Artificial and Real Brains

Is it theoretically possible for a computer to have a mind?

Brains and Computers: Similarities

- Both store and use information
- Both have "working memory"
  - Computer (RAM)
- Both have "Long-term memory"
  - Computer (hard-disk, cd)"
- Both have control structures
  - Computer (CPU)
  - Man (Attention?)

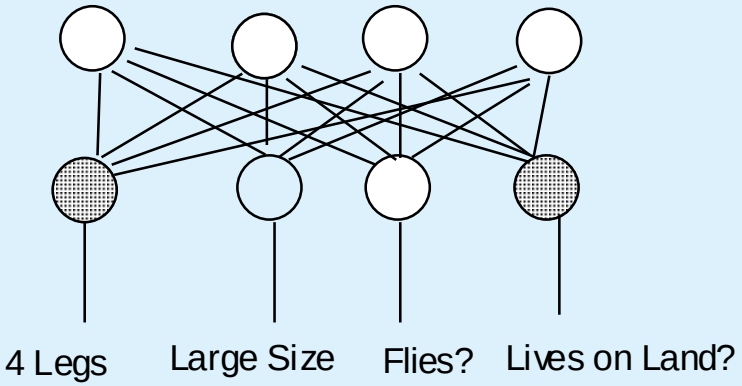
Brains and Computers: Differences

- Brains: Distributed parallel power - like a billion little computers(relatively slow)
  - Fault tolerant (tough to break)
  - Very good at learning
  - Coded in fuzzy analog format
  - Distributed Representation
- Computers: Usually 1 single serial processor - super fast
  - Very sensitive to damage (fragile)
  - Not naturally suited to learn
  - Coded in 1's and 0's (binary)
  - Local representation

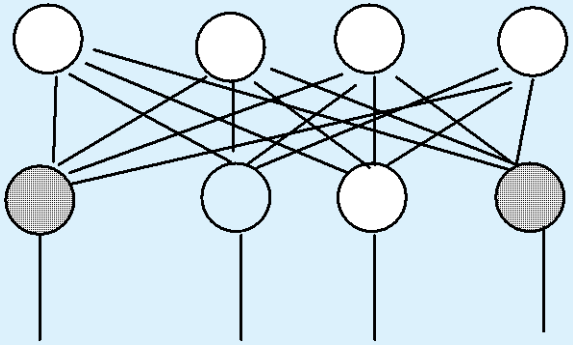
Distributed and Local Representations

- Local representations code a concept with one node
- Distributed representations code information by a pattern of activations across a set of units

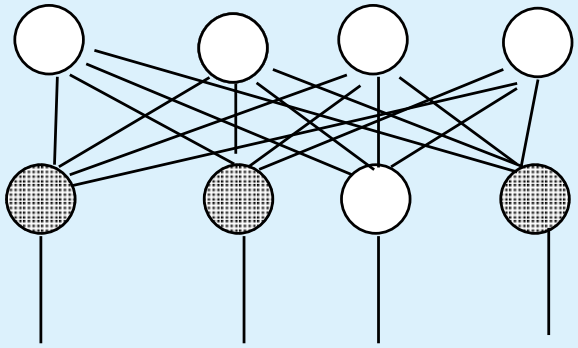
Distributed Representations of Animals



More Animals



Dog



Elephant

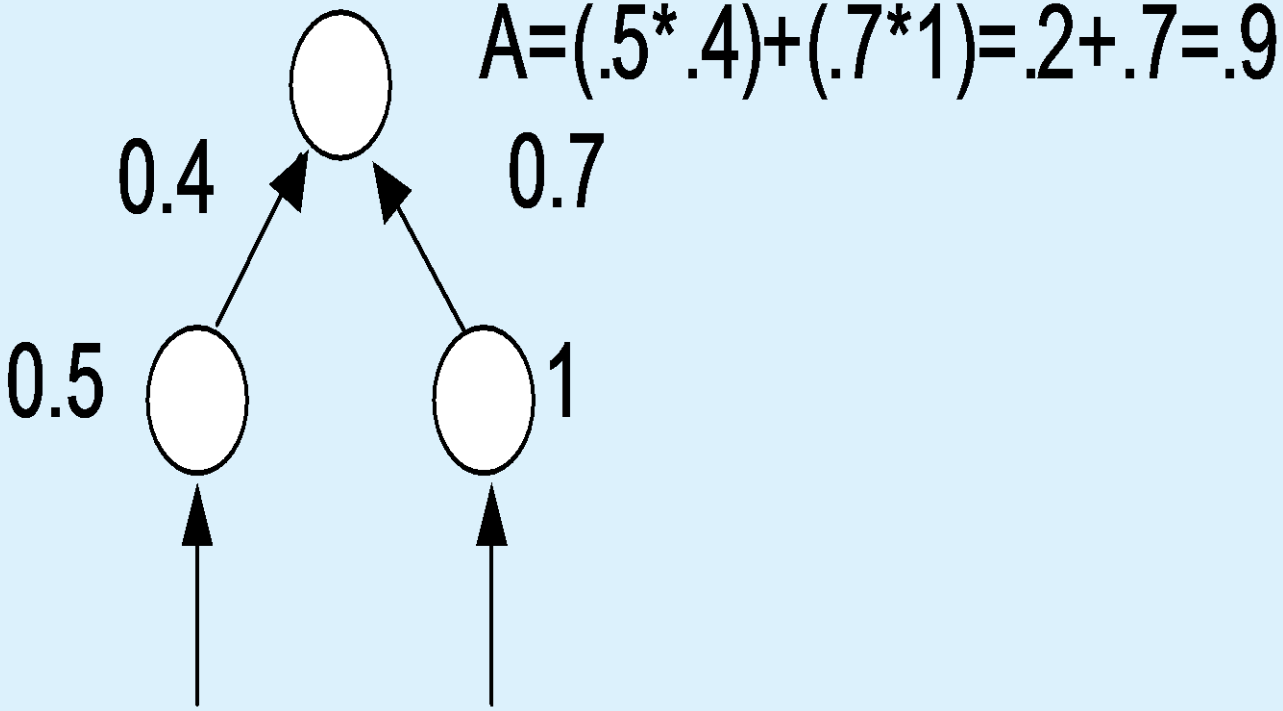
Can we simulate a brain with a computer?

