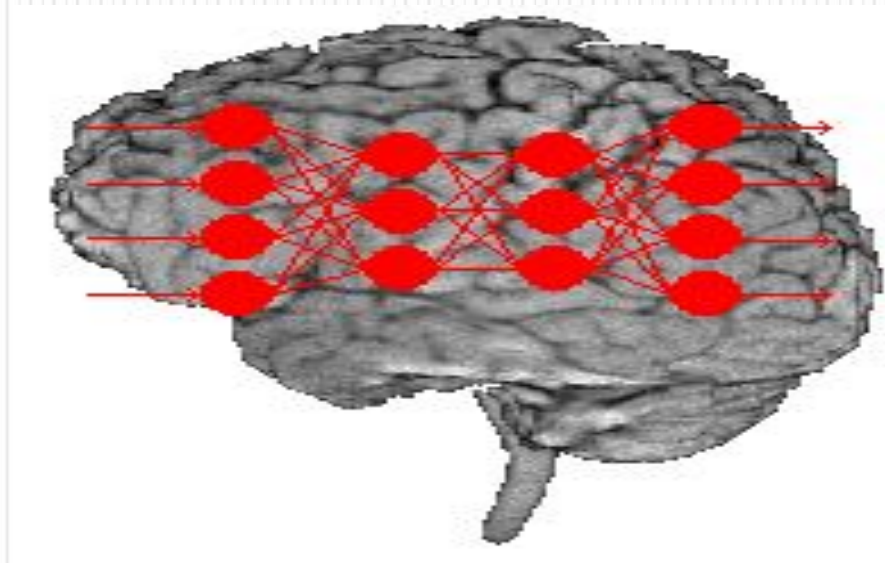


# Artificial Neural Networks



# Agenda

- What is an Artificial Neural Networks?
- How it works?
- Learning
  - Learning paradigms
    - Supervised learning
    - Unsupervised learning
    - Reinforcement learning
    - Applications areas
    - Advantages and Disadvantages

# Artificial Neural Network

- An artificial neural network consists of a pool of simple processing units which communicate by sending signals to each other over a large number of weighted connections.

# Artificial Neural Network

- A set of major aspects of a parallel distributed model include:
  - a set of processing units (cells).
  - a state of activation for every unit, which equivalent to the output of the unit.
  - connections between the units. Generally each connection is defined by a weight.
  - a propagation rule, which determines the effective input of a unit from its external inputs.
  - an activation function, which determines the new level of activation based on the effective input and the current activation.
  - an external input for each unit.
  - a method for information gathering (the learning rule).
  - an environment within which the system must operate, providing input signals and `_` if necessary `_` error signals.

# Computers vs. Neural Networks

## “Standard” Computers

- one CPU
- fast processing units
- reliable units
- static infrastructure

## Neural Networks

- highly parallel processing
- slow processing units
- unreliable units
- dynamic infrastructure

# Why Artificial Neural Networks?

- There are two basic reasons why we are interested in building artificial neural networks (ANNs):
  - **Technical viewpoint:** Some problems such as character recognition or the prediction of future states of a system require massively parallel and adaptive processing.
  - **Biological viewpoint:** ANNs can be used to replicate and simulate components of the human (or animal) brain, thereby giving us insight into natural information processing.

# Artificial Neural Networks

- The “building blocks” of neural networks are the **neurons**.
  - In technical systems, we also refer to them as **units** or **nodes**.
- Basically, each neuron
  - receives **input** from many other neurons.
  - changes its internal state (**activation**) based on the current input.
  - sends **one output signal** to many other neurons, possibly including its input neurons (recurrent network).

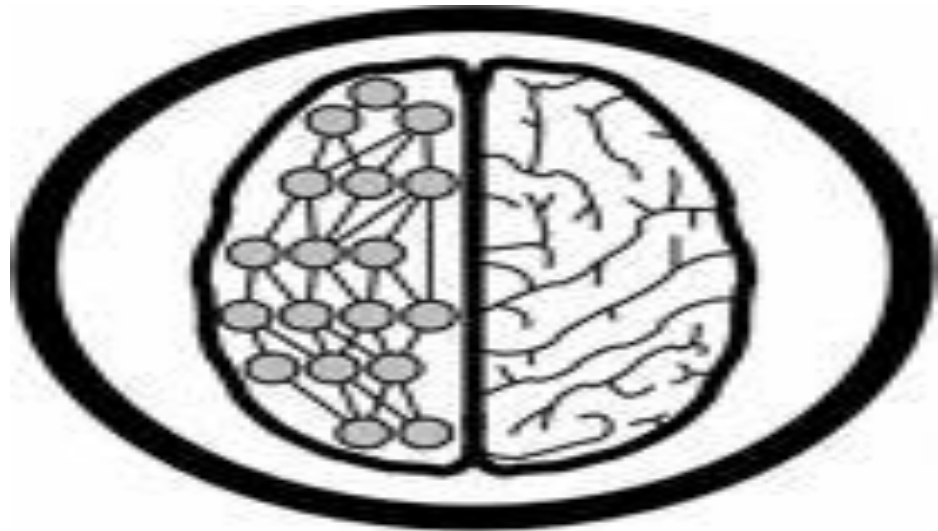
# Artificial Neural Networks

- Information is transmitted as a series of electric impulses, so-called **spikes**.
- The **frequency** and **phase** of these spikes encodes the information.
- In biological systems, one neuron can be connected to as many as **10,000** other neurons.
- Usually, a neuron receives its information from other neurons in a confined area, its so-called **receptive field**.



# How do ANNs work?

- An artificial neural network (ANN) is either a **hardware implementation** or a **computer program** which strives to simulate the information processing capabilities of its biological exemplar. ANNs are typically composed of a great number of interconnected artificial neurons. The artificial neurons are simplified models of their biological counterparts.
- ANN is a technique for solving problems by constructing software that works like our brains.



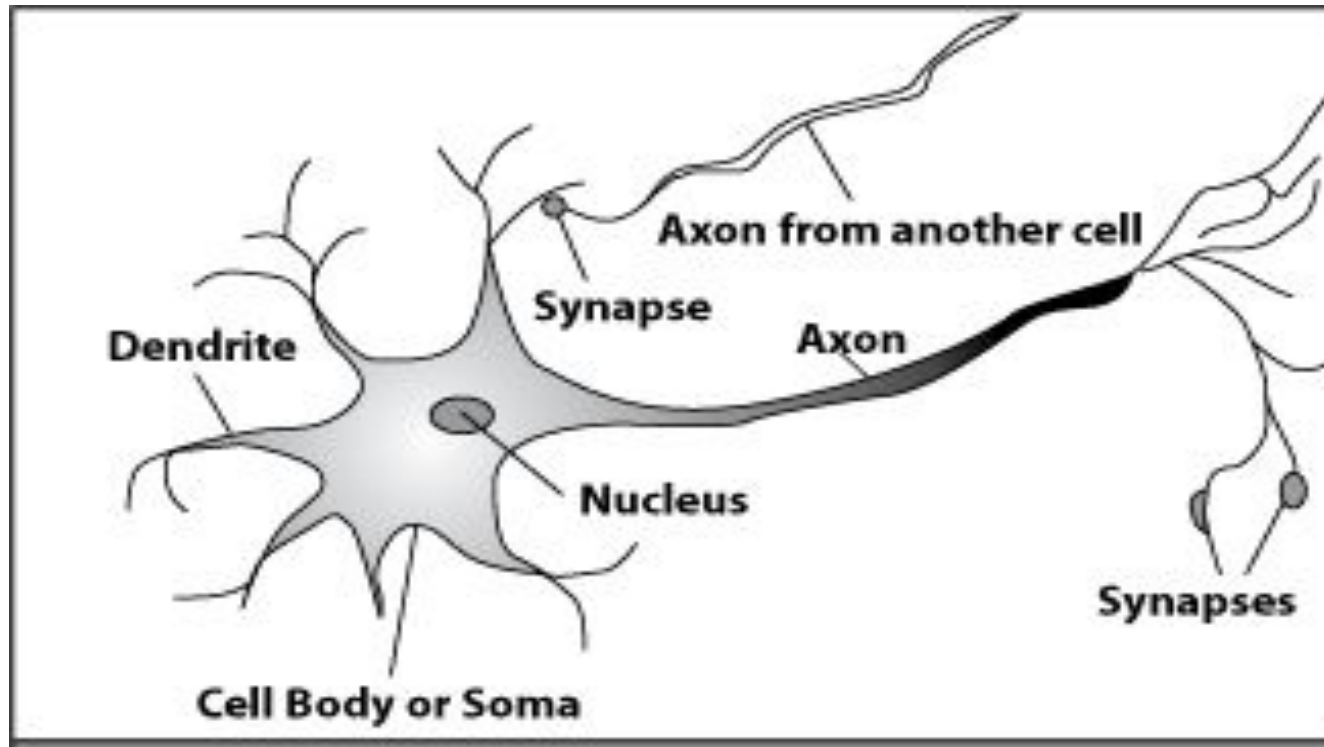
# How do our brains work?

