CS344: Introduction to Artificial Intelligence (associated lab: CS386)

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Lecture 20: Neural Networks

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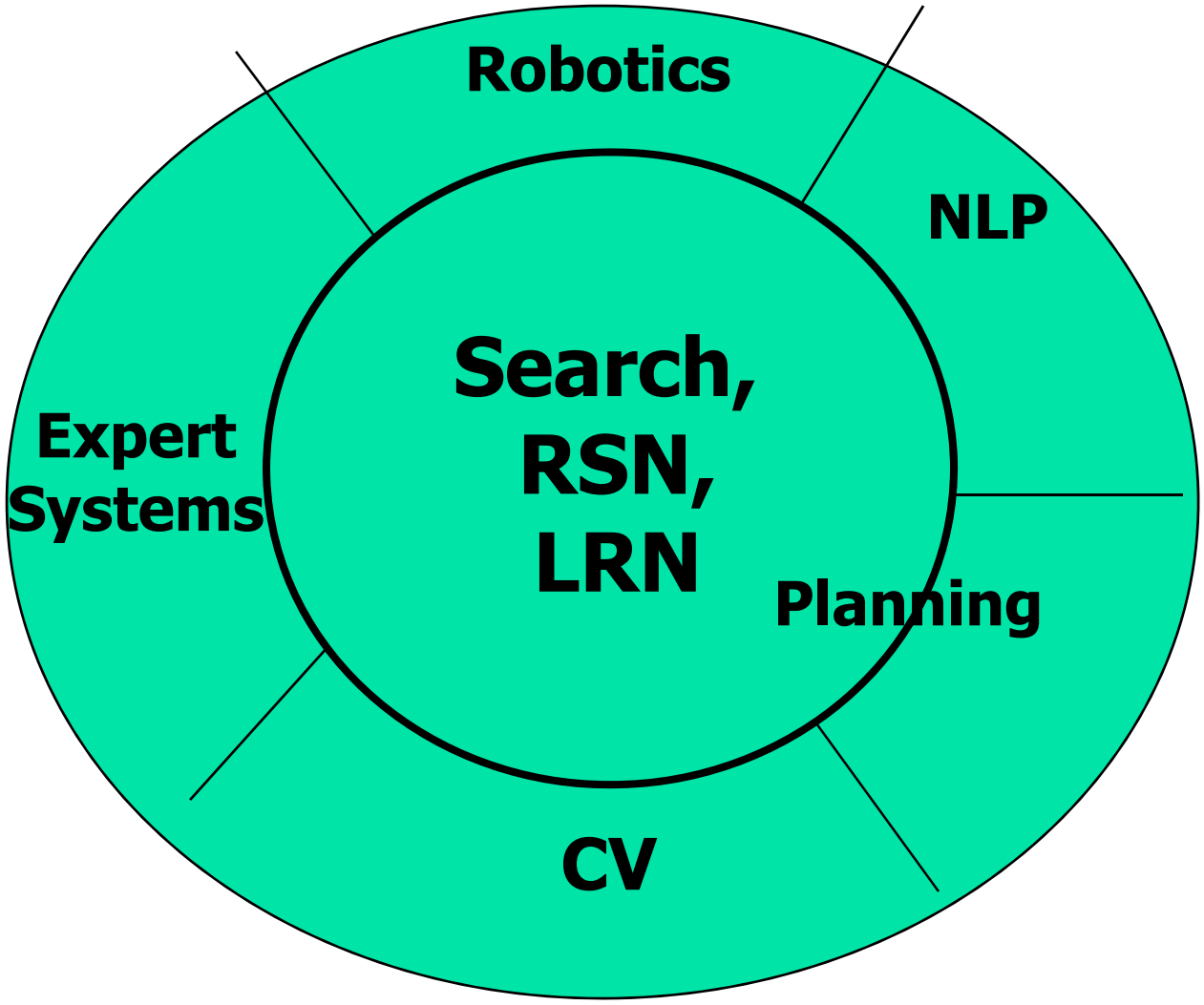
A perspective of AI

Artificial Intelligence - Knowledge based computing

Disciplines which form the core of AI - inner circle

Fields which draw from these disciplines - outer circle.