- Yes!
- Neural Networks

Neural Networks 101

- Network has nodes (kind of like neurons)
- Network has links between nodes (like connections between neurons)
- Nodes have levels of activation
  - Activation rules
- Links between nodes have connection strengths (weights)

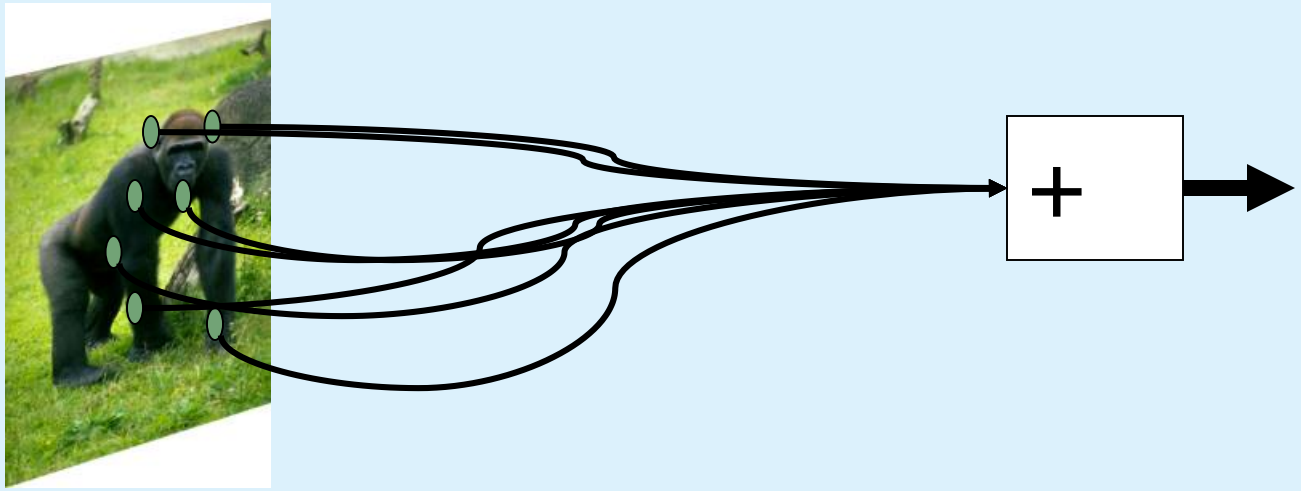
Sample Activation - Summing inputs



Early Neural Network

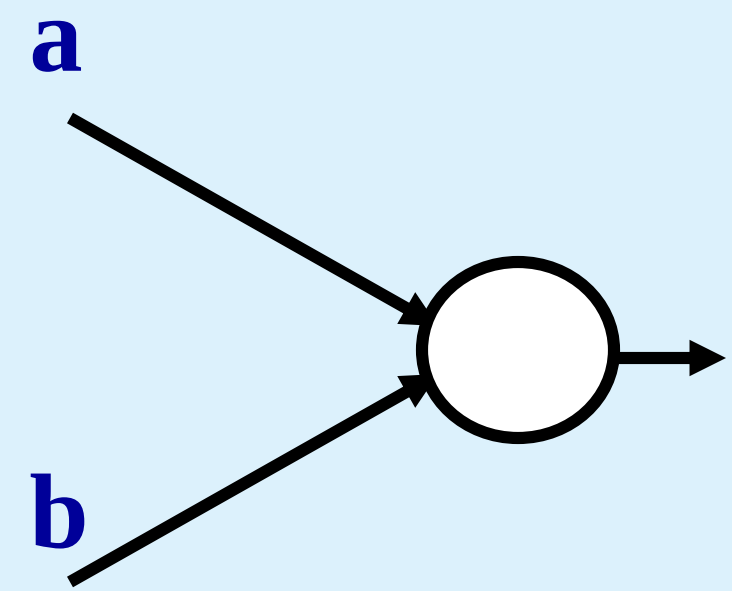
Lets look at the biology of the eye!