- The Brain is A massively parallel information processing system.
- Our brains are a huge network of processing elements. A typical brain contains a network of 10 billion neurons.



# How do our brains work?

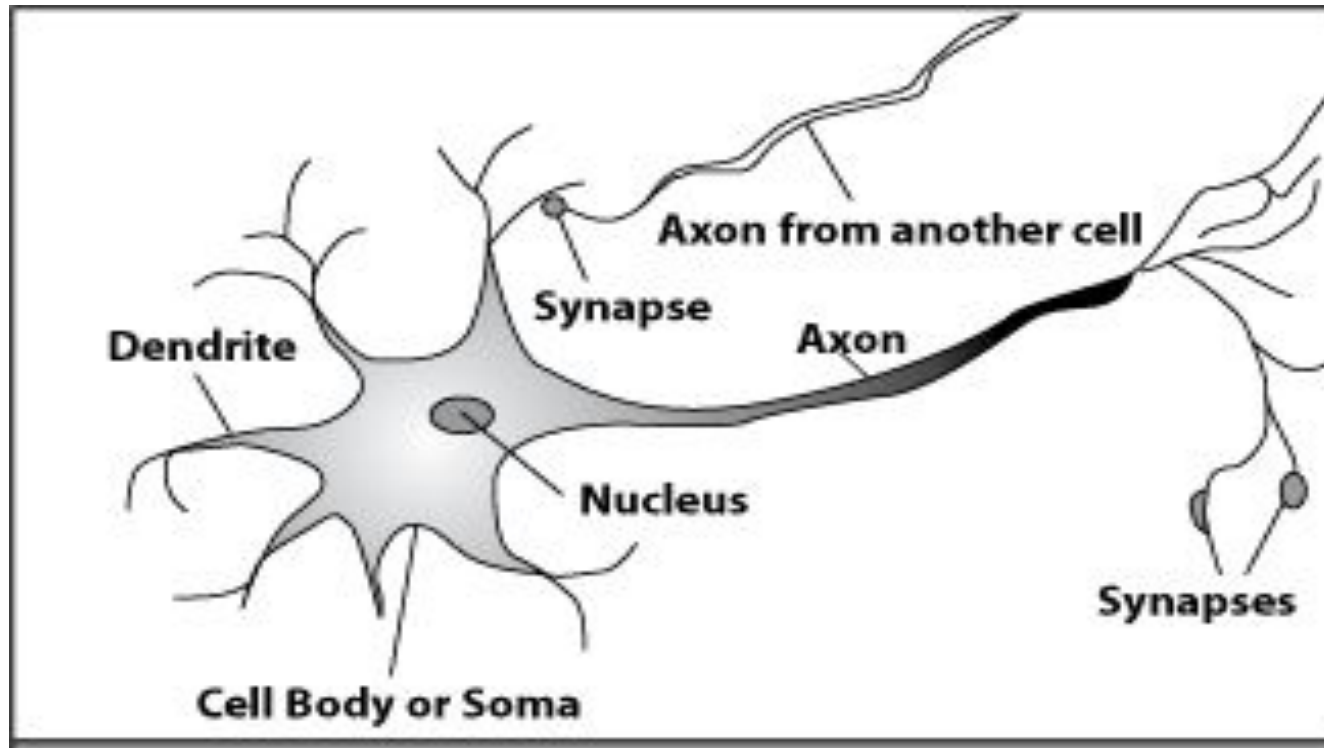
- A processing element



Dendrites: Input  
Cell body: Processor  
Synaptic: Link  
Axon: Output

# How do our brains work?

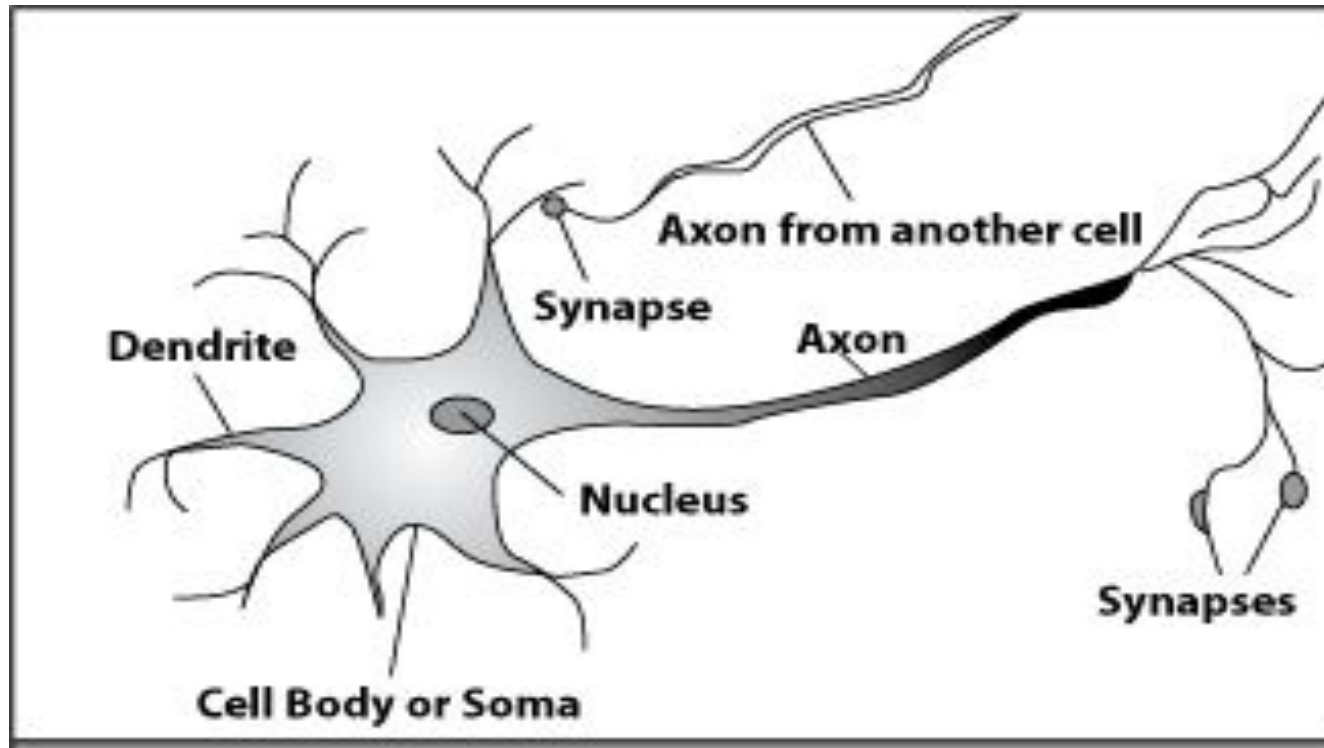
- A processing element



A neuron is connected to other neurons through about *10,000 synapses*

# How do our brains work?

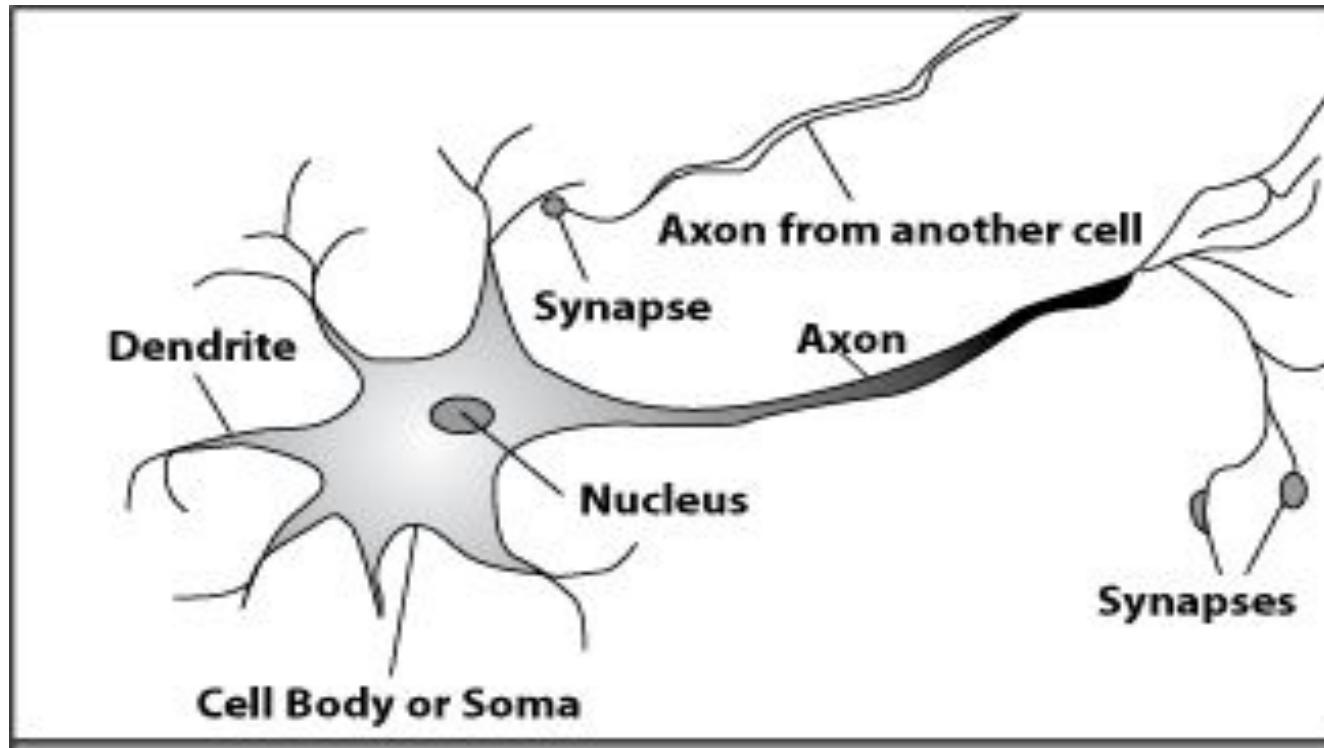