Symbolic AI

Connectionist AI is contrasted with Symbolic AI

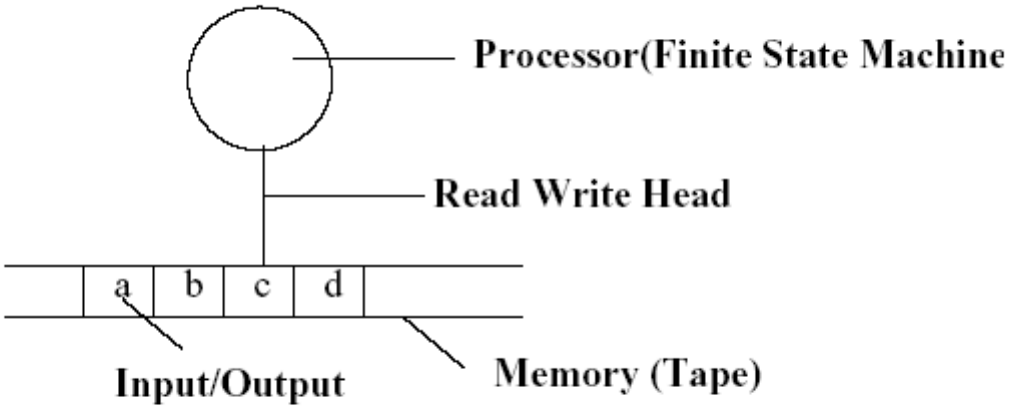
Symbolic AI - Physical Symbol System Hypothesis

> **Every intelligent system can be constructed by storing and processing symbols and nothing more is necessary.**

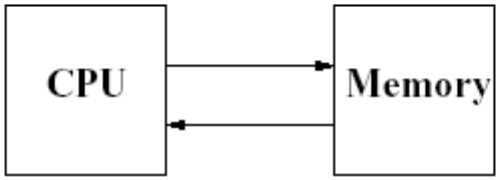
Symbolic AI has a bearing on models of computation such as

- **Turing Machine**
- **Von Neumann Machine**
- **Lambda calculus**

Turing Machine & Von Neumann Machine



Turing machine



VonNeumann Machine

Challenges to Symbolic AI

Motivation for challenging Symbolic AI

A large number of computations and information process tasks that living beings are comfortable with, are not performed well by computers!

The Differences

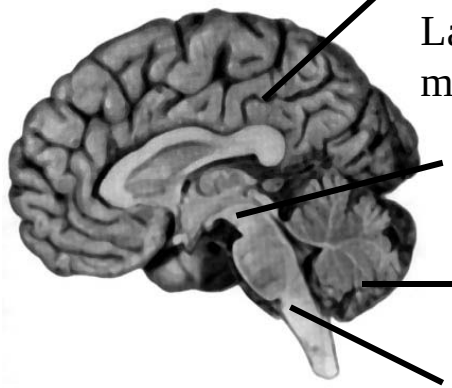
Brain computation in living beings	**TM computation in computers**
Pattern Recognition	**Numerical Processing**
Learning oriented	**Programming oriented**
Distributed & parallel processing	**Centralized & serial processing**
Content addressable	**Location addressable**

The human brain

Seat of consciousness and cognition

Perhaps the most complex information processing machine in nature

Beginner's Brain Map



Forebrain (Cerebral Cortex): Language, maths, sensation, movement, cognition, emotion

Midbrain: Information Routing; involuntary controls

Cerebellum: Motor Control

Hindbrain: Control of breathing, heartbeat, blood circulation

Spinal cord: Reflexes, information highways between body & brain

Brain : a computational machine?