The first artificial neural model: The Perceptron



The Basic Perceptron

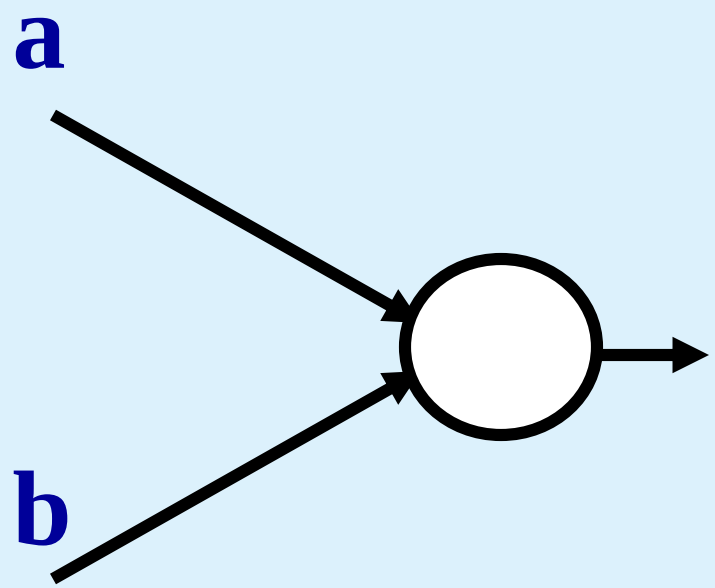
a \ b	0	1
1	0	1
0	0	0



a AND b

The Basic Perceptron

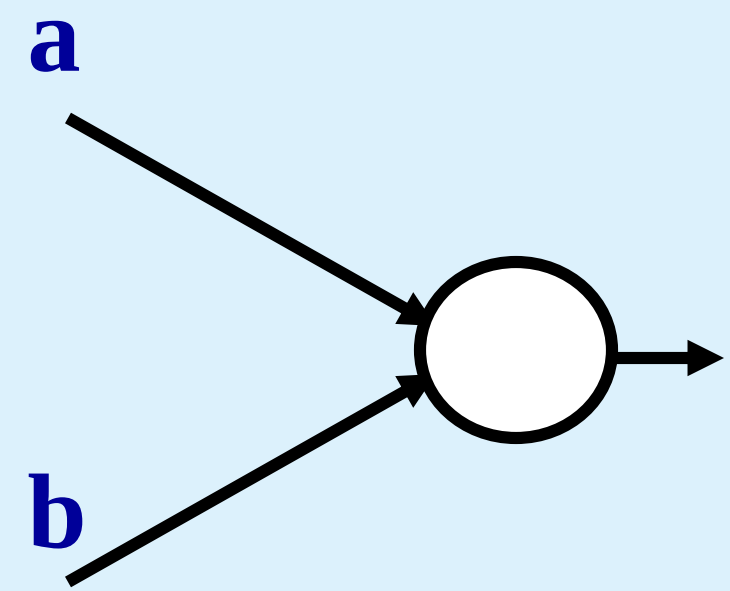
a \ b	0	1
1	1	1
0	0	1



a OR b

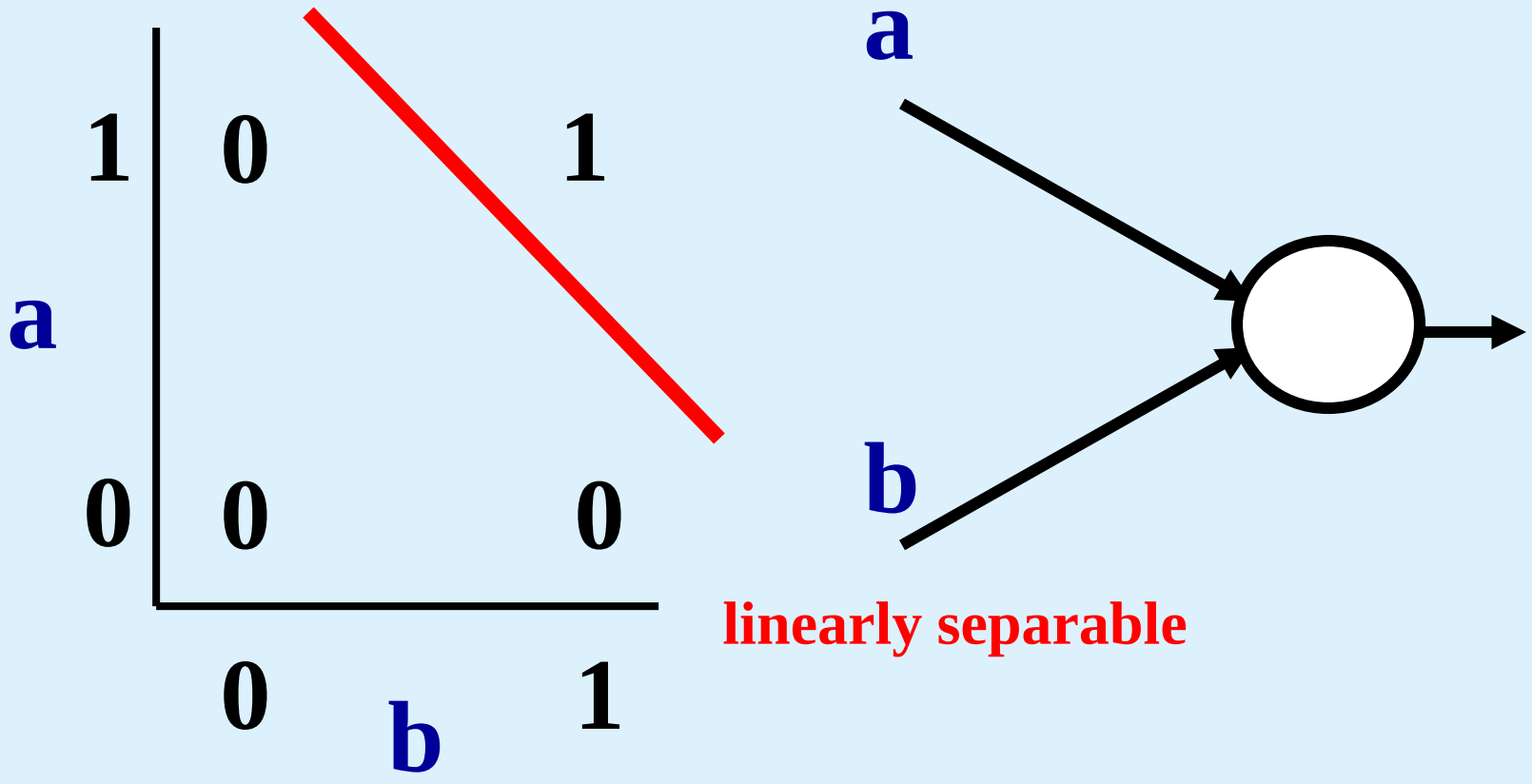
The Basic Perceptron

a \ b	0	1
1	1	0
0	0	1



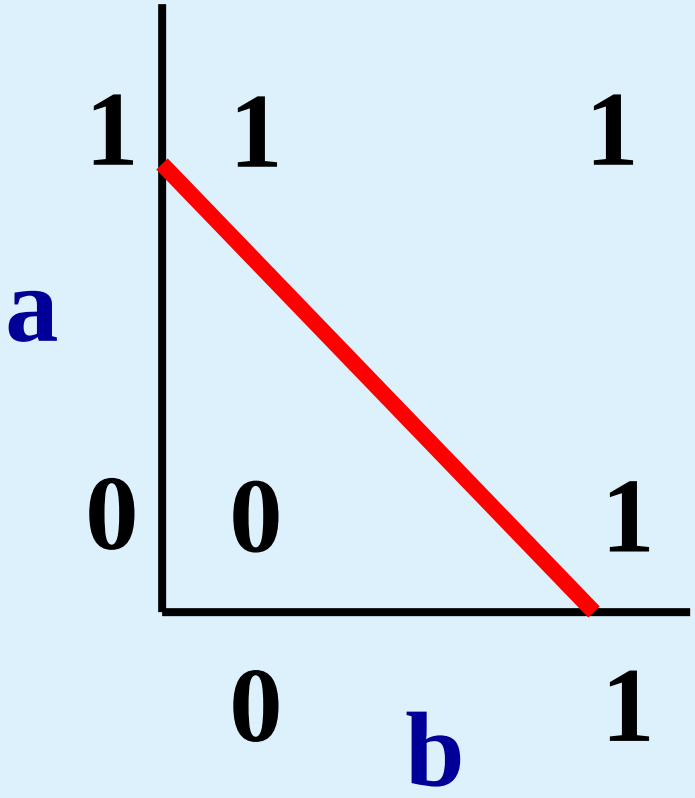
a XOR b

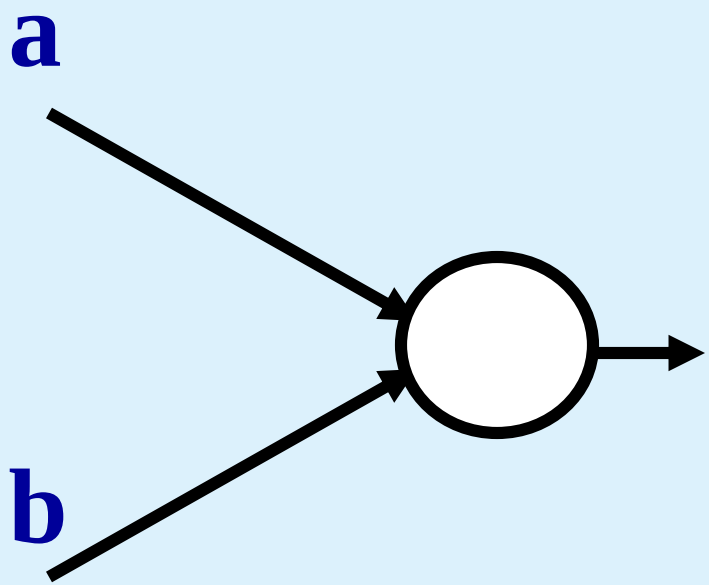
The Basic Perceptron



a AND b

The Basic Perceptron

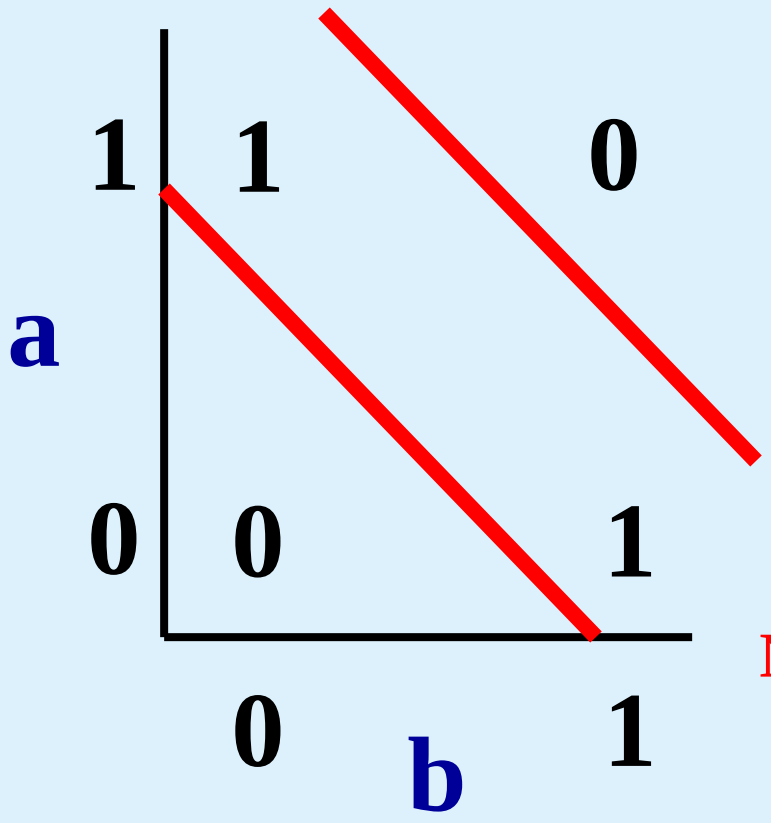