- A processing element



A neuron receives input from other neurons. Inputs are combined.

# How do our brains work?

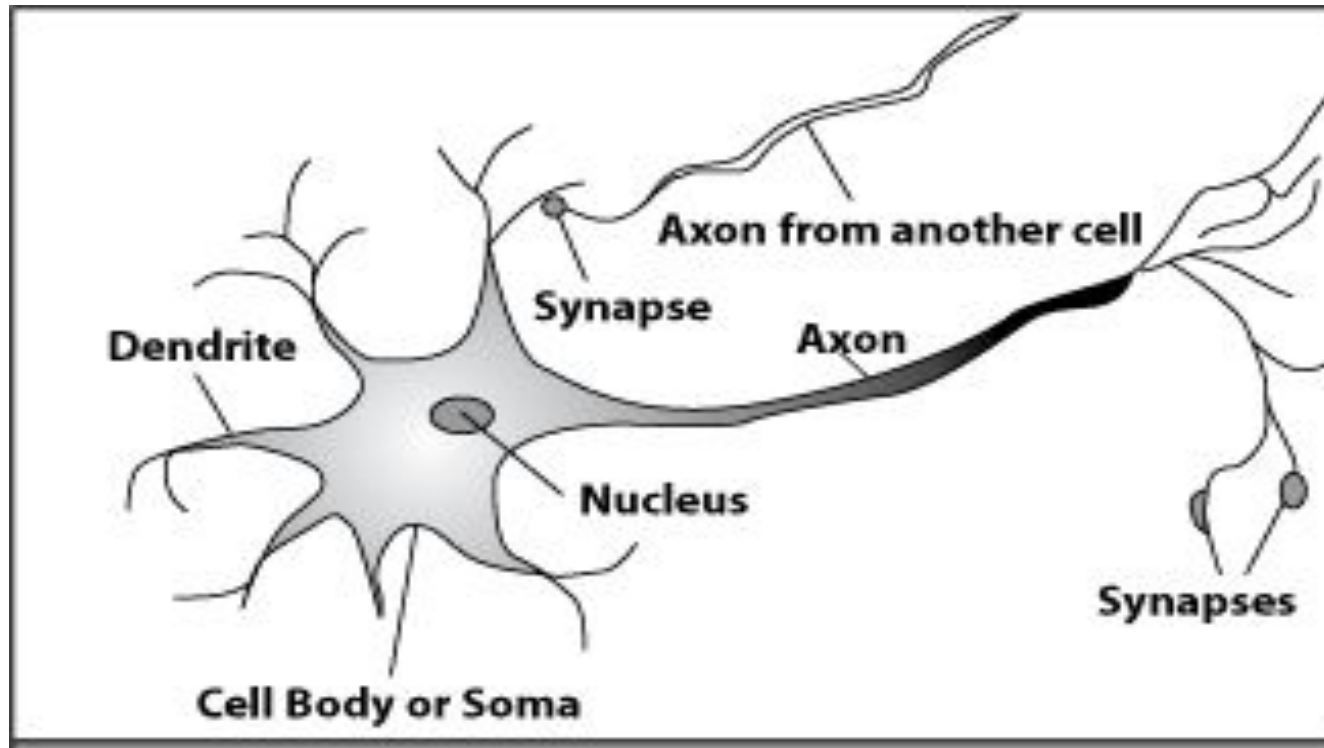
- A processing element



Once input exceeds a critical level, the neuron discharges a spike  
- an electrical pulse that travels from the body, down the axon, to  
the next neuron(s)

# How do our brains work?

- A processing element

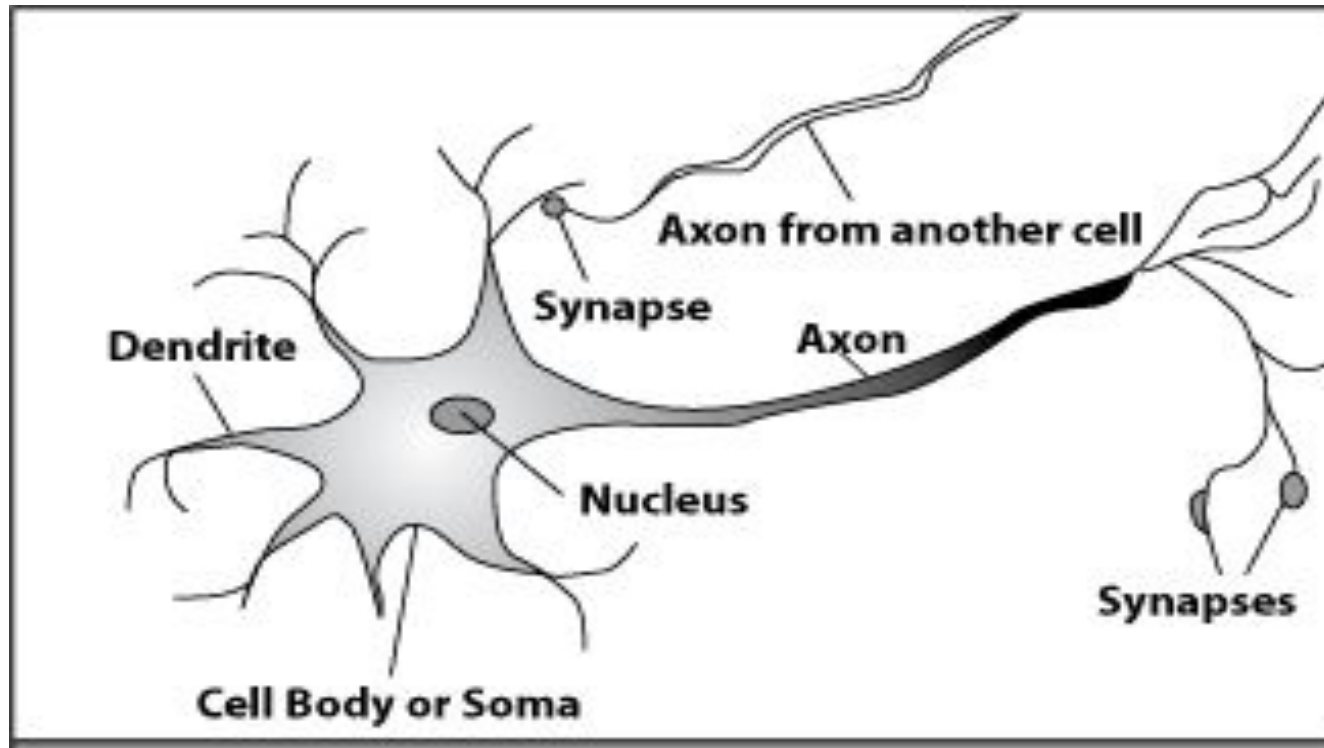


The axon endings almost touch the dendrites or cell body of the next neuron.