Information processing: brains vs computers

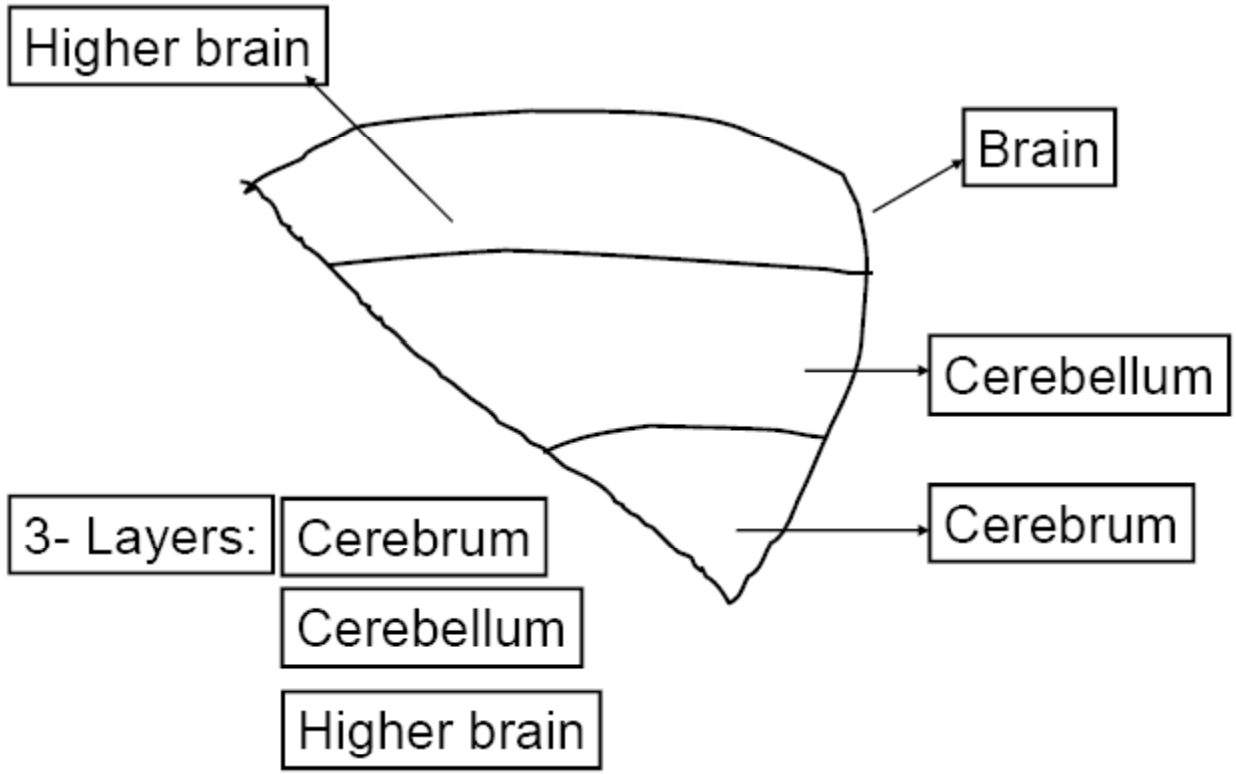
- brains better at perception / cognition
- slower at numerical calculations
- parallel and distributed Processing
- associative memory

Brain : a computational machine? *(contd.)*

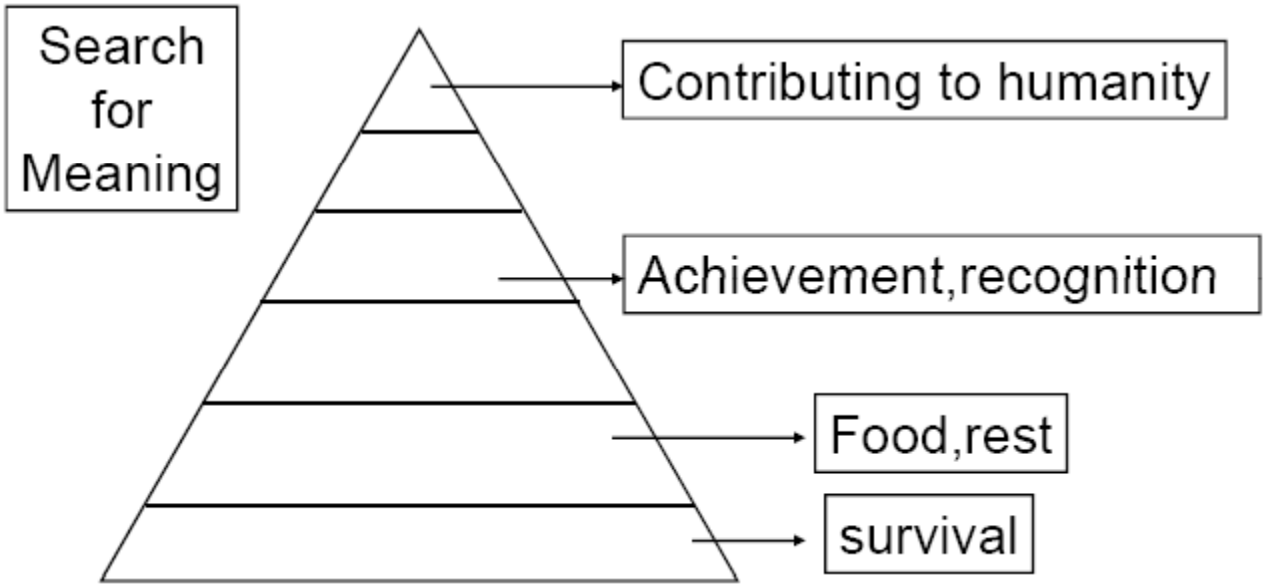
- Evolutionarily, brain has developed algorithms most suitable for survival
- Algorithms unknown: the search is on
- Brain astonishing in the amount of information it processes
  - Typical computers: 10^9 operations/sec
  - Housefly brain: 10^{11} operations/sec