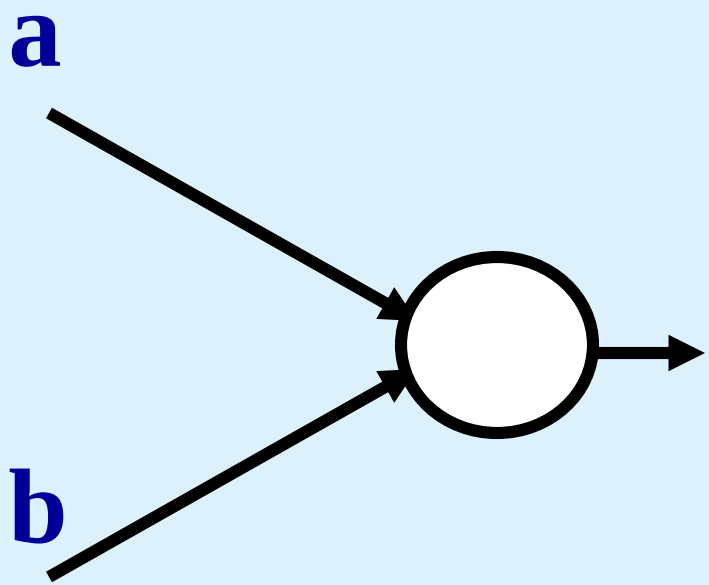


linearly separable

a OR b

The Basic Perceptron





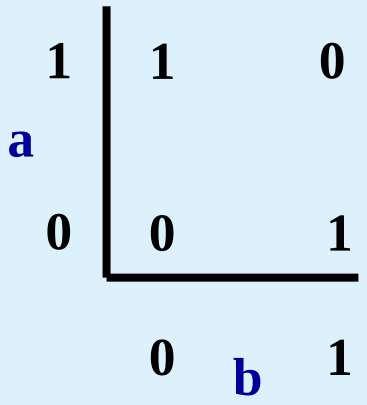
NOT linearly separable

a XOR b

The Basic Perceptron

What the perceptron can't do:

- **Exclusive OR**



The Basic Perceptron

What the perceptron can't do:

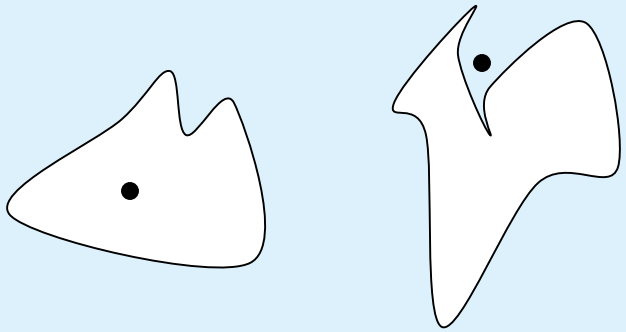
- **Exclusive OR**
- **Even/Odd discrimination**

Total inputs: 0 1 2 3 4 5 6 7
ouput: 1 0 1 0 1 0 1 0

The Basic Perceptron

What the perceptron can't do:

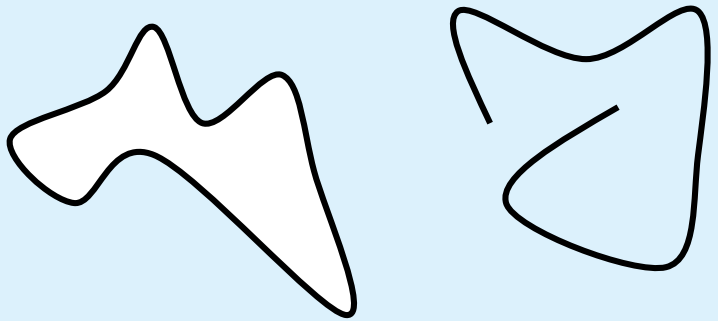
- **Exclusive OR**
- **Even/Odd discrimination**
- **Inside/Outside discrimination**



The Basic Perceptron

What the perceptron can't do:

- **Exclusive OR**
- **Even/Odd discrimination**
- **Inside/Outside discrimination**
- **Open/Closed discrimination**



The Basic Perceptron

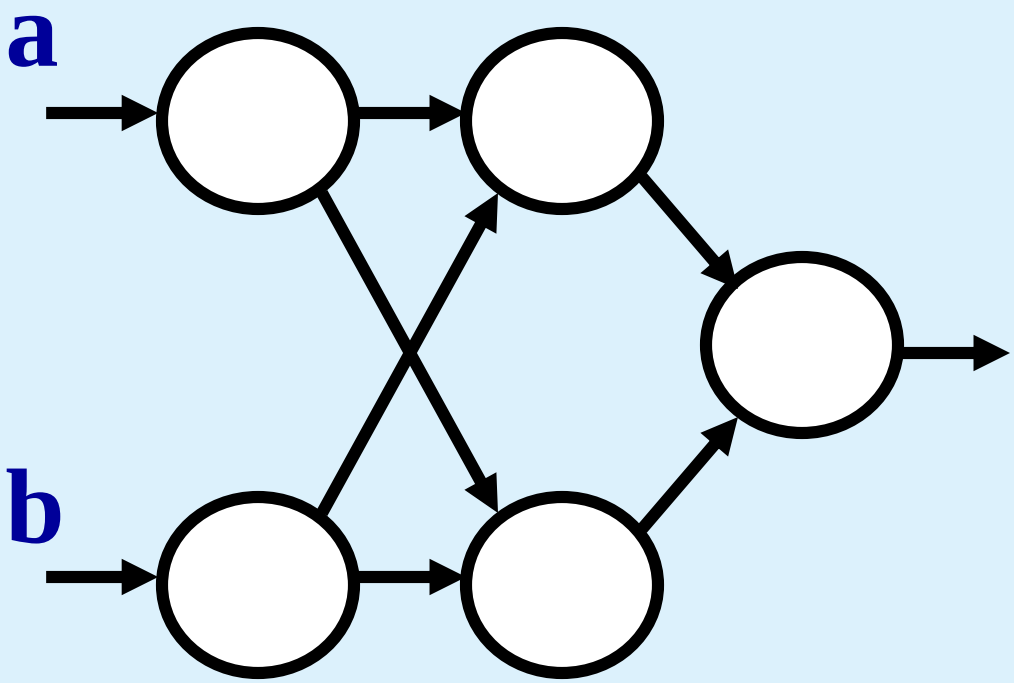
What the perceptron can't do:

- **Exclusive OR**
- **Even/Odd discrimination**
- **Inside/Outside discrimination**
- **Open/Closed discrimination**

BIG PROBLEMS

The Multi-Layer Perceptron

a \ b	0	1
1	1	0
0	0	1



a XOR b

The Multi-Layer Perceptron

a \ b	0	1
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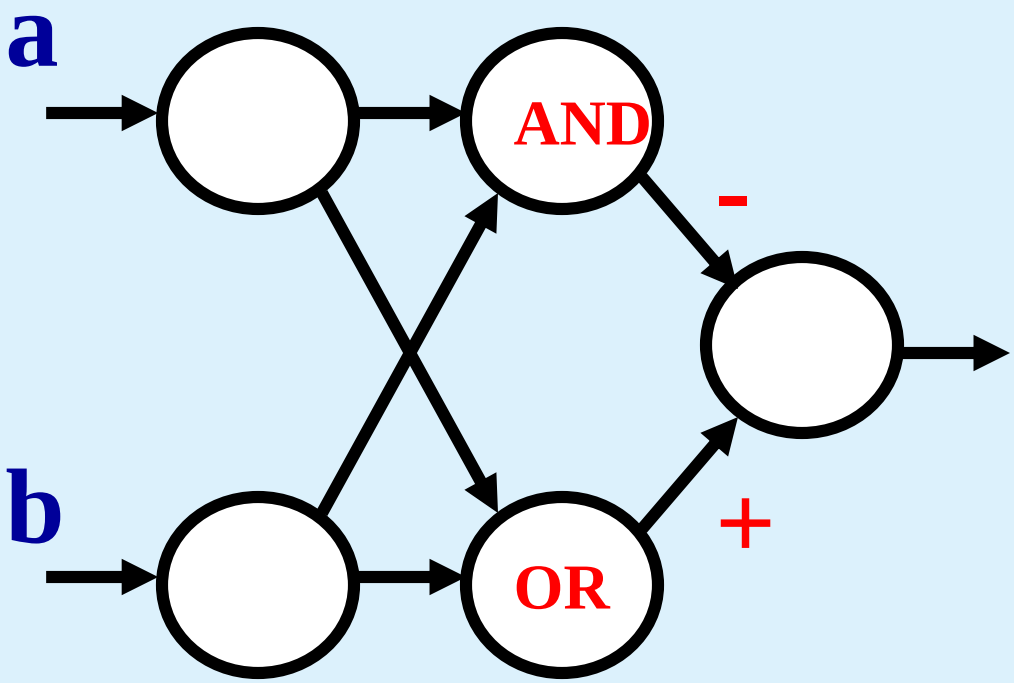
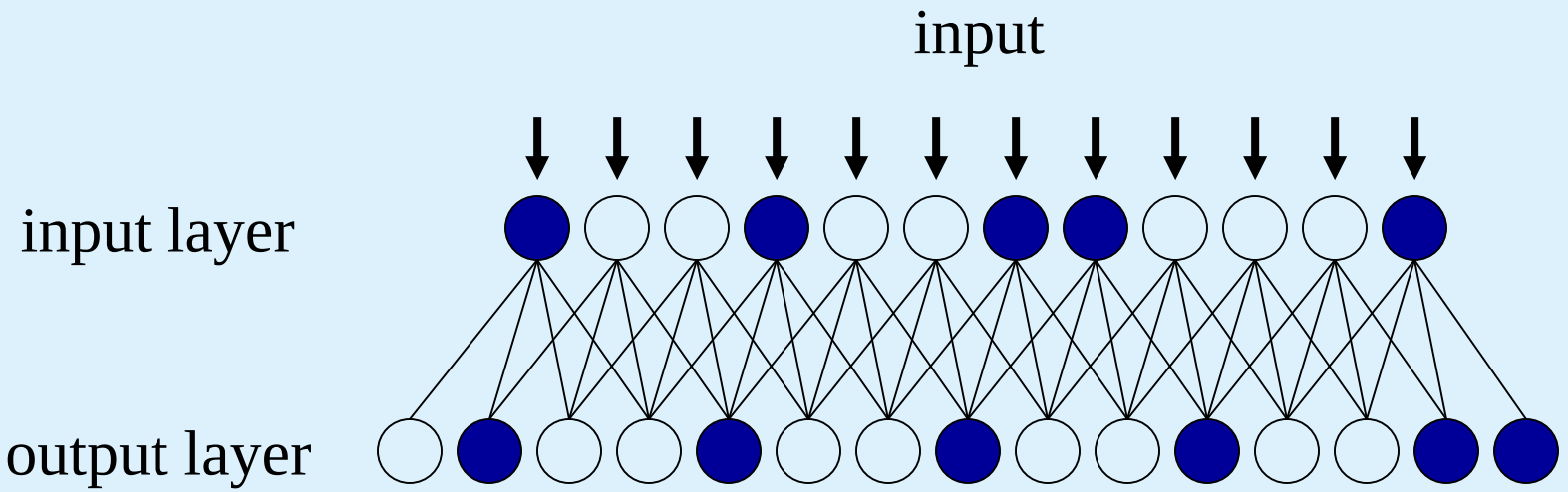
0	0	1