# How do our brains work?

- A processing element

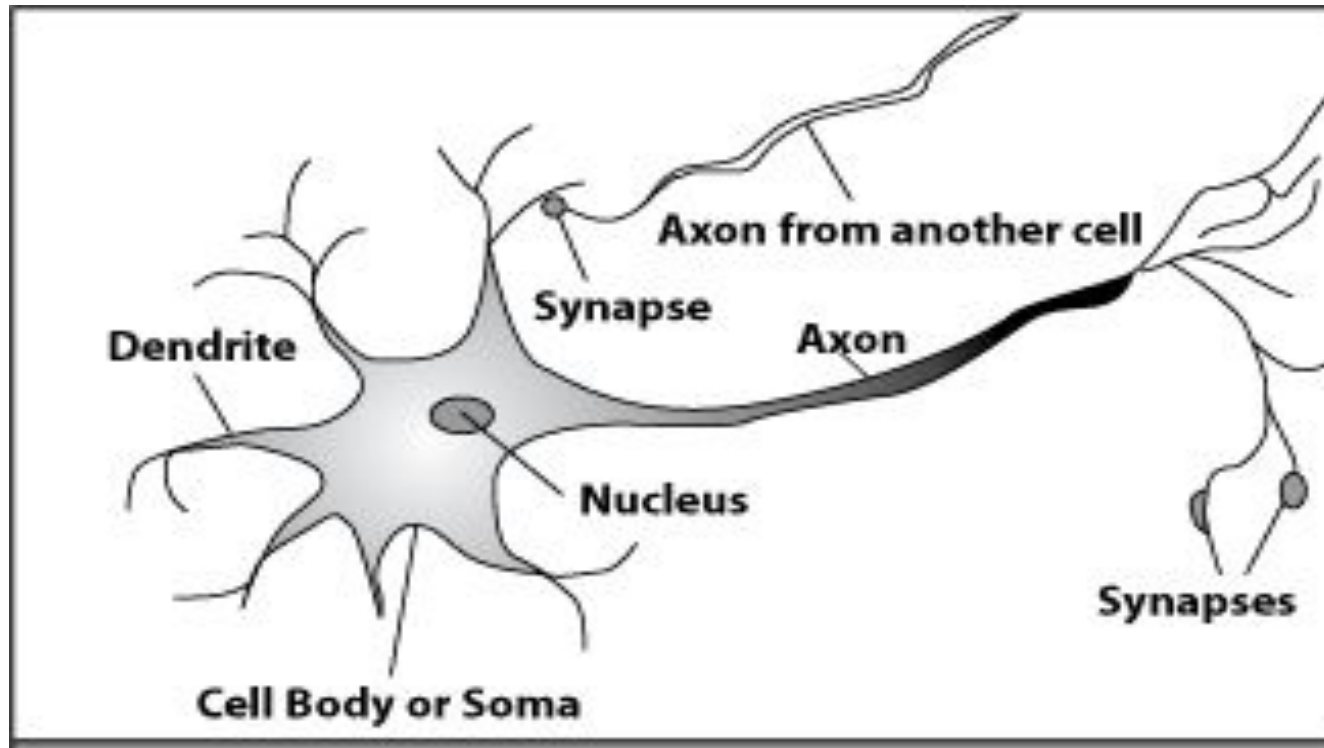


Transmission of an electrical signal from one neuron to the next is effected by neurotransmitters.



# How do our brains work?

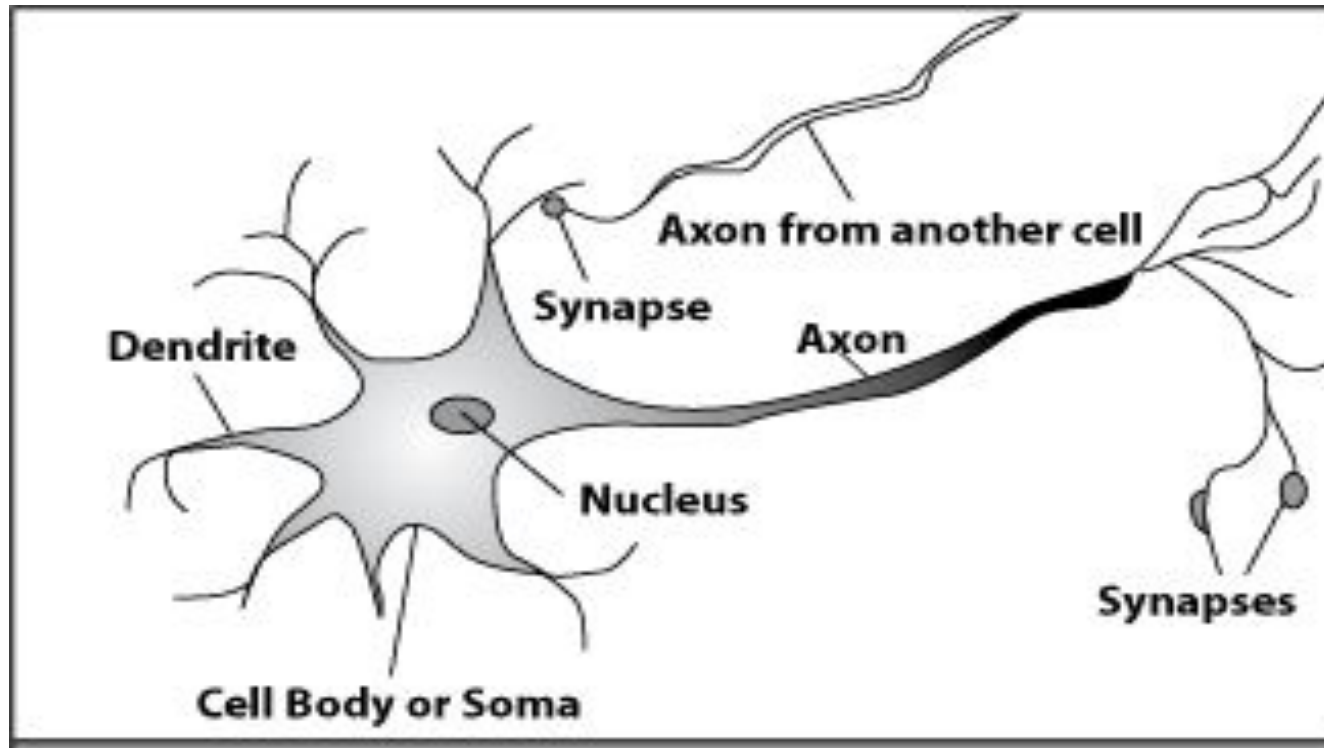
- A processing element



Neurotransmitters are chemicals which are released from the first neuron and which bind to the Second.

# How do our brains work?

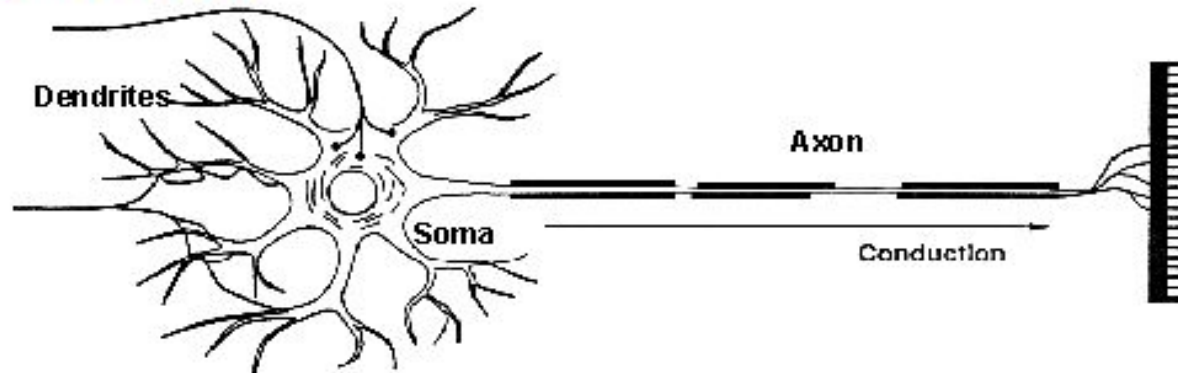
- A processing element



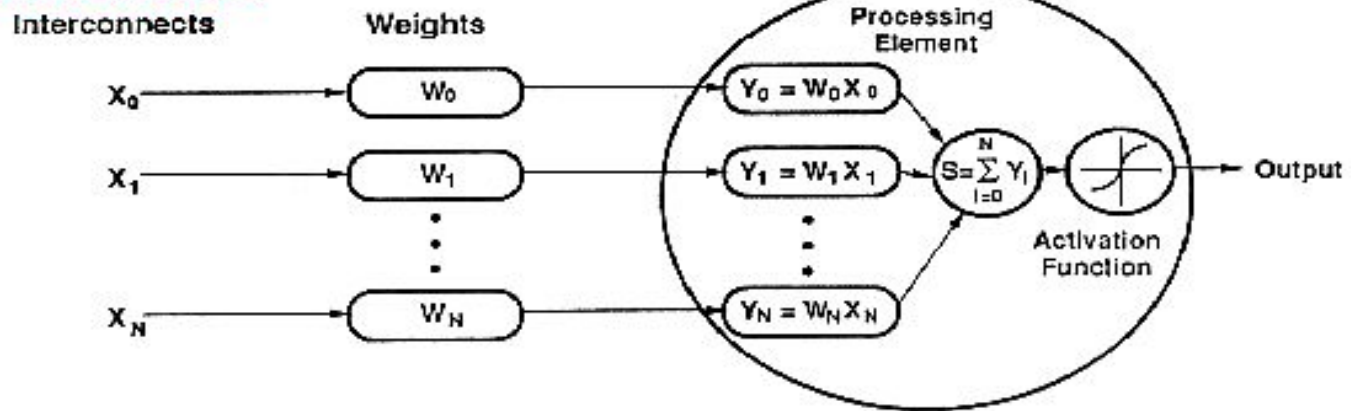
This link is called a synapse. The strength of the signal that reaches the next neuron depends on factors such as the amount of neurotransmitter available.

