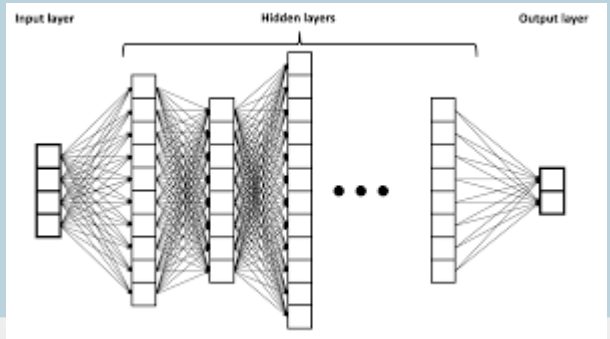


Progress in Neural Networks

- Learning algorithm for single neuron system (Perceptron) developed in 1958.
- Extended to multi-layer networks in the 1980's using error "backpropagation."
- Refined for deep (hundreds of layer) networks in the 2010's.







Basic Learning Algorithm

- Iteratively update weights using "gradient descent" until convergence.

Initialize weights to random values
Until outputs of all training examples are correct
    For each training pair do:
        Compute current output for example given its inputs
        Compare current output to target value
        If output is wrong, tweak weights to help correct this example

Weaknesses of Neural Nets

- Learning mechanisms do not really model neurobiological systems.
- Requires very large amounts of data and compute resources to be effective.
- Learns complex “black box” systems that are hard to interpret and explain.