a XOR b

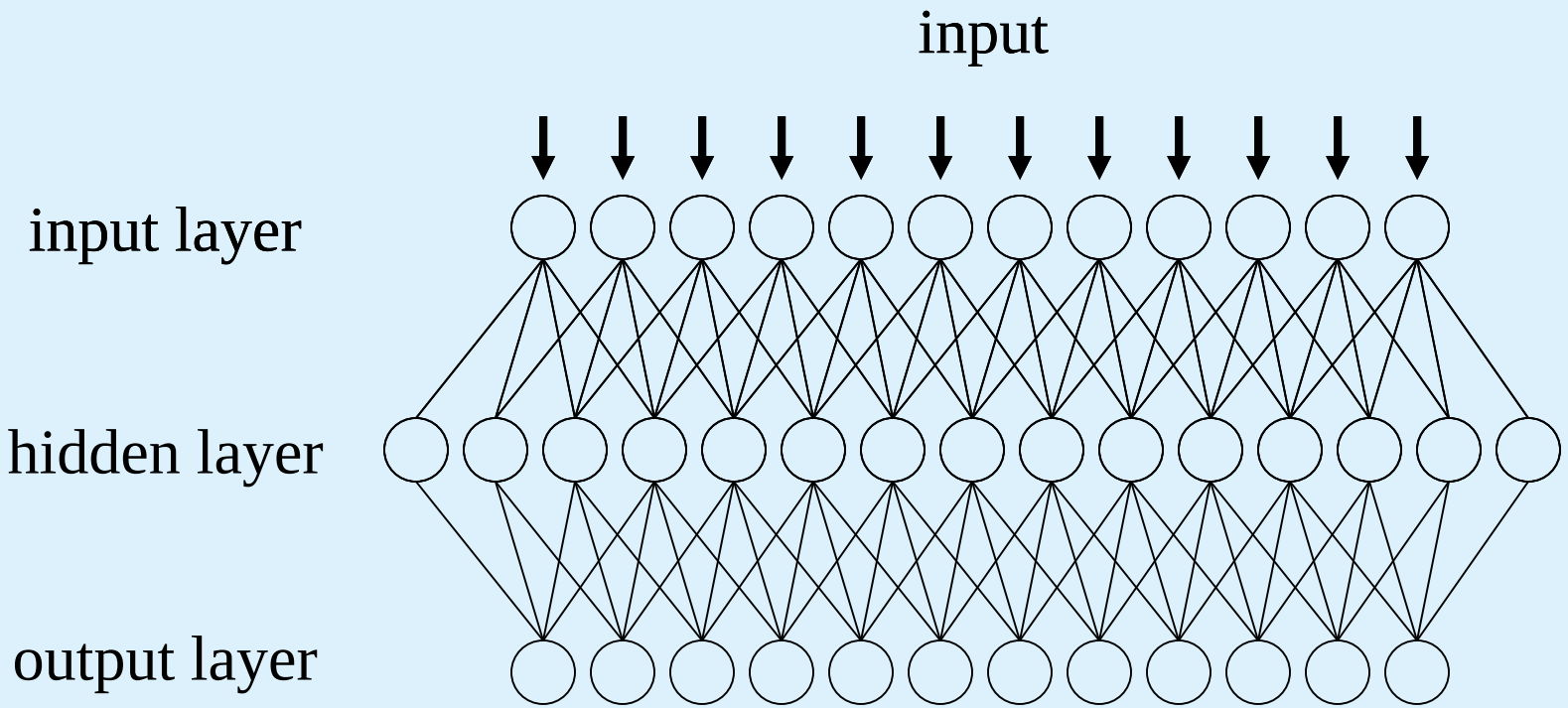
The Two-Layer Network



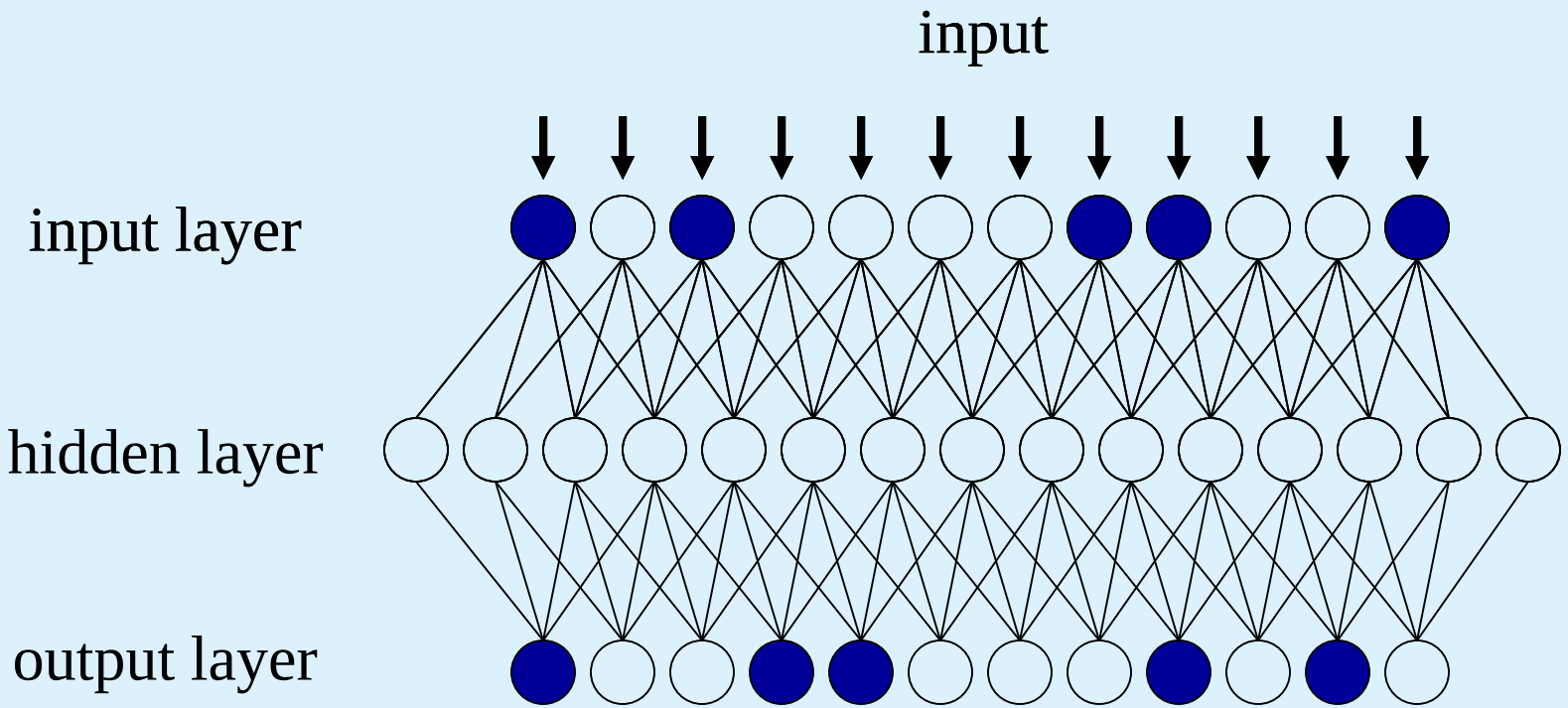
Supervised learning: The delta rule

- Feed the network inputs
- See what the activations become
- Compare this to what it should be (desired output)
- Change the weights between nodes according to how much error they contribute

