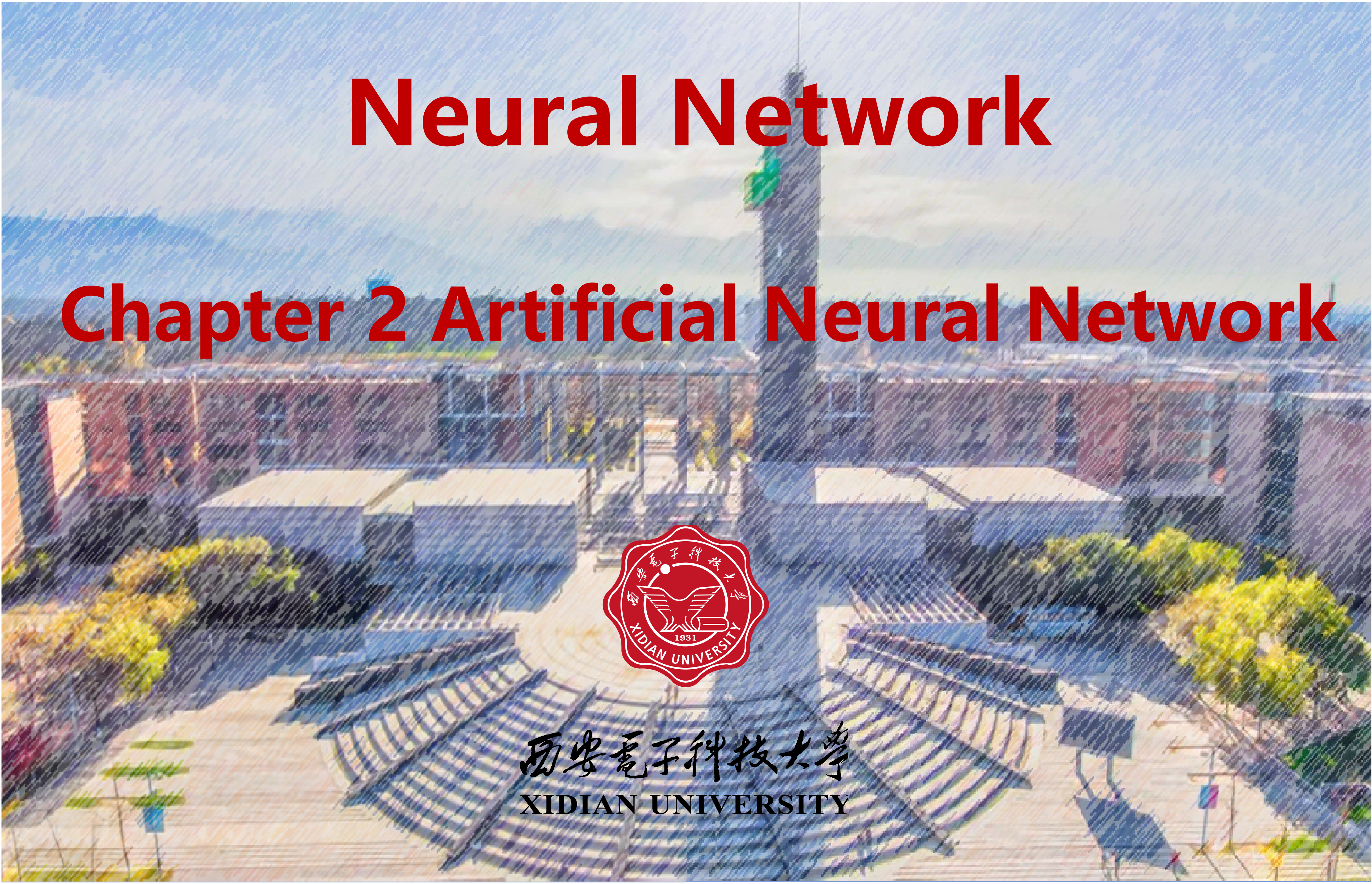
Neural Network

Chapter 2 Artificial Neural Network



西安電子科技大學

XIDIAN UNIVERSITY

Outline

01 Basic Conception

02 Brain Function

03 Biological Neuron

04 Artificial Neuron

01 Basic Conception

OAL: This course will bring you to a fascinating scientific journe
inside your own brain & its computational mechanism!

This course will bring you to a fascinating scientific journeys inside your own brain & its computational mechanism!

Understanding what individual neurons in your neocortex do with the roughly 10K synaptic (突触) input signals that they receive from other neurons.

The neocortex is the most evolutionarily recent part of the brain, and is where most of your thinking takes place.

Basic Conception

- # of neurons and synapses between neurons in the neocortex are astounding: roughly 20 billion neurons, each of which is interconnected with roughly 10K others.
  - *Estimates of the size of stable human social networks are only around 150-2 people.*

- At these scales, the influence of any one neuron on any other is relatively smal But it can be shaped in powerful ways through learning mechanisms, to achiev complex and powerful forms of information processing.

- Learning in Brian requires little complexity from the individual neurons themselves --- fairly simple forms of information integration (1) accurately describe the response properties of neurons, and (2) enable sophisticated information processing at the level of aggregate neural networks.

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Foundational issues in cognitive computing
Basic neural information processing mechanisms

Vision

We can effortlessly recognize countless people, places, and things. Why is this so hard robots? We will explore this issue in a network that views natural scenes (mountains, tr etc.), and develops brain-like ways of encoding them using principles of learning.

Attention:

Where's Handsome GU? We'll see in a model how two visual processing pathways wor together to help focus our attention in different locations in space (whether we are sear for something or just taking things in), and why damage to one of these pathways leads people to ignore half of space.

Dopamine and Reward:

Why do we get bored with things so quickly? Because our dopamine system is constantly adapting to everything we know, and only gives us rewards when something new or diffe occurs. We'll see how this all happens through interacting brain systems that drive dopam release.

Memory:

How can damage to a small part of our brain cause amnesia (记忆缺失)? We'll see how model that replicates the structure of the hippocampus(海马区). This model provides ins nto why the rest of the brain isn't well-suited to take on the job of forming new episodic memories.

Basic Conception

. **Meaning:**

We'll explore meaning through a network that "reads" every paragraph in a textbook, acquires a surprisingly good semantic understanding by noting which words tend to b used together or in similar contexts.

. **Task directed behavior:**

How do we stay focused on tasks that we need to get done or things that we need to p attention to, in the face of an ever-growing number of distractions (like email, phone calls, and Wechat)? We'll explore this issue through a network that simulates the "executive" part of the brain, the prefrontal cortex. We will see how this area is uniqu suited to protect us from distraction.

hy Should We Care about the Brain?

Commonly, we don't need to know much of anything about how computer ardware works to program. Vastly different kinds of hardware can all run th ame programming languages and software. Can't we just focus on the softw f the mind and ignore the hardware?

Wouldn't it just be a lot simpler if we could ignore all brain details, and just ocus on what we really care about?

How does cognition itself work?

David Marr (Marr, 1977) argued that one can somewhat independently examine cognition at three different levels:

Computational:

what computations are being performed? What information is being processed?

Algorithmic:

how are these computations being performed, in terms of a sequence of information processing steps?

Implementational:

how does the hardware actually implement these algorithms?

3y dividing up the problem, one can safely ignore the implementation (i.e., t rain), and focus on the computational and algorithmic levels. Like in a omputer, the hardware really doesn't matter so much.

- It holds because hardware are all specifically designed to be functionally equivalent i the first place. They are all implementing a basic serial Von Neumann architecture.

n the 1960's through the early 1990's, the dominant approach was to assume nat the brain actually operates much like a standard computer, and researche ended to use concepts like logic and symbolic propositions in their cognitive nodels.

Since then, a more statistical operator has become popular, with the Bayesia probabilistic framework being widely used. It emphasizes the graded nature nformation processing in the brain.