Brain facts & figures

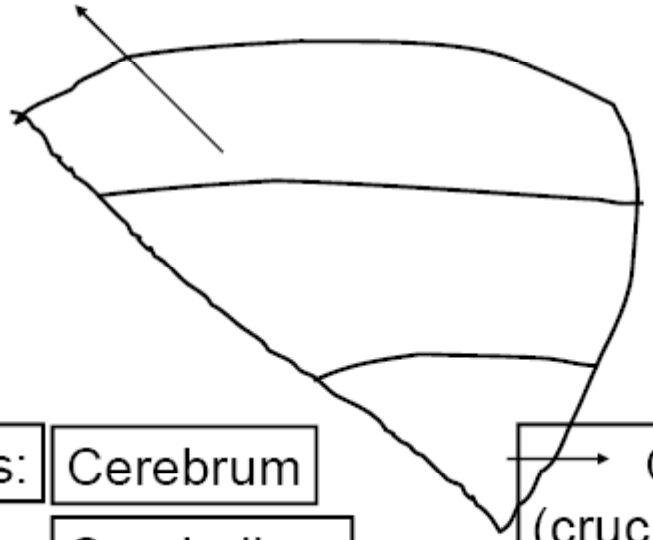
- Basic building block of nervous system: nerve cell (neuron)
- ~ 10^{12} neurons in brain
- ~ 10^{15} connections between them
- Connections made at “synapses”
- The speed: events on millisecond scale in neurons, nanosecond scale in silicon chips


Higher brain
Brain
Cerebellum
Cerebrum
3- Layers:
Cerebrum
Cerebellum
Higher brain

Maslow's hierarchy



Higher brain (responsible for higher needs)

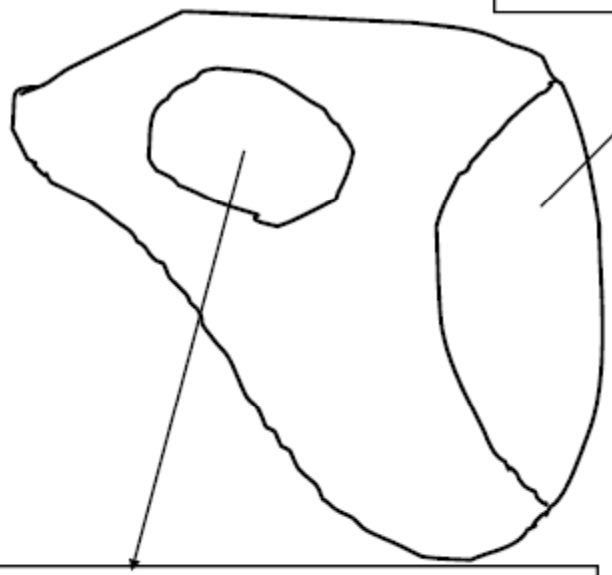


3- Layers:

- Cerebrum
- Cerebellum
- Higher brain

Cerebrum
(crucial for survival)

Mapping of Brain



Back of brain(vision)

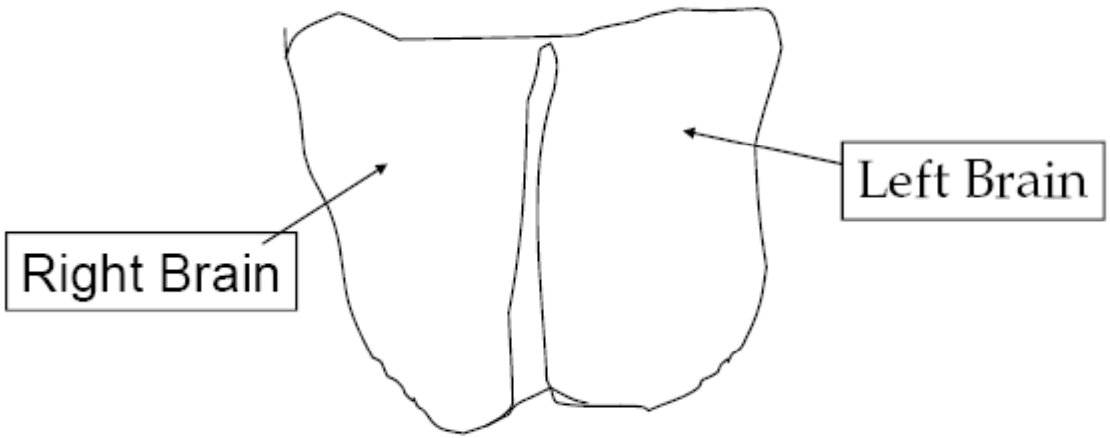
Lot of resilience:

Visual and auditory areas can do each other's job

Side areas
For auditory information processing

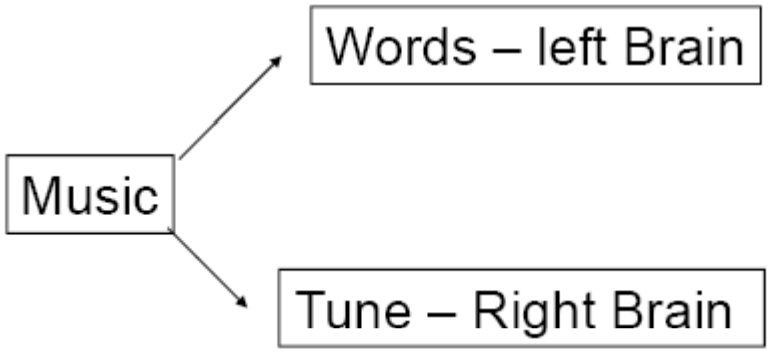
Left Brain and Right Brain

Dichotomy



Left Brain – Logic, Reasoning, Verbal ability

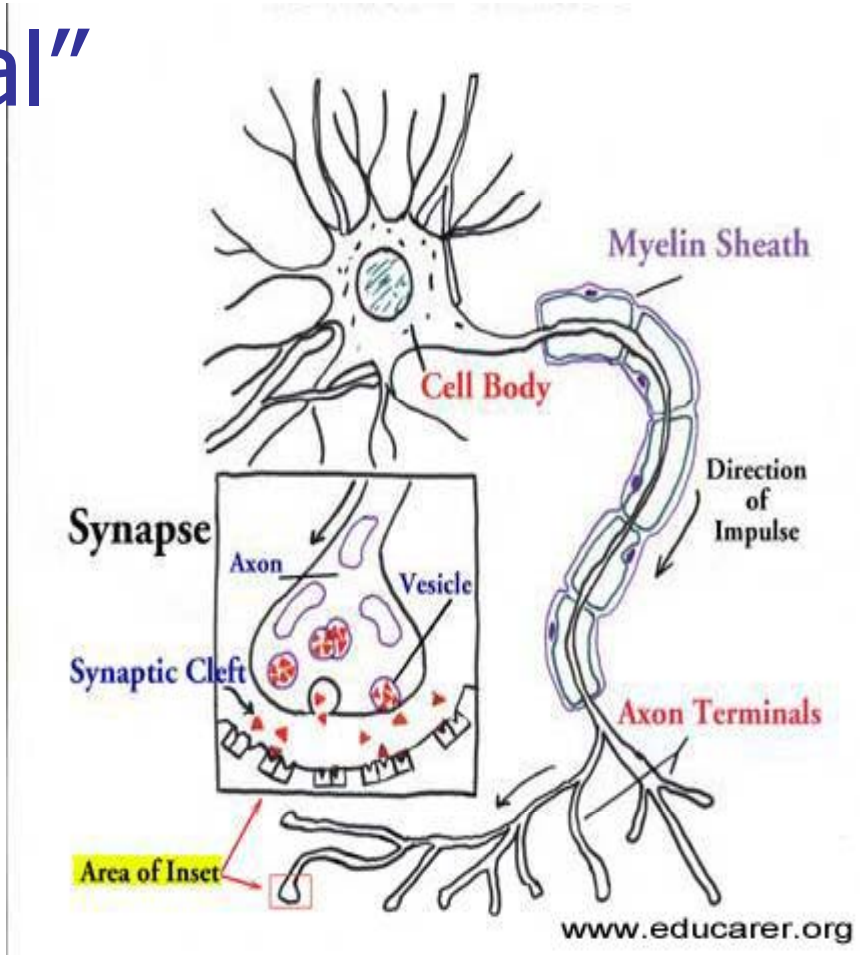
Right Brain – Emotion, Creativity



Maps in the brain. Limbs are mapped to brain

Neuron - "classical"