# How do ANNs work?

## Biological Neuron



## Artificial Neuron

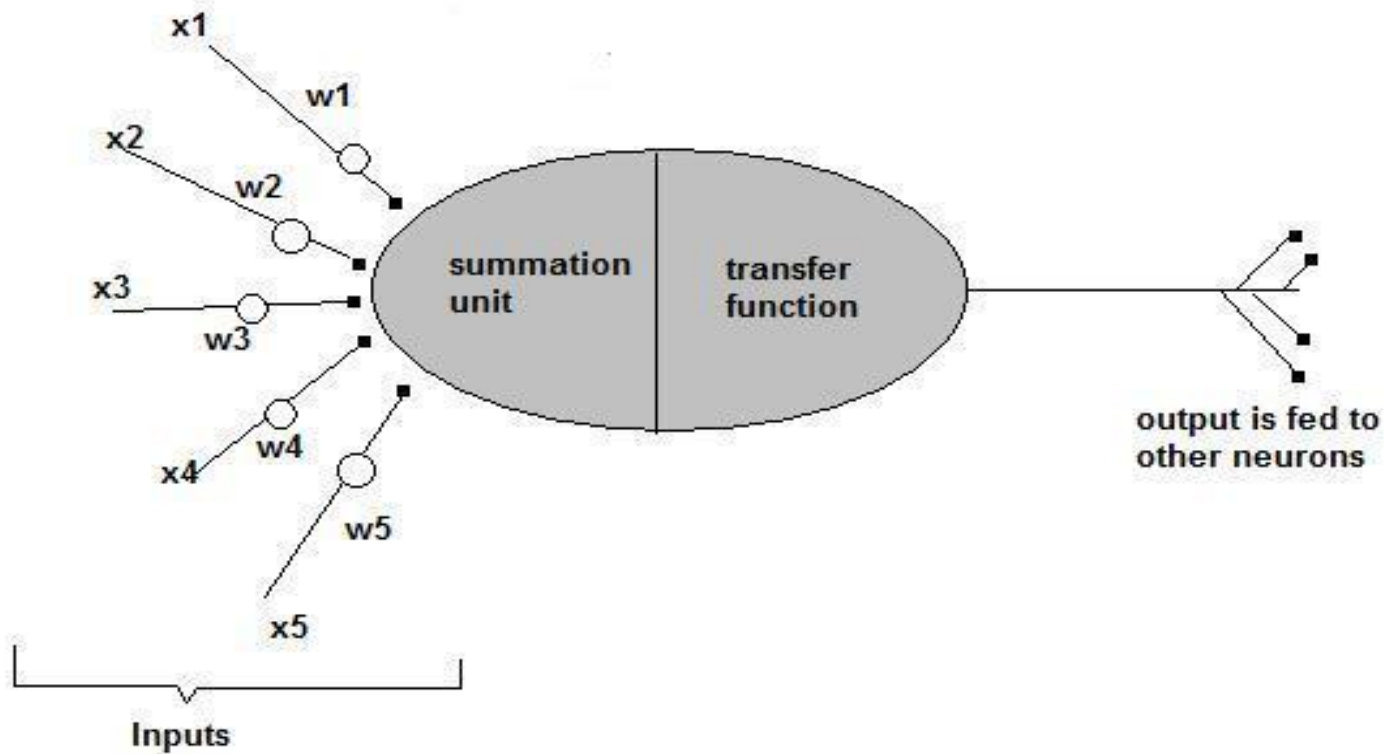


An artificial neuron is an imitation of a human neuron

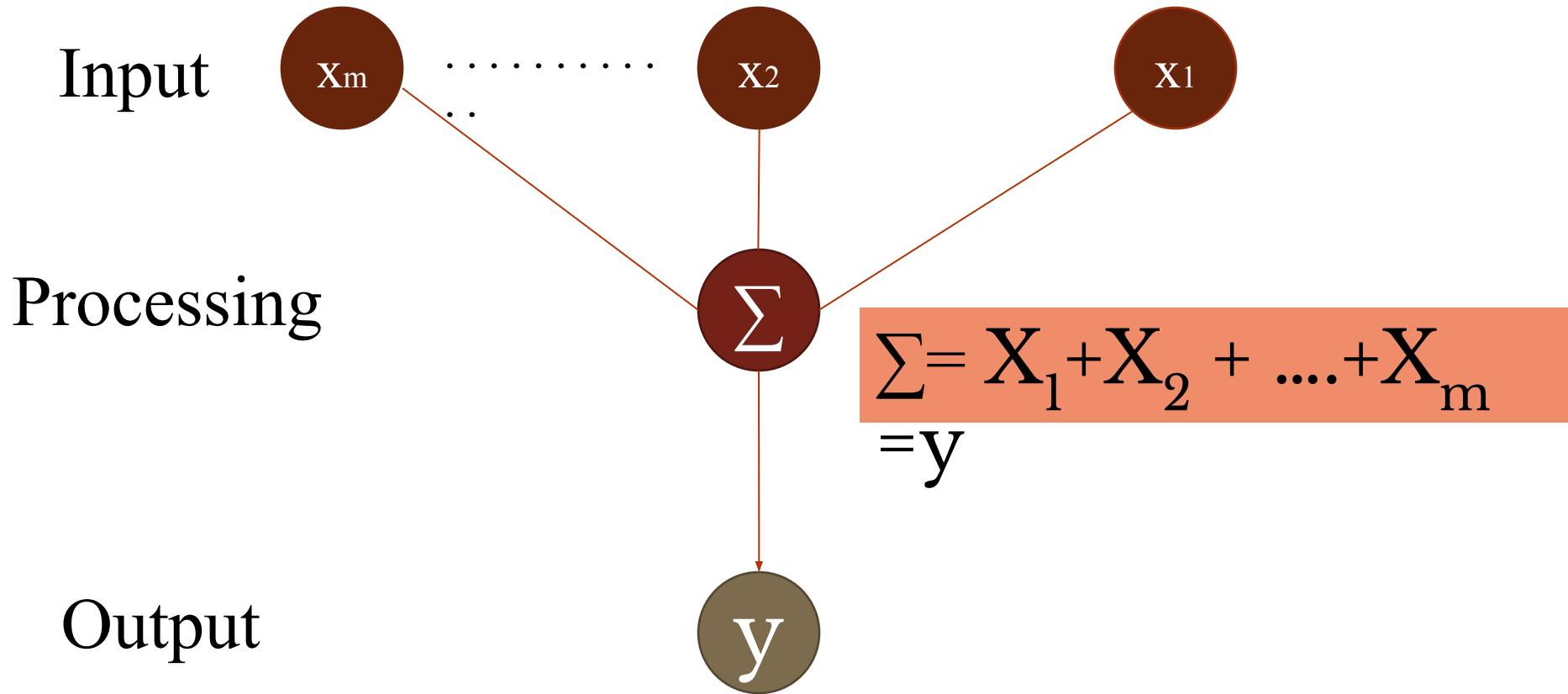
# How do ANNs work?

- Now, let us have a look at the model of an artificial neuron.