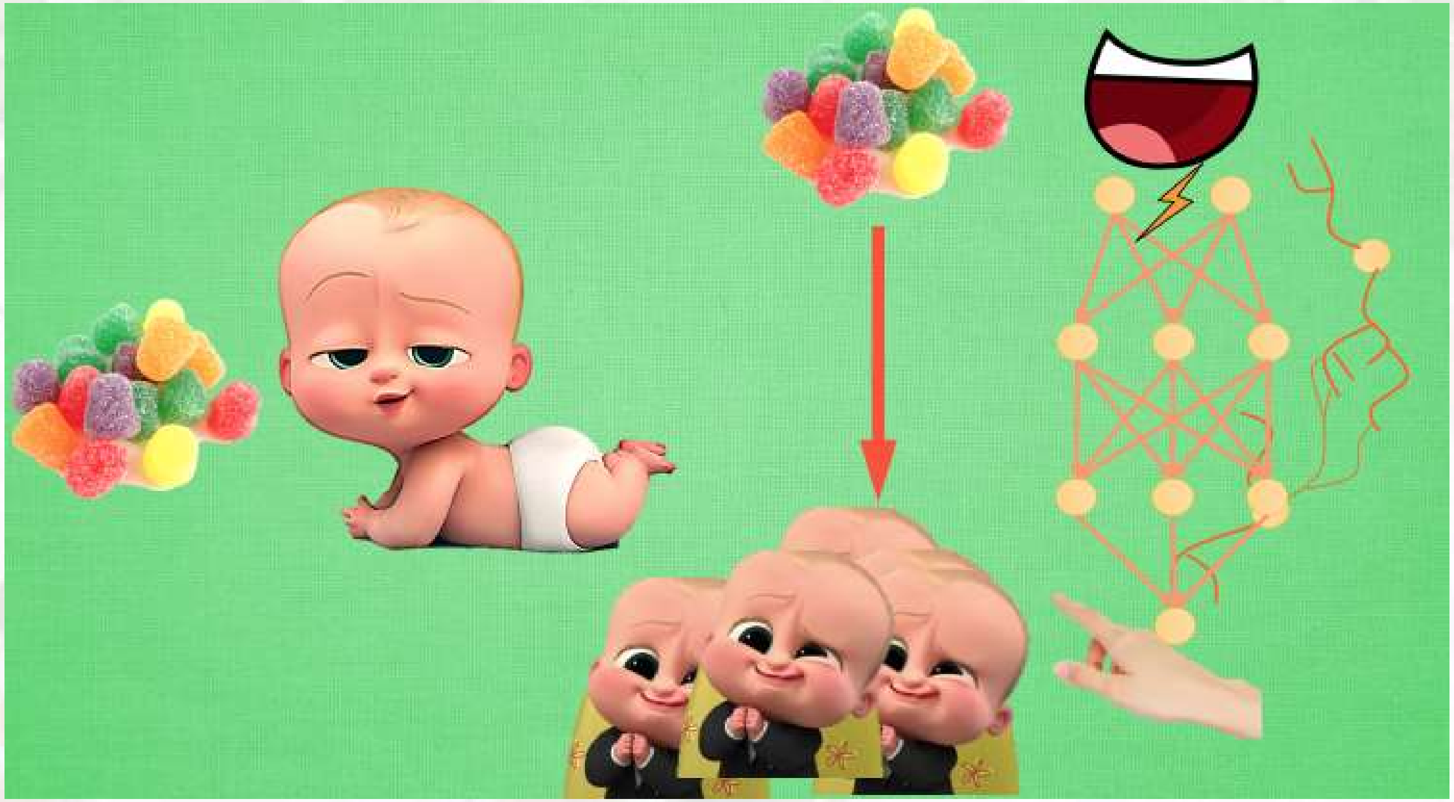
However, the Bayesian probability computations are not a particularly good o how the brain operates at the neural level.

n fact, the brain is not at all like a general purpose computational device.

02

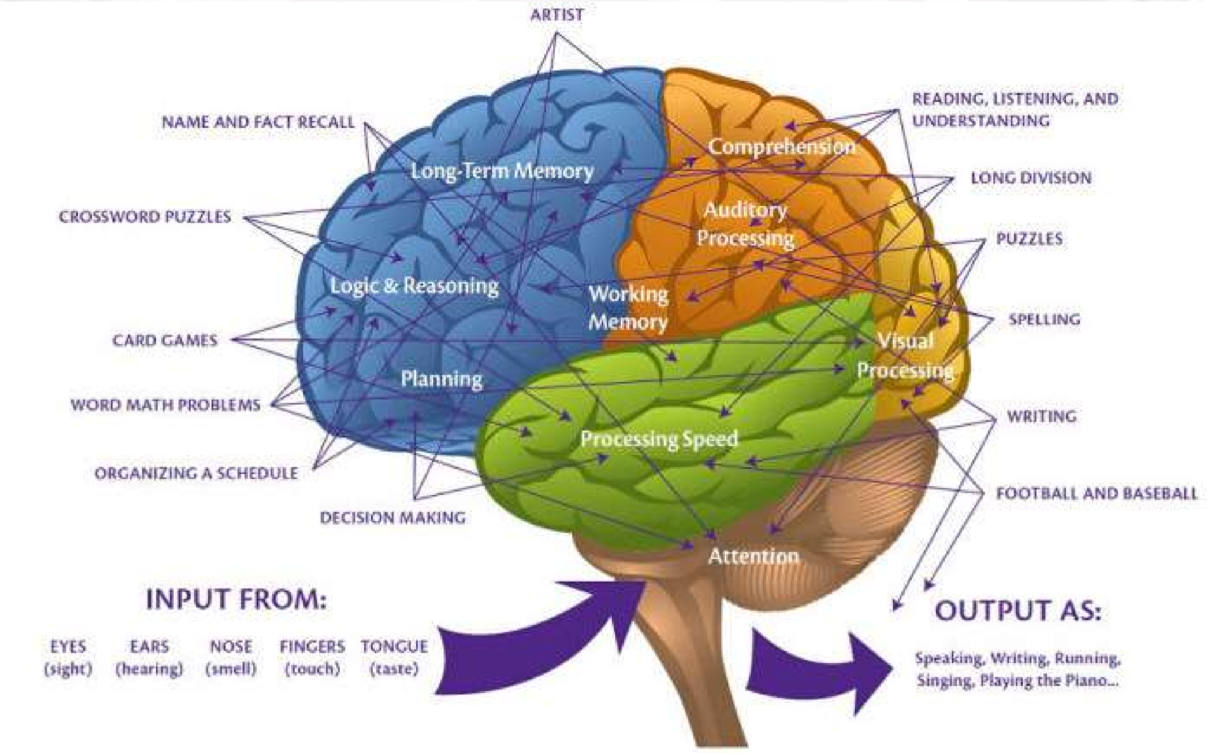
Brain Function

Brian Learning Function



- EYES
- EARS
- NOSE
- FINGERS
- TONGUE
- …..

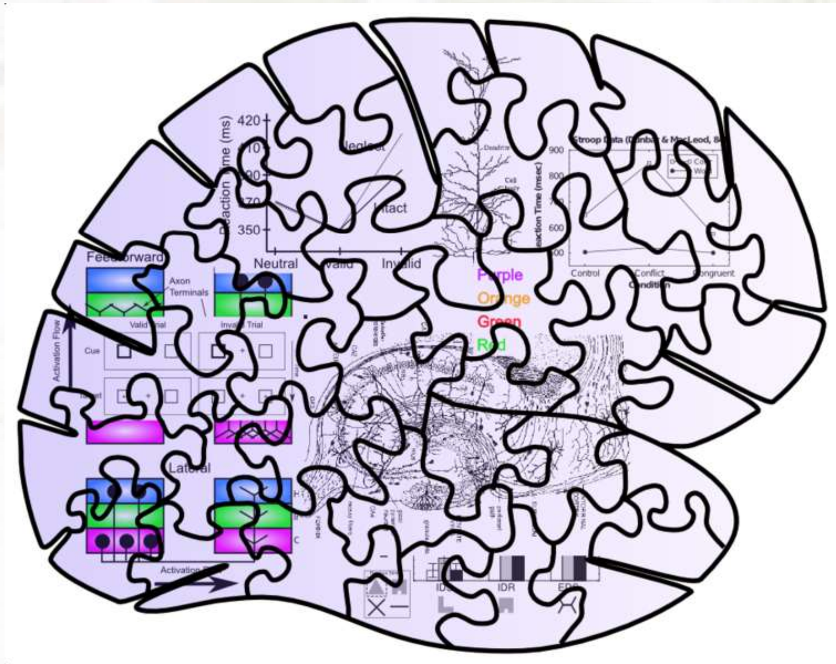
Brian Function



- Speaking
- Writing
- Running
- Singing
- ….