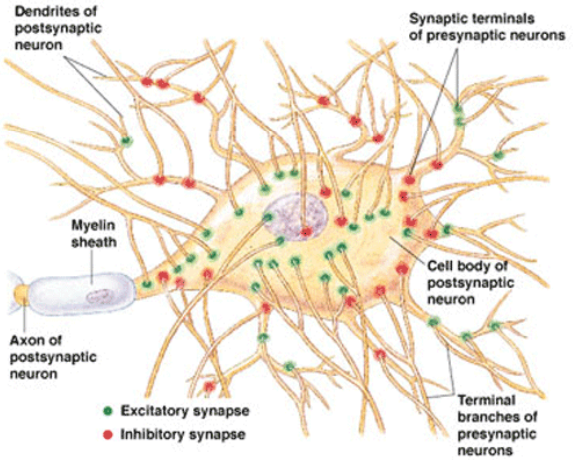
- Dendrites
  - Receiving stations of neurons
  - Don't generate action potentials
- Cell body
  - Site at which information received is integrated
- Axon
  - Generate and relay action potential
  - Terminal
    - Relays information to next neuron in the pathway



http://www.educarer.com/images/brain-nerve-axon.jpg

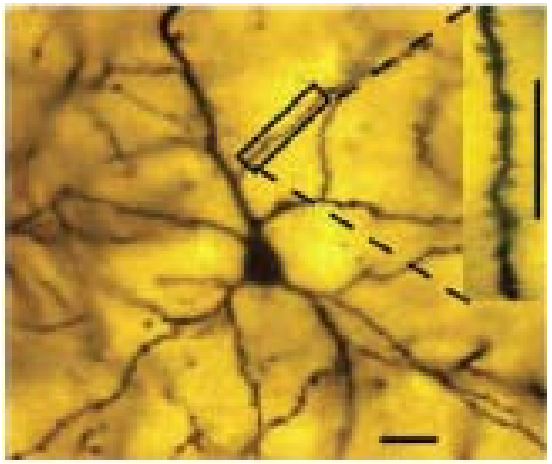
Computation in Biological Neuron

- Incoming signals from synapses are summed up at the soma
- Σ , the biological "inner product"
- On crossing a threshold, the cell "fires" generating an action potential in the axon hillock region

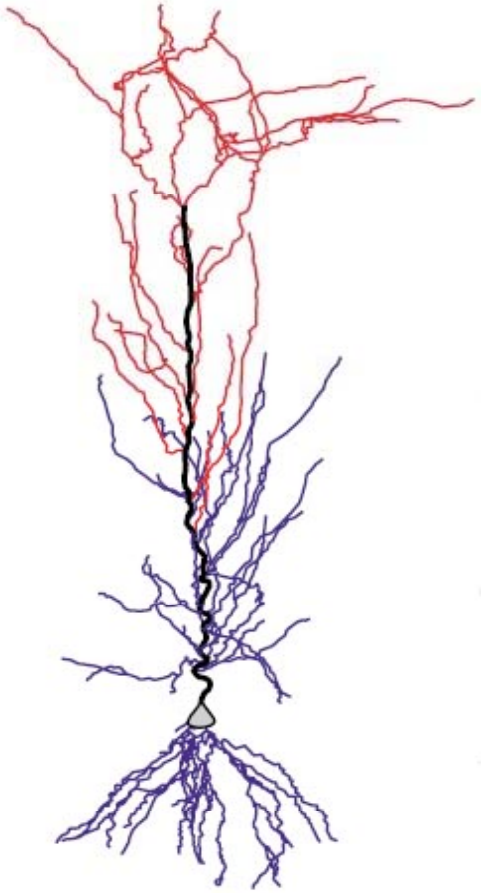


Synaptic inputs: Artist's conception

The biological neuron



Pyramidal neuron, from the amygdala (Rupshi *et al.* 2005)