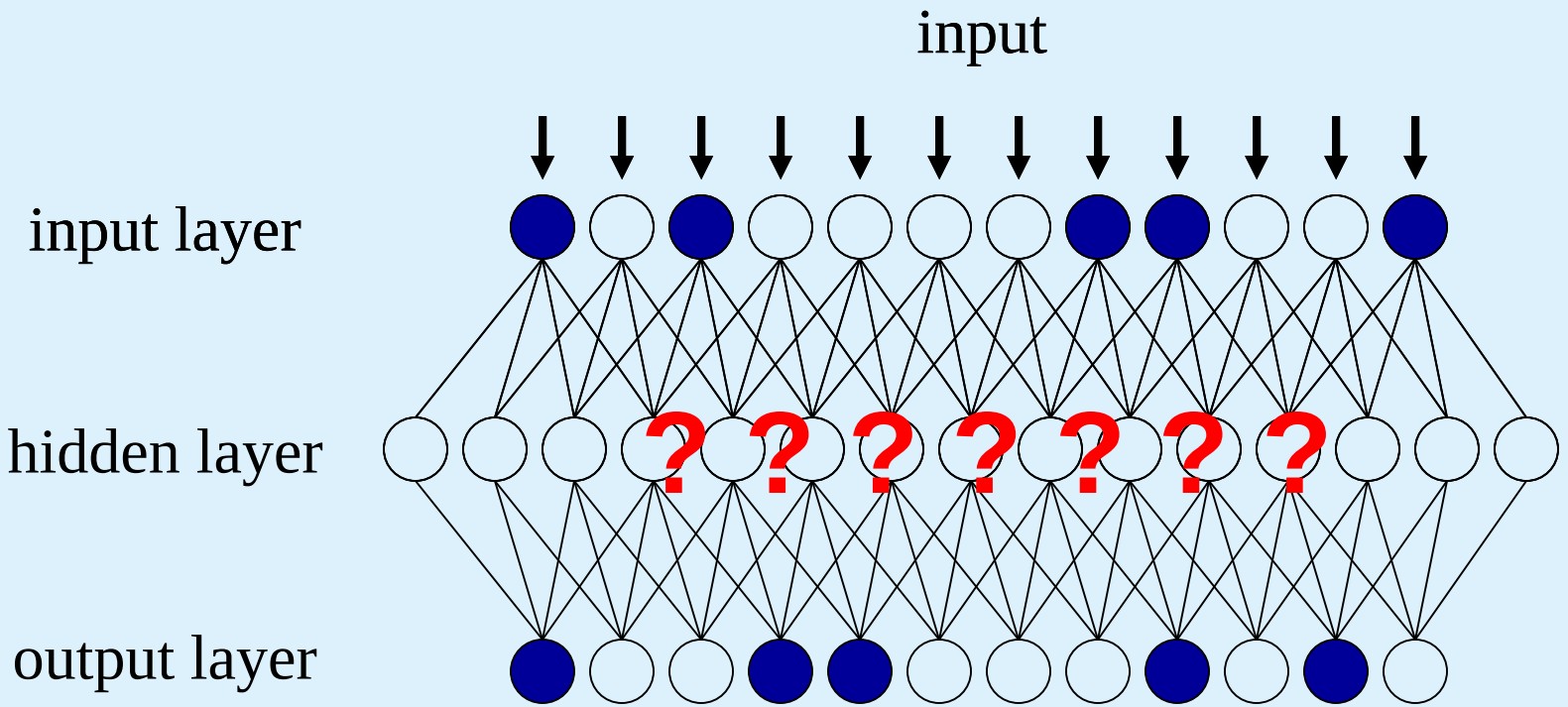
The Three-Layer Network



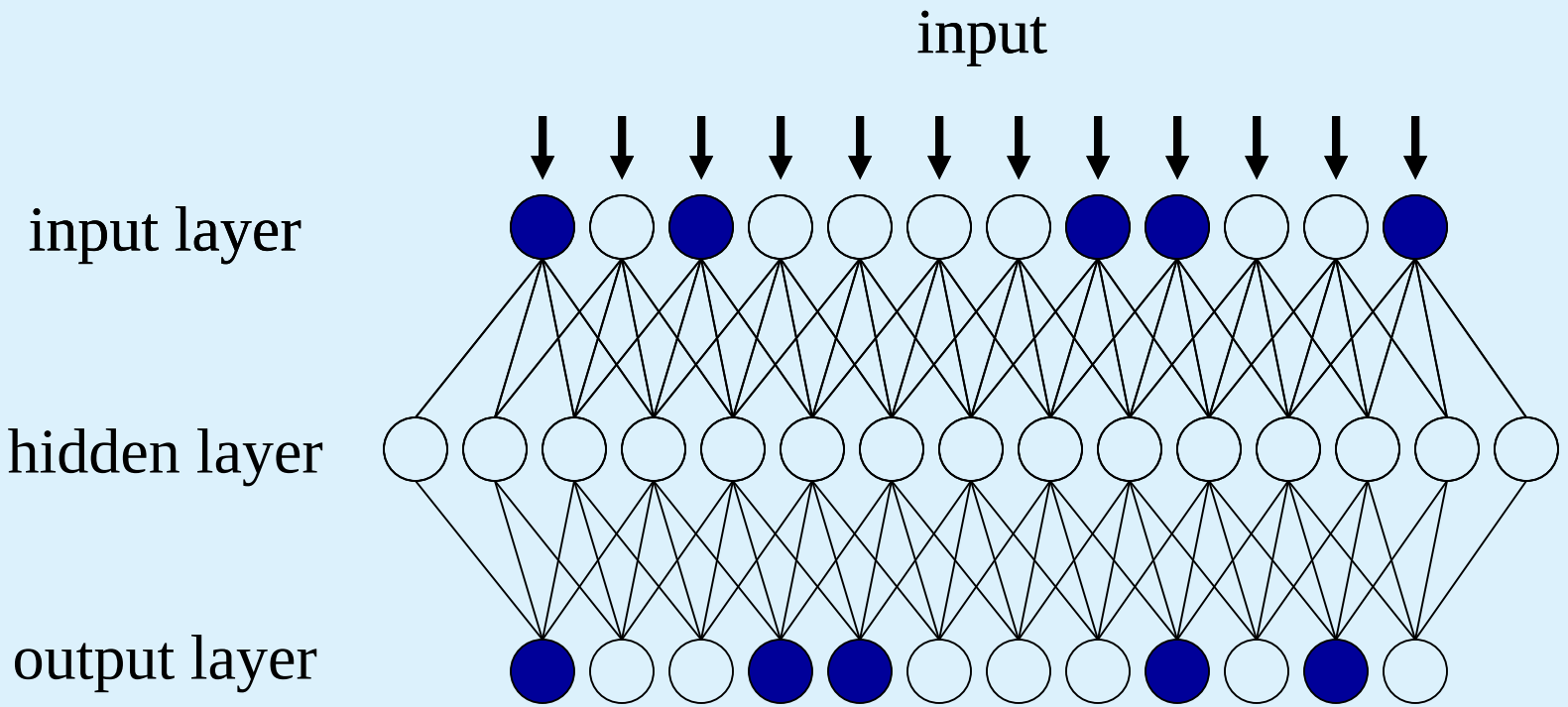
The Three-Layer Network



The Three-Layer Network



The Three-Layer Network



Back-propagation is the learning procedure that allows you to adjust the weights in multi-layer networks to train them to respond correctly.

Some Properties of Artificial Neural Nets

- **Distributed Representation**: Ideas, thoughts, concepts, memories, are all represented in the brain as patterns of activation across a large number of neurons. As a result, there is a lot of ***redundancy*** in neural representation.
- **Graceful Degradation**: Performance of the system decreases gradually as the system is damaged.
- **Learning**: Delta rule / Backpropagation

More Properties of Artificial Neural Nets

- **Generalization**: Because of how the network learns, and its distributed representation, it can respond to inputs that it was never officially trained on, generalizing based on similarity to things it *was* trained on.
- **Distributed Processing**: Not only representation, but processing is distributed, too, so there is no central controlling function, or CPU, in the brain. It is more cooperative.

Problems with Artificial Neural Nets

- **Stability-plasticity dilemma**: Learn new info while retaining old info
- **Catastrophic interference**: System falls apart when new info is learned
- **Supervised networks – Where is the teacher?**