How do we know the brain actually functions?

Ideally, we wish to work on a such puzzle -- the easiest puzzles are full of distinctive textures and junk everywhere, so you can really see when the pieces fit together.



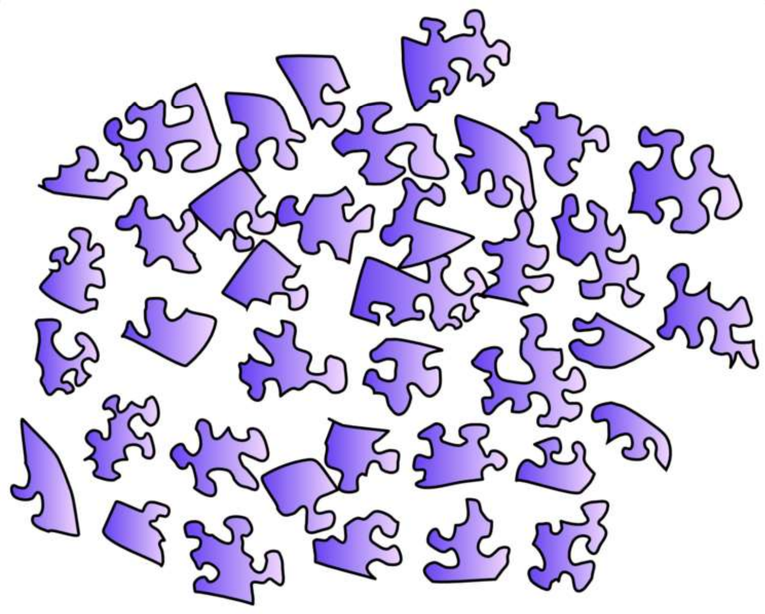
We wish neuroscience provides the rich tableau of all this distinctive junk to constrain the process of puzzling together cognition.

Adding constraints from biology and detailed consideration of behavior provide a rich set of clues for figuring out how to solve the puzzle of the brain!

How do we know the brain actually functions?

In reality, abstract, purely cognitive models are like a puzzle with only a big featureless blue sky.

Only have the logical constraints of the piece shapes, which are all highly similar and difficult to discriminate.



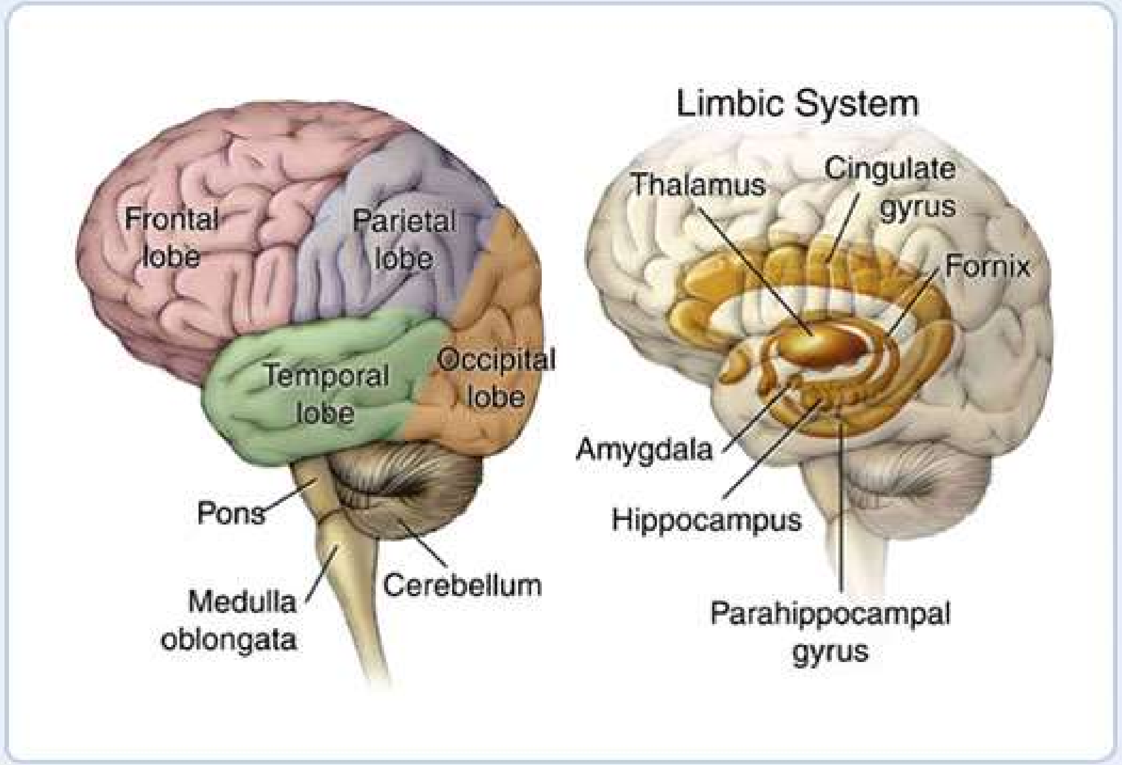
Brain Function

It would be better to exploring a wide range of cognitive phenomena.

The big picture view of the overall functional organization of the brain.

It helps you understand at a broad level how different brain areas wo together to perform different cognitive functions.

Brain Function



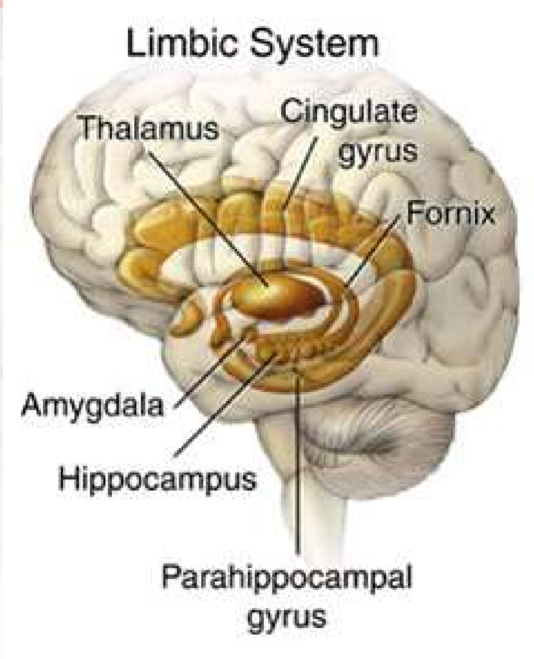
Gross anatomy of the brain. Left panel shows the major lobes of the outer *neocortex* layer of the brain, and right panel shows some of the major brain areas internal to the neocortex.

The outer portion is the "wrinkled sheet" (upon which our thoughts rest) of the neocorte showing all of the major lobes. This is where most of our complex cognitive function occurs.

The inner portion are generally referred to as subcortical (皮质下) brain areas.

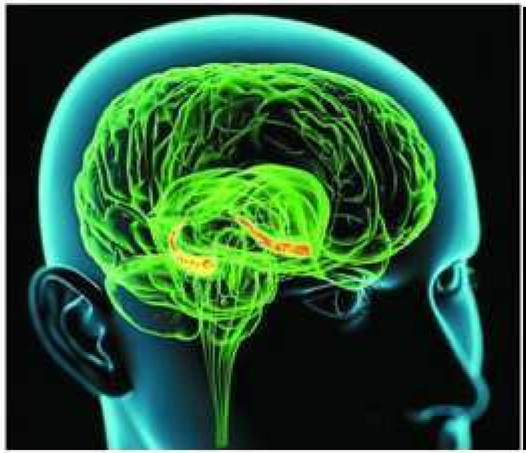
Hippocampus (海马区)

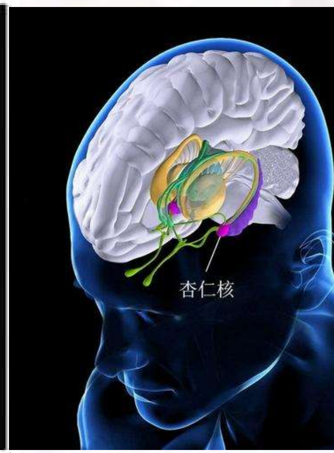
This brain area is actually an "ancient" form of cortex called "archicortex", and it plays a critical role in learning new "everyday" memories about events and facts.