## A Single Neuron

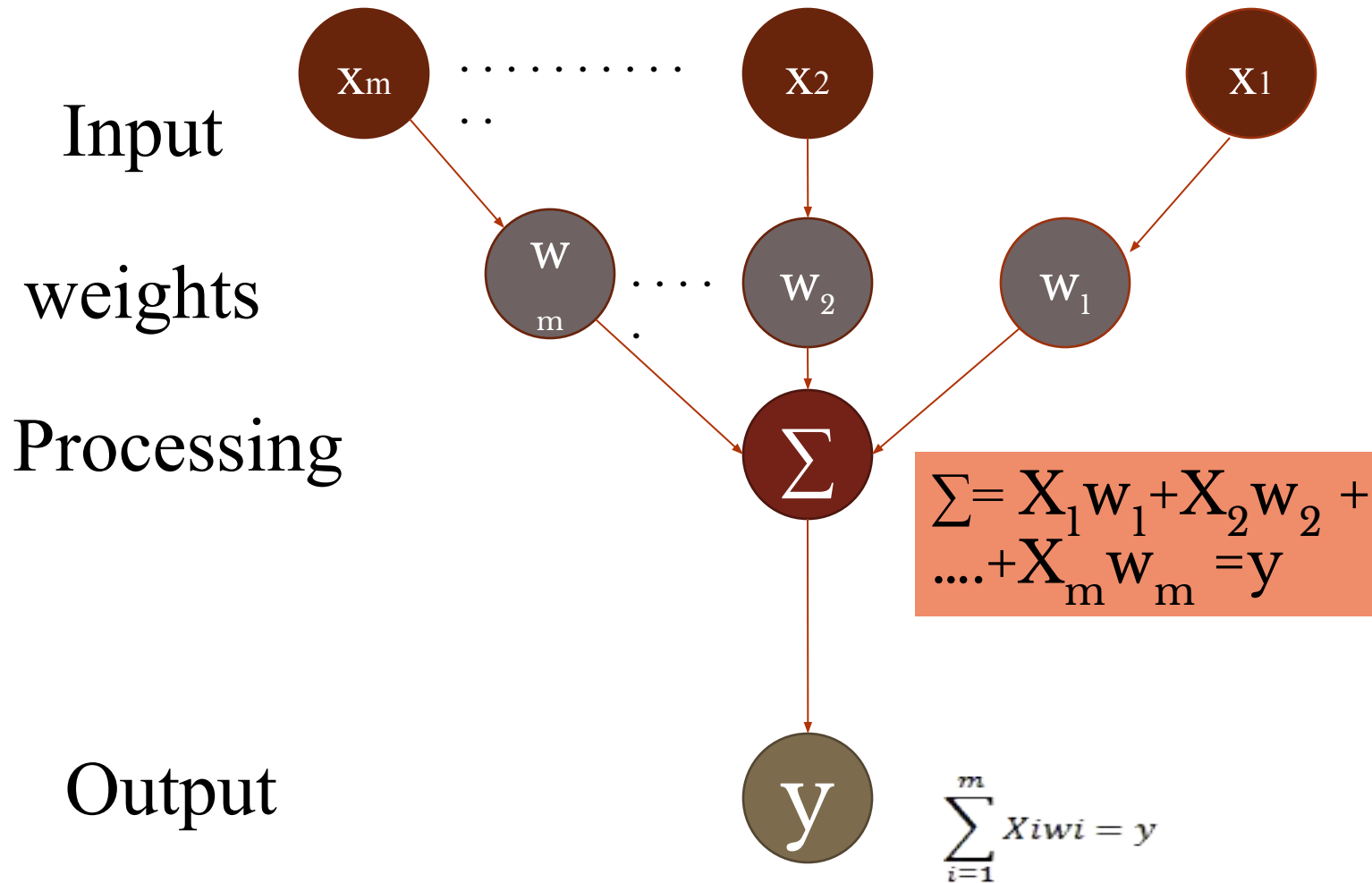


# How do ANNs work?



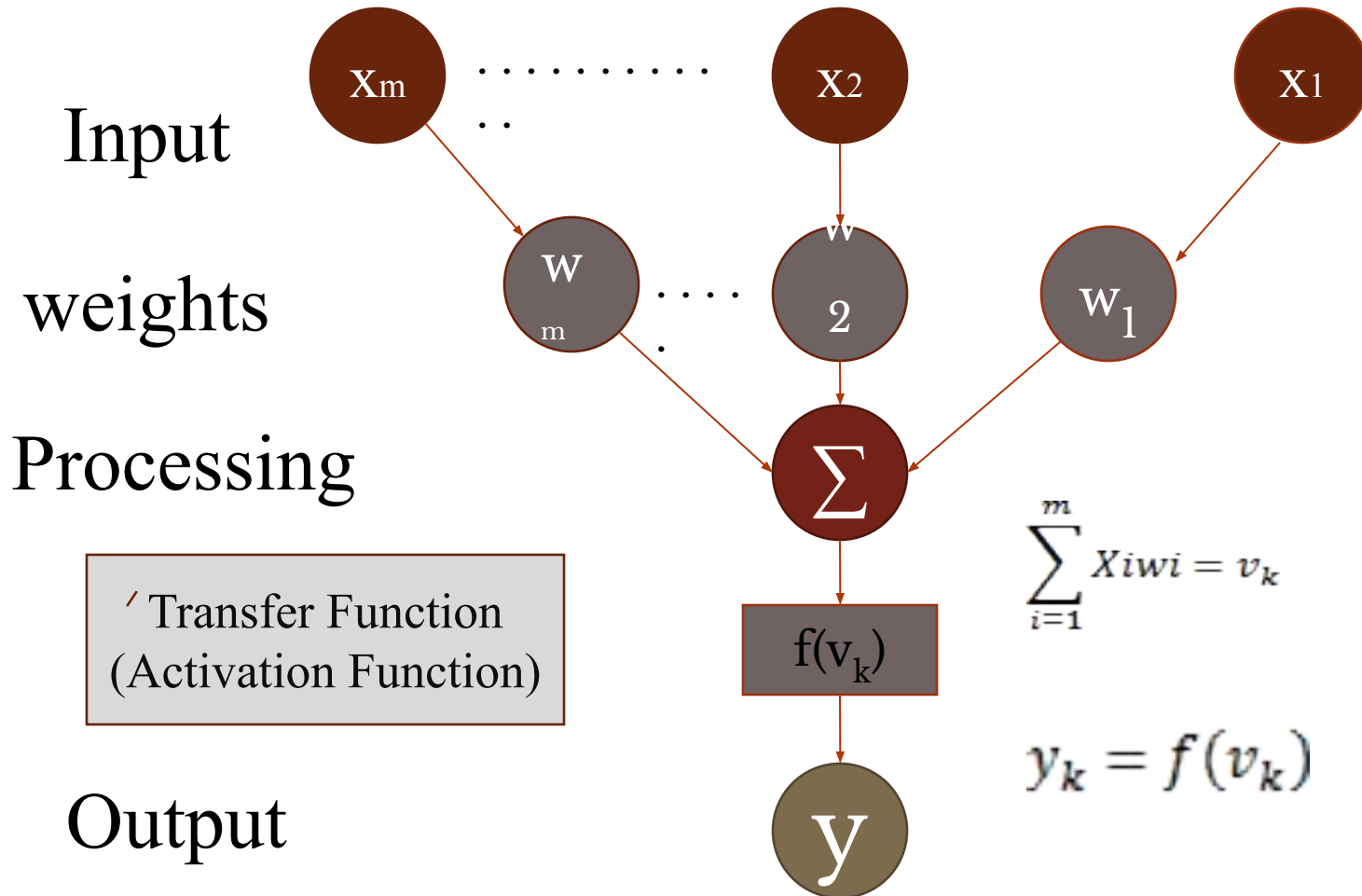
# How do ANNs work?