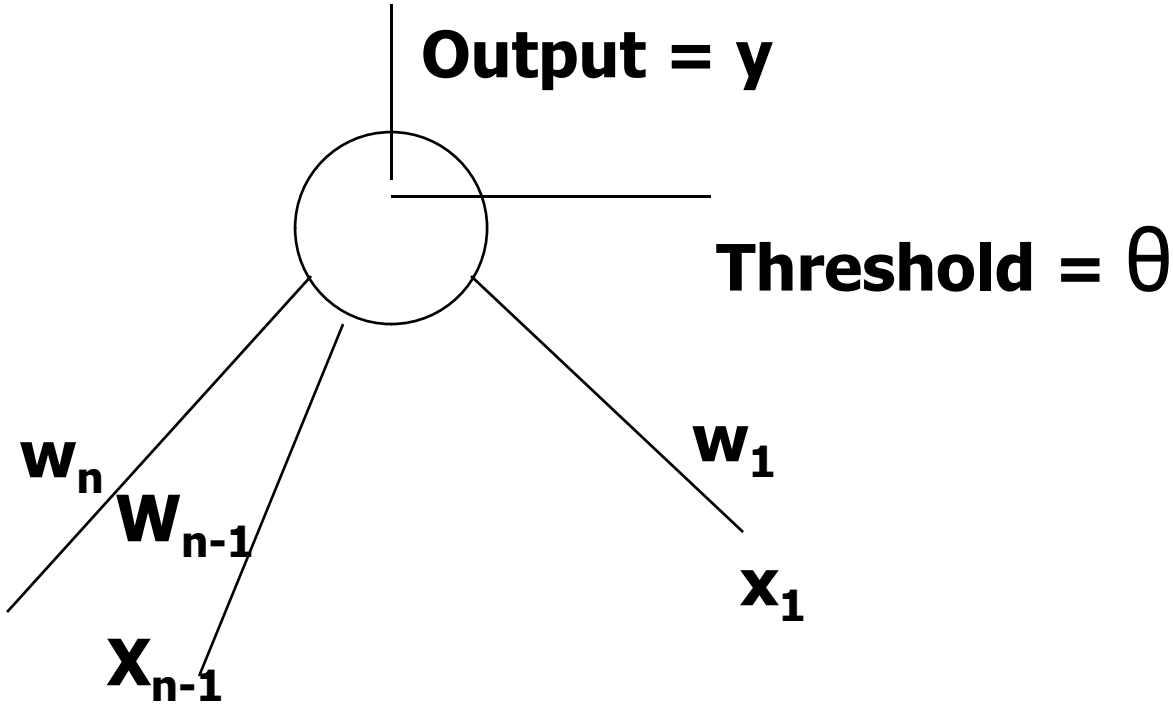


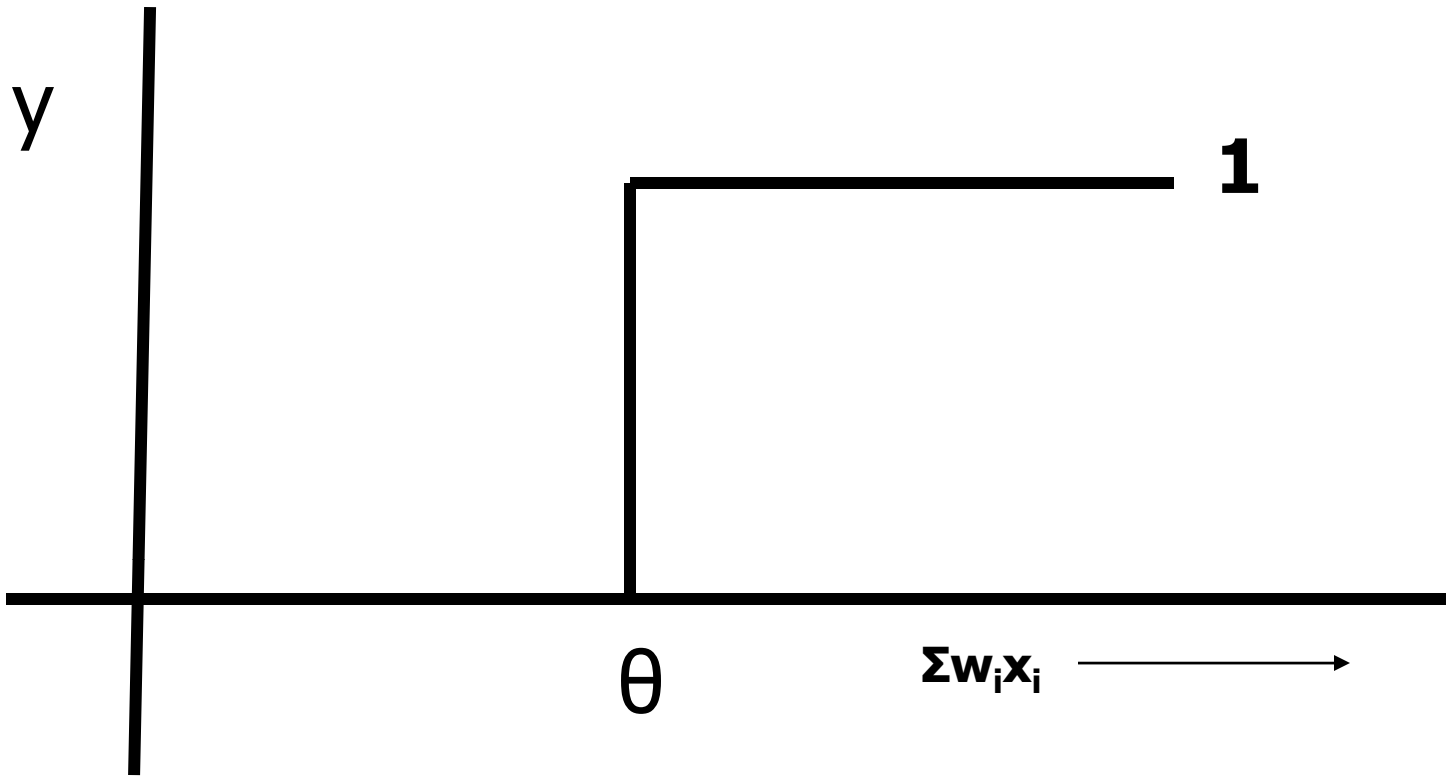
A CA1 pyramidal neuron (Mel *et al*. 2004)