Amygdala (杏仁核)

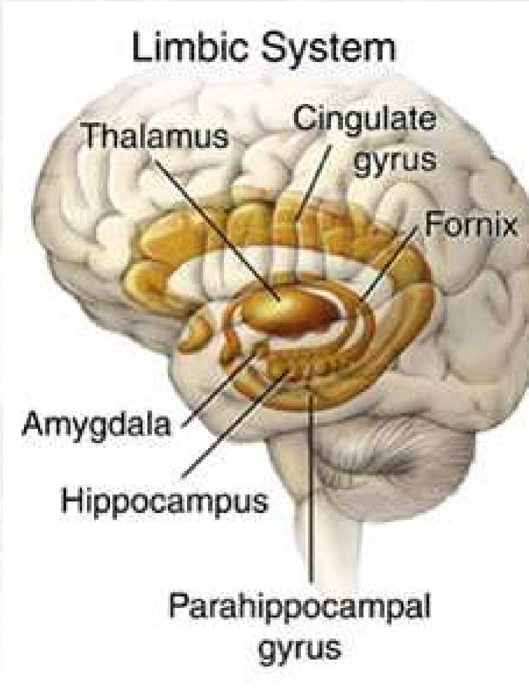
This brain area is important for recognizing emotionally salient stimuli, and alerting the rest of the brain about them. It plays an important role in reinforcing motor (and cognitive) actions based on reward (and punishment).





halamus(丘脑)

 provides the primary pathway for sensory information on its ay to the neocortex, and is also likely important for attention, rousal, and other modulatory functions. It plays roles in erception and Attention and in Motor Control and einforcement Learning.



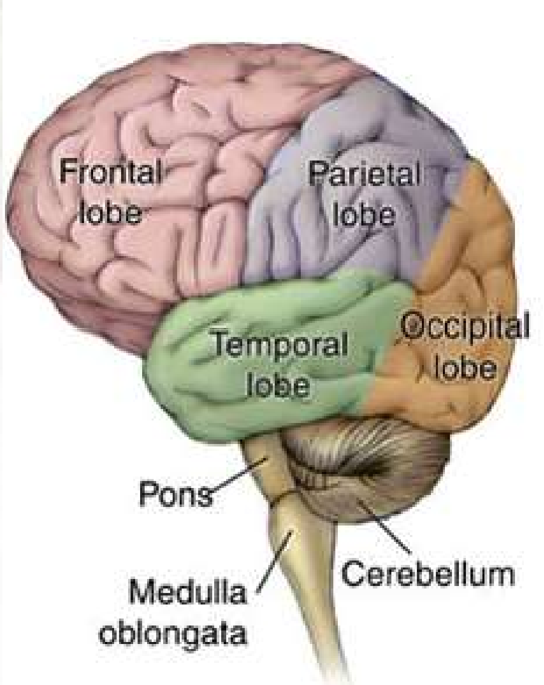
asal Ganglia(基底核)

his is a collection of subcortical areas that plays a ritical role in Motor Control and Reinforcement Learning, and so in Executive Function. It helps to make the final "Go" call on hether (or not) to execute particular actions that the cortex roposes', and whether or not to update cognitive plans in the refrontal cortex.

Cerebellum(小脑)

This massive brain structure contains 1/2 of the neurons in the brain, and plays an important role in motor coordination. It is also active in most cognitive tasks.

Understanding exactly what its functional role is in cognition remains somewhat elusive.

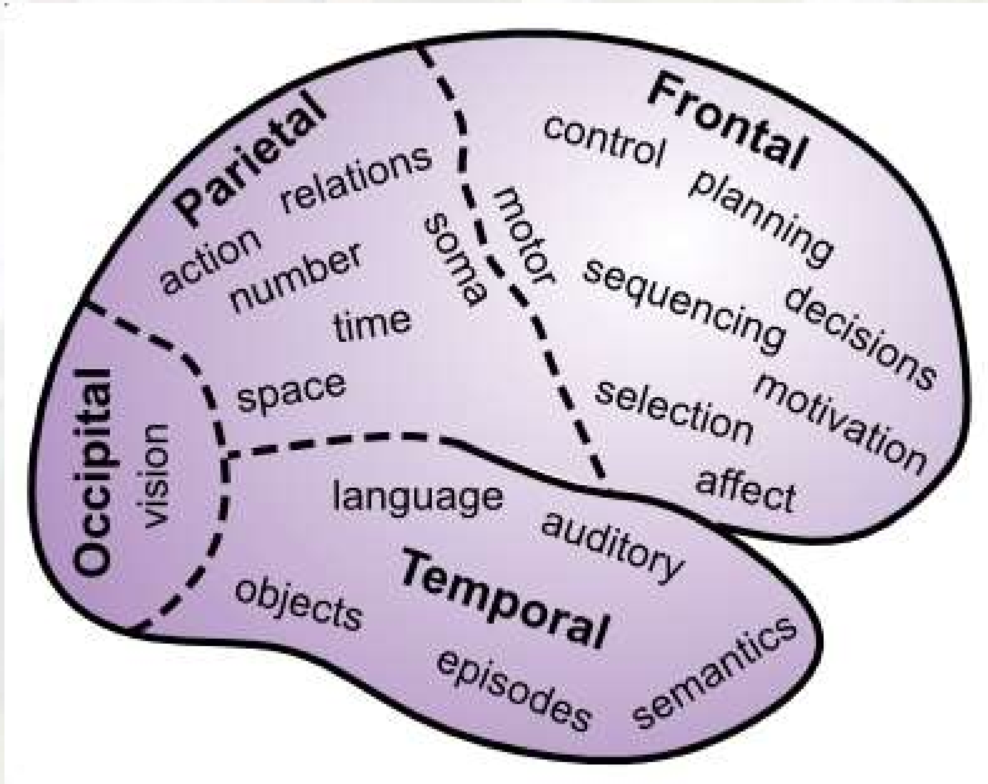


- The structure of the neocortex, in terms of **Brodmann areas**

identified by Korbinian Brodmann on the basis of anatomical (解剖) differences, principally the differences in thickness of different cortical layers.

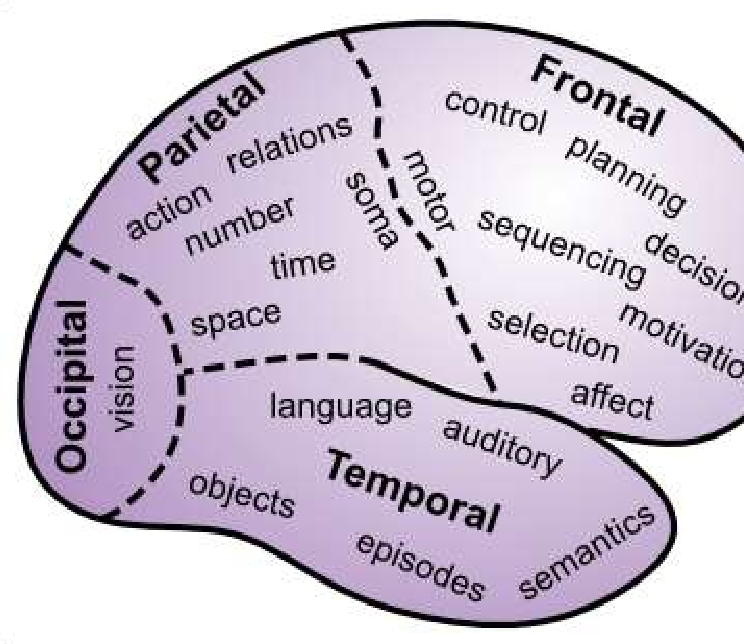
- **Occipital lobe (枕叶)**

this contains primary visual cortex (V1), located at the very back tip of the neocortex, and higher-level visual areas that radiate out (forward) from it. Clearly, its main function is in visual processing.