- **Biological plausibility of teacher**

Network Science

- **Examine structure and function of**
  - **Power grids**
  - **Companies**
  - **Stock markets**
  - **Societies**
  - **Social networks (facebook!)**

Network Science: Centrality

- **Computers -> CPU**
- **Armies-> Generals**
- **Politics->Presidents and Dictators**
- **Human Mind?**

Network Science
Hierarchical Networks

- **Simple Cells: oriented bars**
- **Complex Cells: Oriented bars moving**
- **Hypercomplex Cells: Right angle of vertical and horizontal lines moving in same direction**

Network Science
Characteristics of Networks

- **Small-World Networks:**
  - **6 degrees of Separation**
  - **4 degrees of Kevin Bacon**
  - **Electrical Power Grid**
  - **Railroads**
  - **Nervous systems of many animals**
- **Random Networks : Local and Global Links**
- **Ordered Networks: Local Links**

Network Science
Characteristics of Networks

- **Small-World Networks:**
  - **Egalitarian: Links are evenly distributed**
  - **Aristocratic: Some hub links are especially Important (e.g. the internet)**

Network Science
Disease and Information

- **Percolation: Spread of disease in a network of people**
- **Percolating cluster: Many connections representing**
  - **Majority of network (epidemic)**
- **Schizophrenia: Disorganized thinking (spread of activation similar to a percolating cluster)**

Divergent Thinking: A little bit of a percolating cluster might be helpful ion generating creative output