Perceptron

The Perceptron Model

A perceptron is a computing element with input lines having associated weights and the cell having a threshold value. The perceptron model is motivated by the biological neuron.





Step function / Threshold function

y = 1 for $\Sigma w_i x_i$ >=θ

=0 otherwise

Features of Perceptron

- Input output behavior is discontinuous and the derivative does not exist at $\mathbf{\Sigma w_i x_i = \theta}$

- $\mathbf{\Sigma w_i x_i - \theta}$ is the net input denoted as net

- Referred to as a linear threshold element - linearity because of **x** appearing with power **1**

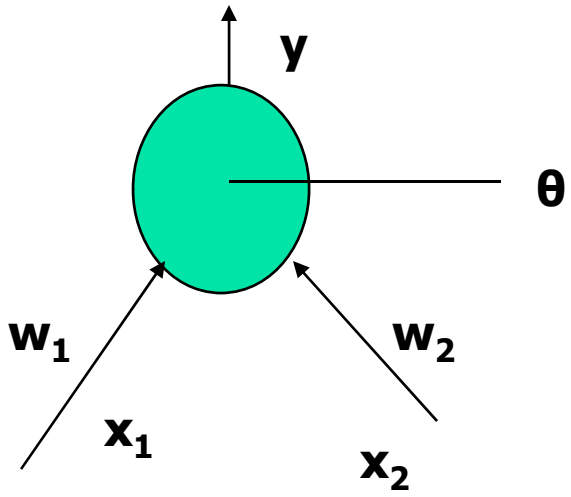
- **y= f(net)**: Relation between y and net is non-linear

Computation of Boolean functions

AND of 2 inputs

X1	x2	y
0	0	0
0	1	0
1	0	0
1	1	1

The parameter values (weights & thresholds) need to be found.



Computing parameter values

$w1 * 0 + w2 * 0 <= \theta \rightarrow \theta >= 0$; since y=0

$w1 * 0 + w2 * 1 <= \theta \rightarrow w2 <= \theta$; since y=0

$w1 * 1 + w2 * 0 <= \theta \rightarrow w1 <= \theta$; since y=0

$w1 * 1 + w2 * 1 > \theta \rightarrow w1 + w2 > \theta$; since y=1

$w1 = w2 = = 0.5$

satisfy these inequalities and find parameters to be used for computing AND function.

Other Boolean functions

- **OR can be computed using values of w1 = w2 = 1 and = 0.5**

- **XOR function gives rise to the following inequalities:**

  $w1 * 0 + w2 * 0 <= \theta \rightarrow \theta >= 0$

  $w1 * 0 + w2 * 1 > \theta \rightarrow w2 > \theta$

  $w1 * 1 + w2 * 0 > \theta \rightarrow w1 > \theta$

  $w1 * 1 + w2 * 1 <= \theta \rightarrow w1 + w2 <= \theta$

  No set of parameter values satisfy these inequalities.

Threshold functions

n	# Boolean functions (2^{2^n})	#Threshold Functions (2^{n^2})
1	4	4
2	16	14
3	256	128
4	64K	1008

- Functions computable by perceptrons - threshold functions
- #TF becomes negligibly small for larger values of #BF.
- For n=2, all functions except XOR and XNOR are computable.