Temporal lobe

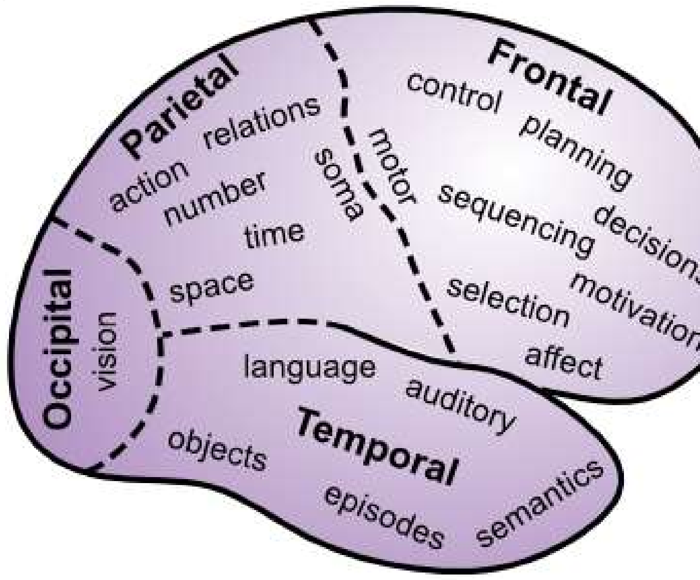
superior temporal cortex contains primary auditory cortex (A1), and associated higher-level auditory and language-processing areas. Thus, the temporal lobes (one on each side) are where the visual appearance of objects gets translated into verbal labels (and vice-versa), and also where we learn to read.



the temporal lobes appears to be important for semantic knowledge -- where all your high-level understanding of things. It contain a huge amount of the stuff that we are consciously aware of -- facts, events, names, faces, objects, words, etc.

Frontal lobe (前叶)

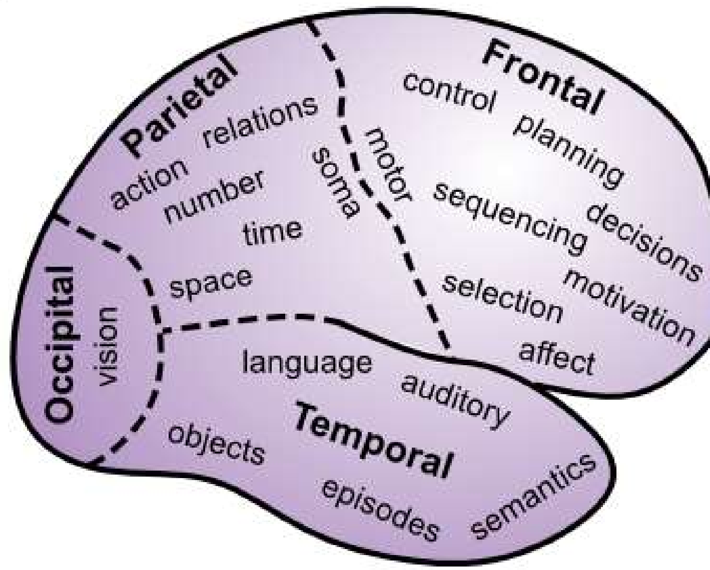
The prefrontal cortex (PFC), known as the brain's executive -- this is where all the high-level shots are called -- where your big plans are sorted out and influenced by basic motivations and emotions, to determine what you really should do next.



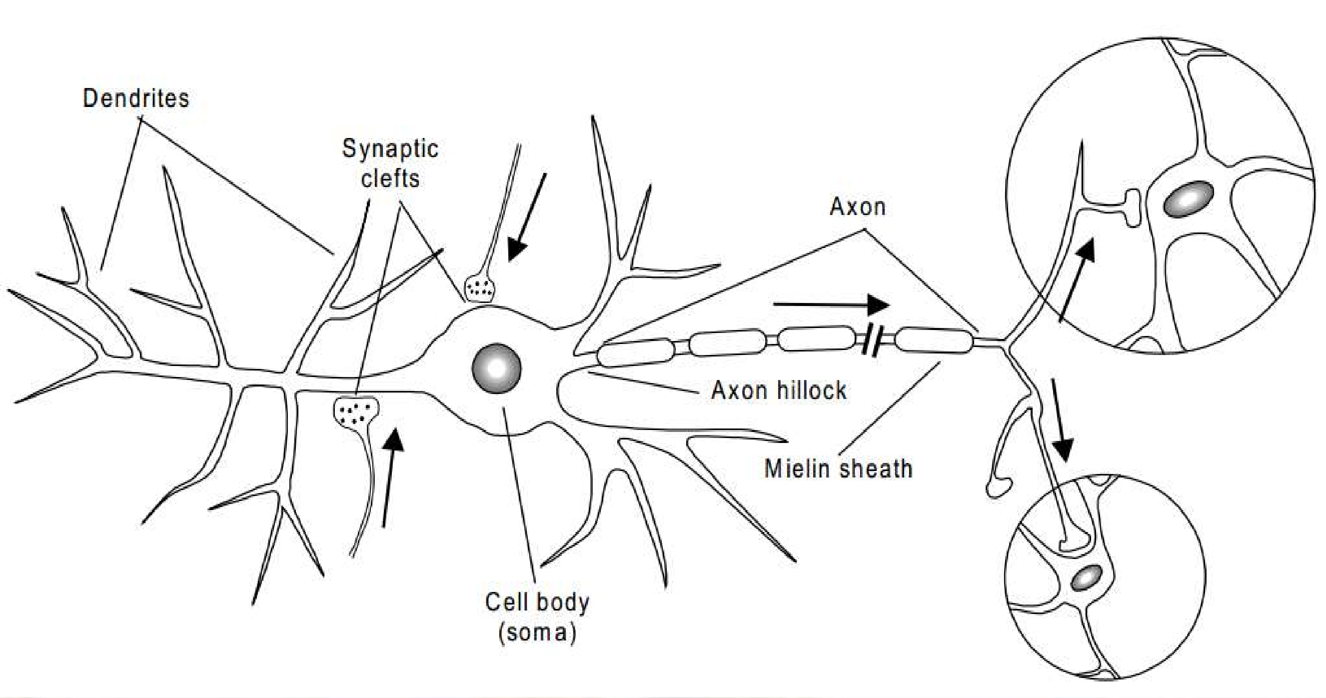
It is important for the most abstract, challenging forms of cognitive reasoning. The medial and ventral regions of the frontal cortex are particularly important for emotion and motivation.

Parietal lobe (顶叶)

It is important for encoding spatial locations, number, mathematics, abstract relationships, and many other "smart" things. It provides the major pathway where visual information can guide motor actions.



Brain is powerful because billions of individual neurons are densely interconnected with each other, and capable of shaping what they do by changing these patterns of interconnections.



This complexity is in the service of a very simple overall function "detection".

- Neurons receive thousands of different input signals from other neurons, looking for specific patterns that are "meaningful" to them. The valuable signal is called "spike", which is the fundamental unit of communication between neurons.

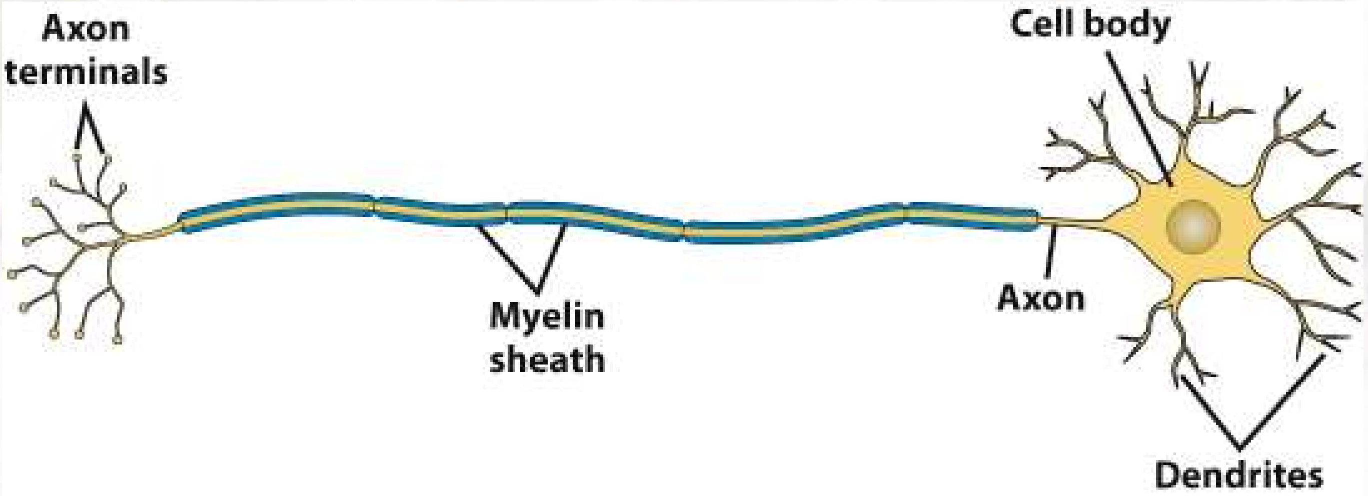
- The neuron receives input signals from other neurons, integrates them into an overall signal strength that is compared against the threshold, and communicates the result to other neurons.