Not all inputs are equal

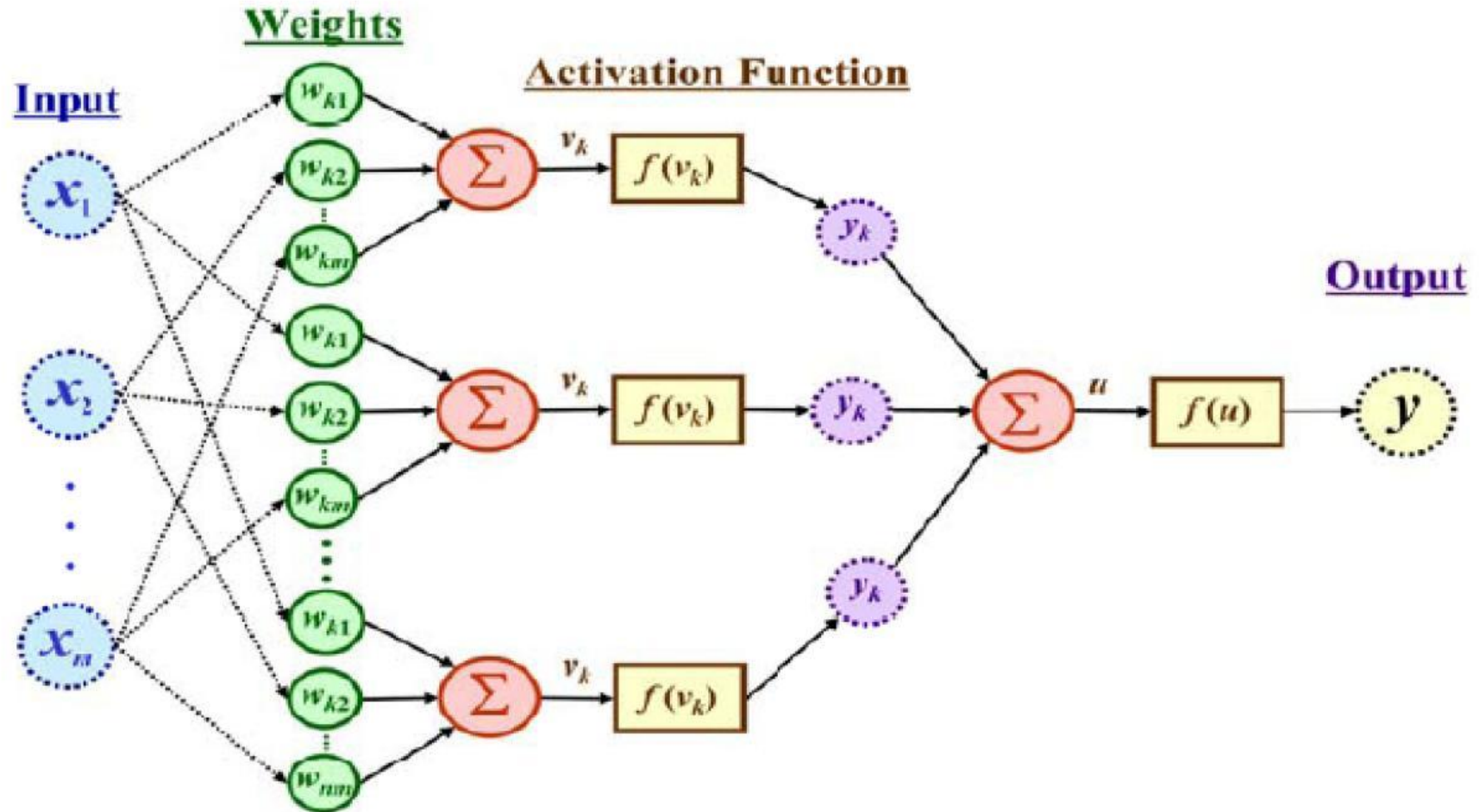


# How do ANNs work?

The signal is not passed down to the next neuron verbatim



The output is a function of the input, that is affected by the weights, and the transfer functions







# Artificial Neural Networks

- An ANN can:
  1. compute *any computable* function, by the appropriate selection of the network topology and weights values.
  2. learn from experience!
    - Specifically, by trial-and-error

# Learning by trial-and-error

Continuous process of:

- Trial:

Processing an input to produce an output (In terms of ANN: Compute the output function of a given input)

- Evaluate:

Evaluating this output by comparing the actual output with the expected output.

- Adjust:

Adjust the *weights*.





# How it works?

- Set initial values of the weights randomly.
- Input: truth table of the XOR
- Do
  - Read input (e.g. 0, and 0)
  - Compute an output (e.g. 0.60543)
  - Compare it to the expected output. (Diff= 0.60543)
  - Modify the weights *accordingly*.
- Loop until a condition is met
  - Condition: certain number of iterations
  - Condition: error threshold

# Design Issues

- Initial weights (small random values  $\in [-1,1]$ )
- Transfer function (How the inputs and the weights are combined to produce output?)
- Error estimation
- Weights adjusting
- Number of neurons
- Data representation
- Size of training set

# Transfer Functions

- **Linear:** The output is proportional to the total weighted input.
- **Threshold:** The output is set at one of two values, depending on whether the total weighted input is greater than or less than some threshold value.
- **Non-linear:** The output varies continuously but not linearly as the input changes.



# Error Estimation

- The **root mean square error (RMSE)** is a frequently-used measure of the differences between values predicted by a model or an estimator and the values actually observed from the thing being modeled or estimated

# Weights Adjusting

- After each iteration, weights should be adjusted to minimize the error.
  - All possible weights
  - Back propagation

# Back Propagation

- Back-propagation is an example of supervised learning is used at each layer to minimize the error between the layer's response and the actual data
- The error at each hidden layer is an average of the evaluated error
- Hidden layer networks are trained this way

# Back Propagation

- $N$  is a neuron.
- $N_w$  is one of  $N$ 's inputs weights
- $N_{out}$  is  $N$ 's output.
- $N_w = N_w + \Delta N_w$
- $\Delta N_w = N_{out} * (1 - N_{out}) * N_{ErrorFactor}$
- $N_{ErrorFactor} = N_{ExpectedOutput} - N_{ActualOutput}$
- This works only for the last layer, as we can know the actual output, and the expected output.

# Number of neurons

- Many neurons:
  - Higher accuracy
  - Slower
  - Risk of over-fitting
    - Memorizing, rather than understanding
    - The network will be useless with new problems.
- Few neurons:
  - Lower accuracy
  - Inability to learn at all
- Optimal number.

# Data representation

- Usually input/output data needs pre-processing
- Pictures
  - Pixel intensity
- Text:
  - A pattern

# Size of training set

- No one-fits-all formula
- Over fitting can occur if a “good” training set is not chosen
- What constitutes a “good” training set?
  - Samples must represent the general population.
  - Samples must contain members of each class.
  - Samples in each class must contain a wide range of variations or noise effect.
- The size of the training set is related to the number of hidden neurons

# Learning Paradigms

- Supervised learning
- Unsupervised learning
- Reinforcement learning



# Supervised learning

- This is what we have seen so far!
- A network is fed with a set of training samples (inputs and corresponding output), and it uses these samples to learn the general relationship between the inputs and the outputs.
- This relationship is represented by the values of the weights of the trained network.

# Unsupervised learning

- No desired output is associated with the training data!
- Faster than supervised learning
- Used to find out *structures within data*:
  - Clustering
  - Compression

# ImageNet vs. PlacesNet

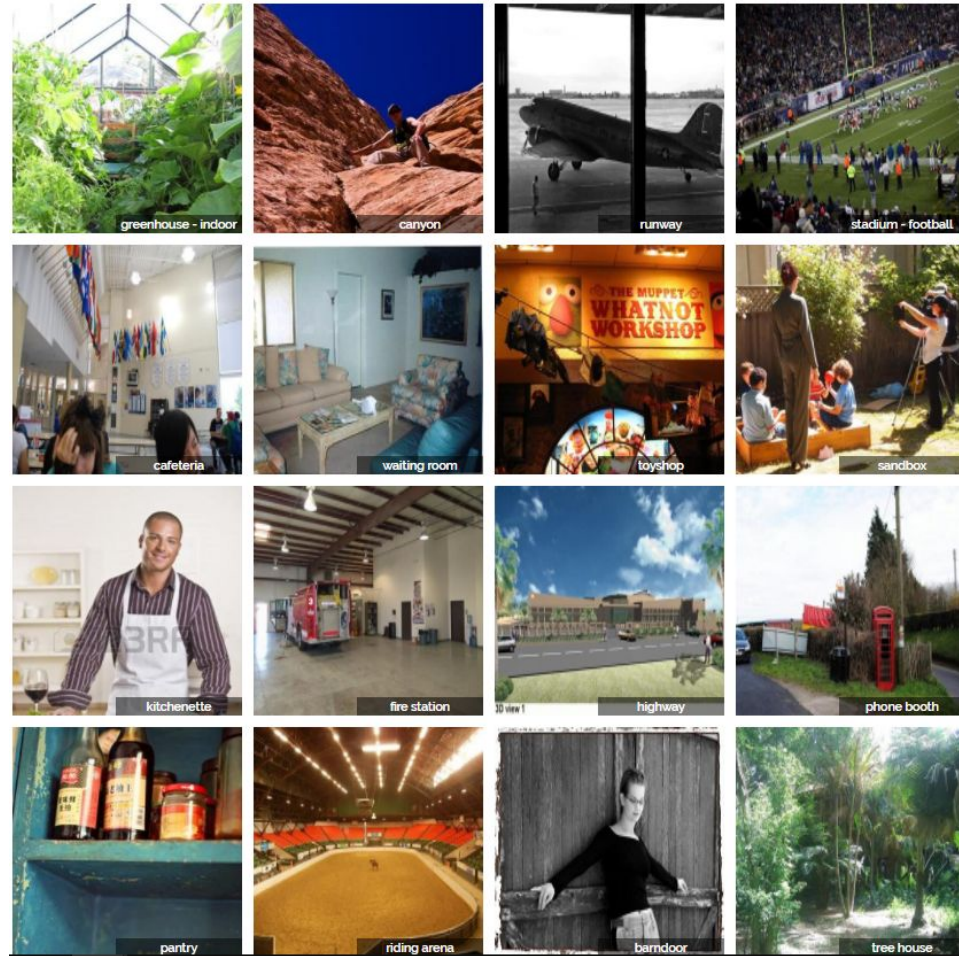
<http://places2.csail.mit.edu/demo.html>