03

Biological Neuron

WHAT is a Neuron ?

Biological Neuron



Neuron consists of:

1. Cell body
2. Dendrites
3. Axon
4. Synapses

Biological Neuron

The Neuron - A Biological Information Processor

- ***dentrites* (树突)** - the receivers
- ***soma*** (细胞体) - neuron cell body (sums input signals)
- ***axon*** (轴突) - the transmitter
- ***Synapse* (突触)** - point of transmission
- neuron activates after a certain *threshold* is met

Learning occurs via electro-chemical changes in effectiveness of *synaptic junction*.

Function of Neuron

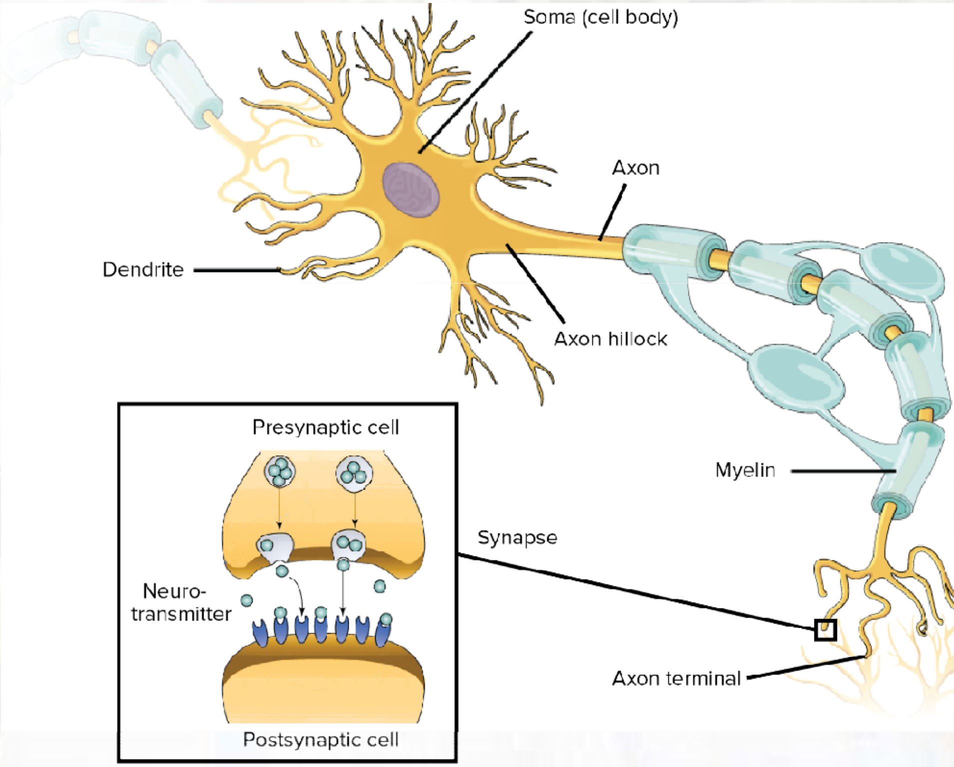
- euron collects signals from ***dendrites***

- ends out spikes of electrical activity through an ***axon***, which splits into thousands of branches.

- t end of each brand, a ***synapses*** converts activity into ither exciting or inhibiting activity of a dendrite at nother neuron.

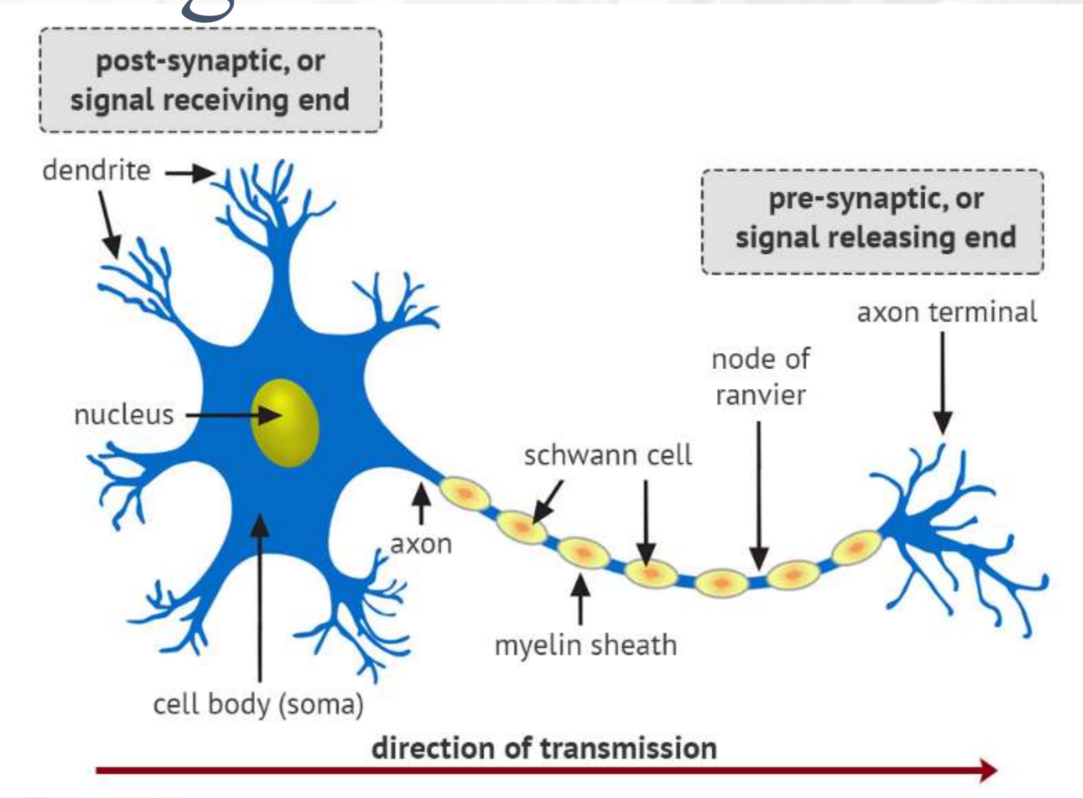
- euron ***fires*** when exciting activity surpasses inhibitory ctivity

- earning changes the effectiveness of the synapses



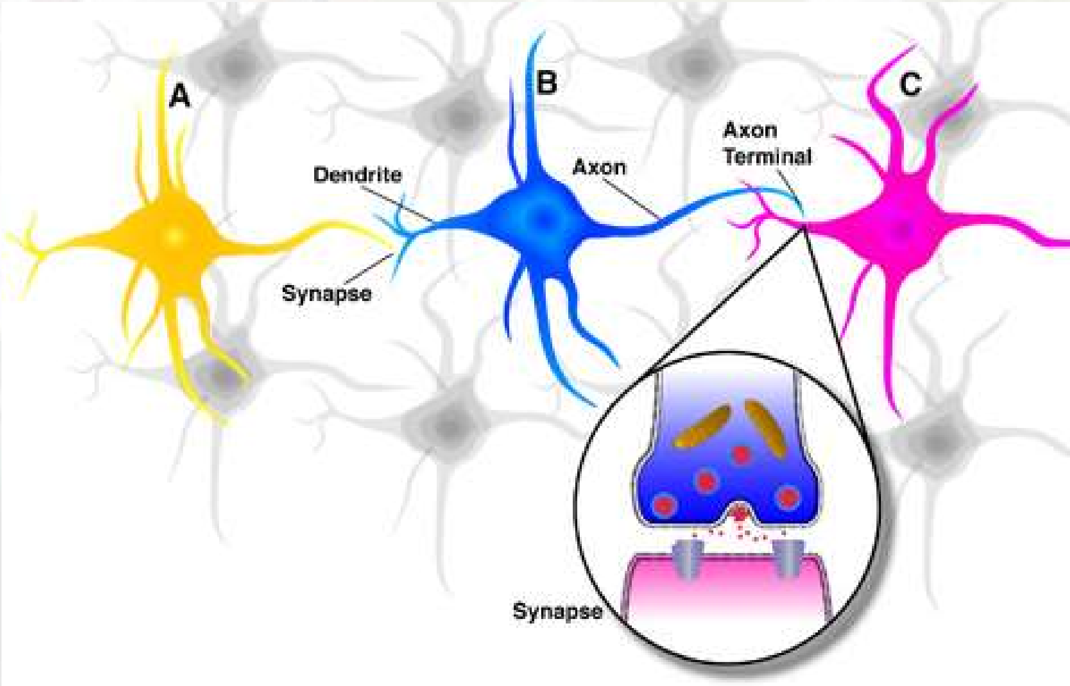
Neuron 'Signal' Transmission — Sending

- Signals "move" via electrochemical signals
- The synapses release a chemical transmitter – the sum of which can cause a threshold to be reached – causing the neuron to "fire"
- Synapses can be inhibitory or excitatory



Neuron 'Signal' Transmission—Receiving

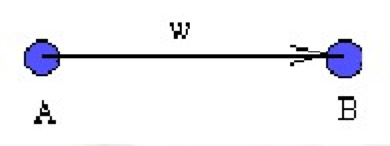
- A neuron receives input from other neurons (generally thousands) from its synapses
- Inputs are approximately summed
- When the input exceeds a threshold the neuron sends an electrical spike that travels that travels from the body, down the axon, to the next neuron(s)

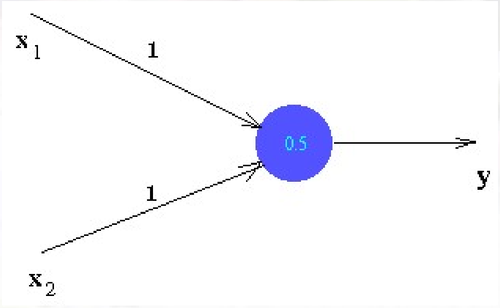


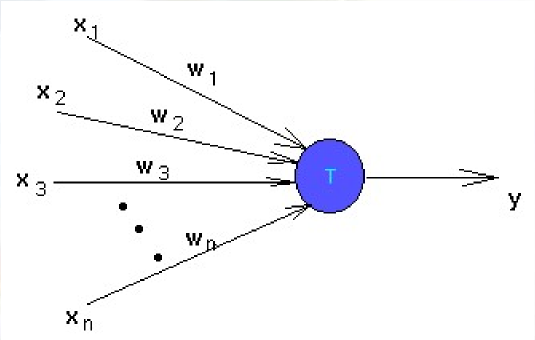
04

Artificial Neuron

How Neuron Transform to Mathematics formulation







Neuron to Math Simulation Function

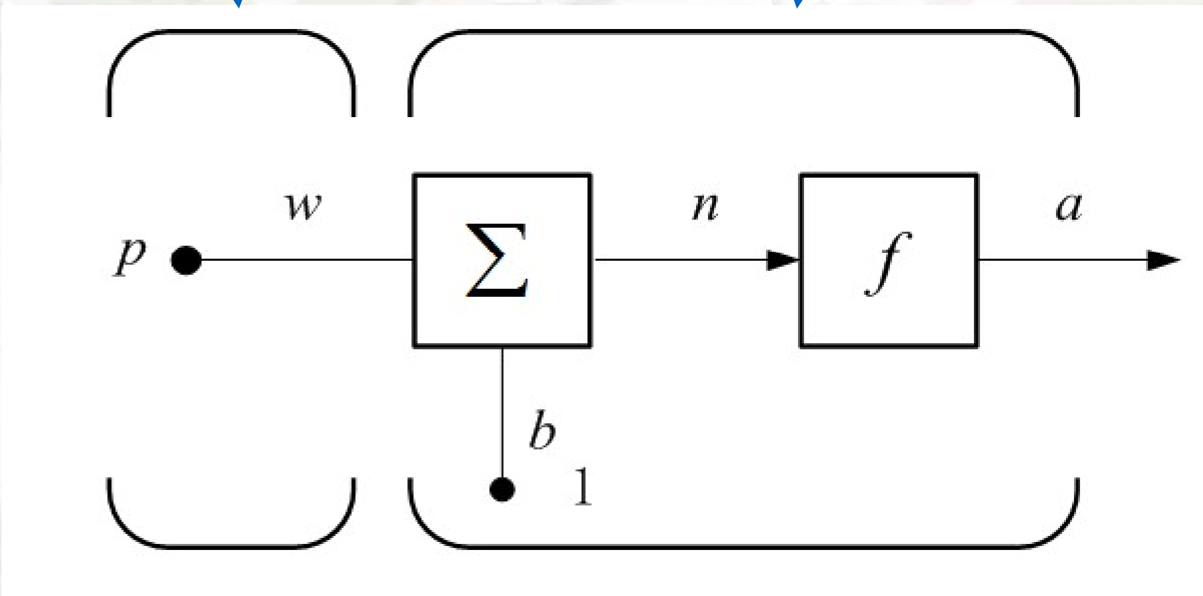
- ***input connections*** - the receivers (***dentrites***)
- ***node, unit, or PE*** simulates neuron body (***soma***)
- ***output connection*** - the transmitter (***axon***)
- ***bias function*** employs a threshold (***synapse***)
- ***activation function***
- ***connection weights***

Learning occurs via changes in value of the connection weights.