## ImageNet

- ~1 mil object-level images over 1000 classes

## PlacesNet

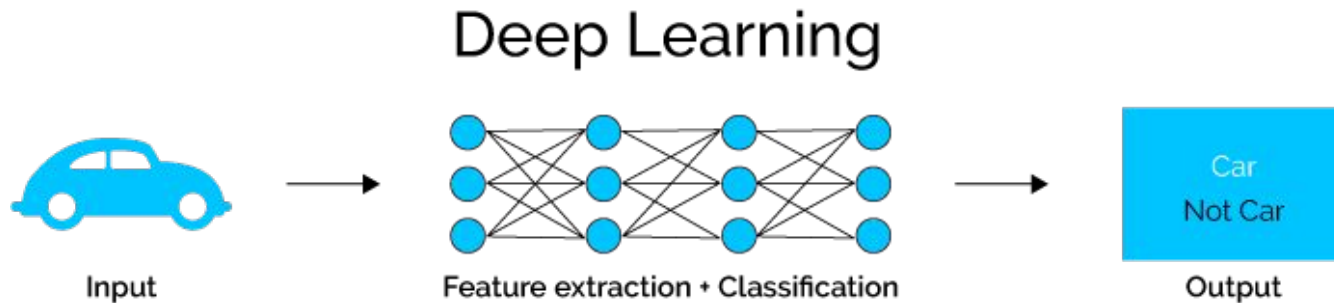
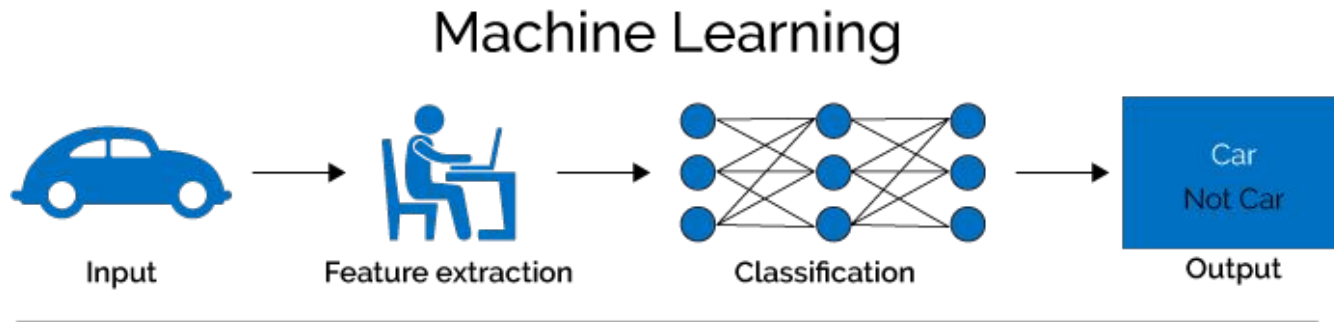
- ~1.8 million images from 365 scene categories (at most 5000 images per category).



# ML vs. Deep Learning

## *Introduction to Deep Learning*

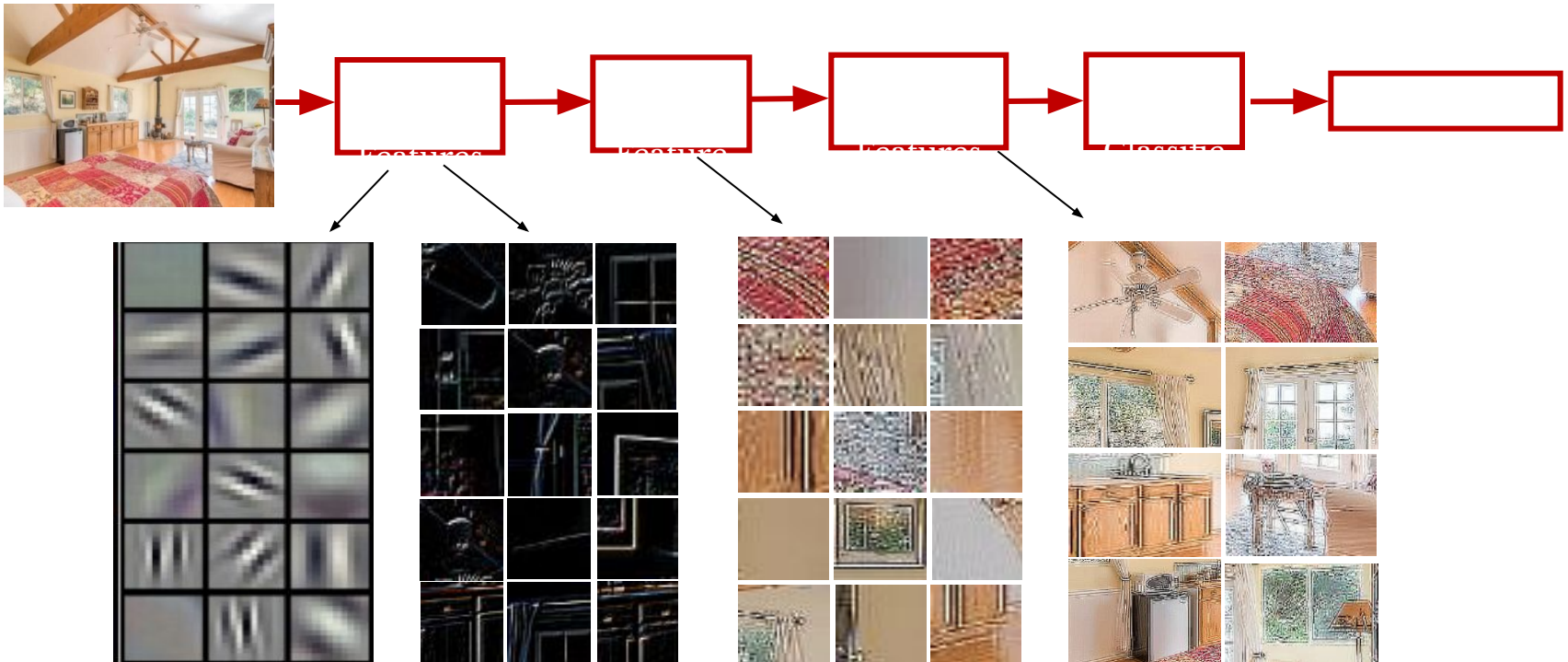
- **Deep learning** (DL) is a machine learning subfield that uses multiple layers for learning data representations
  - DL is exceptionally effective at learning patterns



# ML vs. Deep Learning

## *Introduction to Deep Learning*

- DL applies a multi-layer process for learning rich hierarchical features (i.e., data representations)
  - Input image pixels → Edges → Textures → Parts → Objects



# Why is DL Useful?

*Introduction to Deep Learning*

- DL provides a flexible, learnable framework for representing visual, text, linguistic information
  - Can learn in supervised and unsupervised manner
- DL represents an effective end-to-end learning system
- Requires large amounts of training data
- Since about 2010, DL has outperformed other ML techniques
  - First in vision and speech, then NLP, and other applications

# Reinforcement learning

- Like supervised learning, but:
  - Weights adjusting is not directly related to the error value.
  - The error value is used to randomly, shuffle weights!
  - Relatively slow learning due to ‘randomness’.

# Applications Areas

- Function approximation
  - including time series prediction and modeling.
- Classification
  - including patterns and sequences recognition, novelty detection and sequential decision making.
    - (radar systems, face identification, handwritten text recognition)
- Data processing
  - including filtering, clustering blinds source separation and compression.
    - (data mining, e-mail Spam filtering)



# Advantages / Disadvantages

- Advantages
  - Adapt to unknown situations
  - Powerful, it can model complex functions.
  - Ease of use, learns by example, and very little user domain-specific expertise needed
- Disadvantages
  - Forgets
  - Not exact
  - Large complexity of the network structure

# Conclusion

- Artificial Neural Networks are an imitation of the biological neural networks, but much simpler ones.
- The computing would have a lot to gain from neural networks. Their ability to learn by example makes them very flexible and powerful furthermore there is need to device an algorithm in order to perform a specific task.

# Conclusion

- Neural networks also contributes to area of research such a neurology and psychology. They are regularly used to model parts of living organizations and to investigate the internal mechanisms of the brain.
- Many factors affect the performance of ANNs, such as the transfer functions, size of training sample, network topology, weights adjusting algorithm, ...

# References

- Craig Heller, and David Sadava, *Life: The Science of Biology, fifth edition*, Sinauer Associates, INC, USA, 1998.
- Introduction to Artificial Neural Networks, Nicolas Galoppo von Borries
- Tom M. Mitchell, *Machine Learning*, WCB McGraw-Hill, Boston, 1997.

*Thank You*

Q. How does each neuron work in ANNS?  
What is back propagation?

- A neuron: receives **input** from many other neurons;
- changes its internal state (**activation**) based on the current input;
- sends **one output signal** to many other neurons, possibly including its input neurons (ANN is recurrent network).
- Back-propagation is a type of supervised learning, used at each layer to minimize the error between the layer's response and the actual data.