Single Input Neuron

Single Input

Basical Neuron Function



$$a = f\ (w\,p + b)$$

Neuron Output

Transmission Function

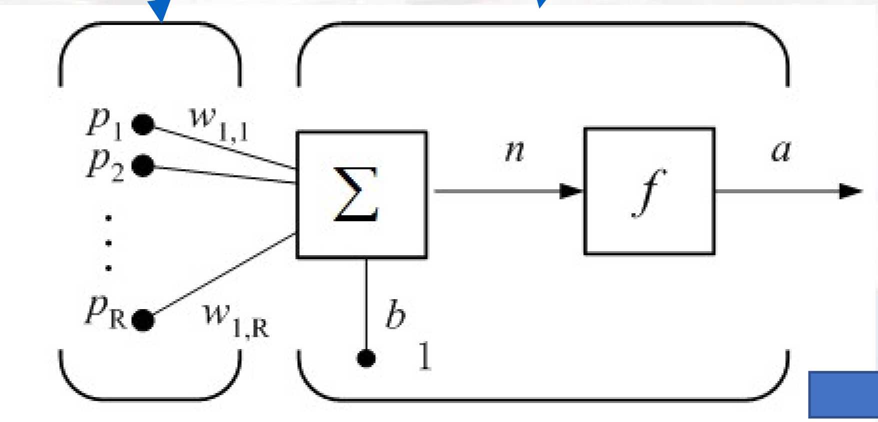
Weight

Input

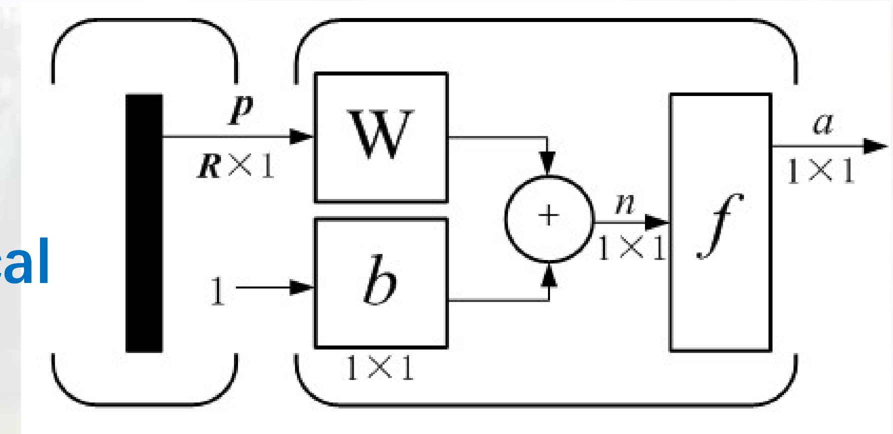
Bias

Multi Input Neuron

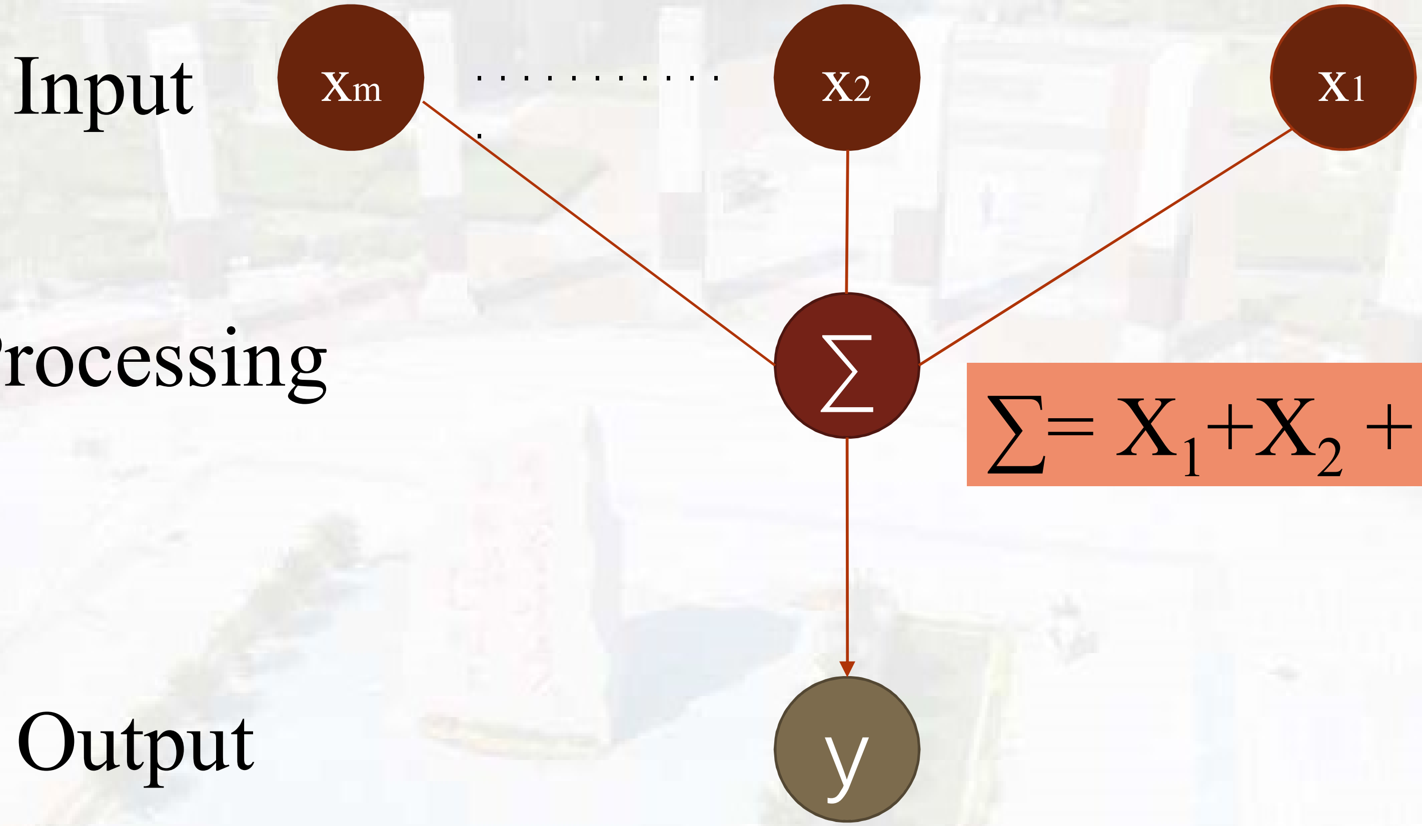
Multi Input Single Input



Mathematical



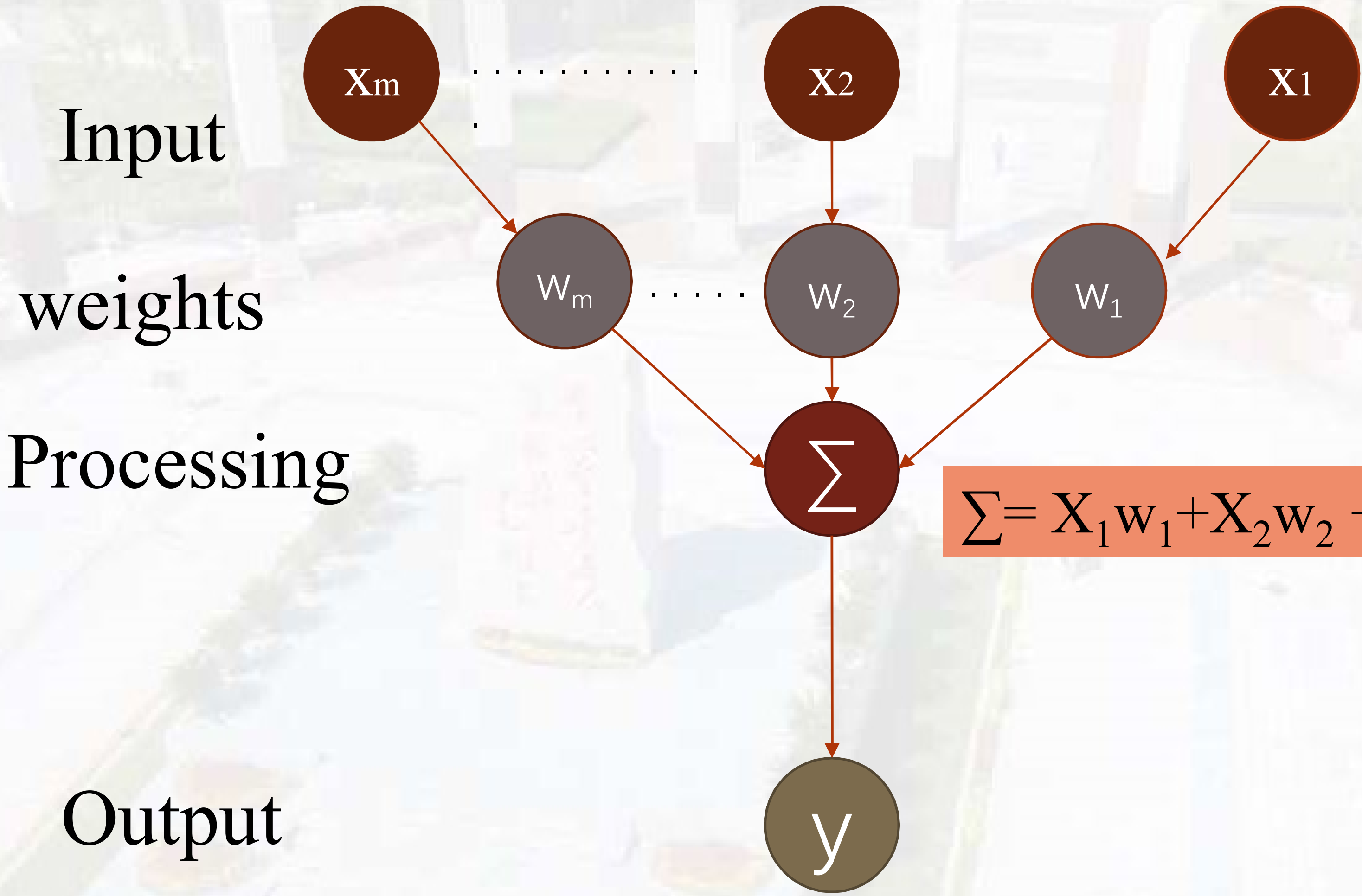
Artificial Neuron



$$\sum = X_1 + X_2 + \ldots + X_m = y$$

Artificial Neuron

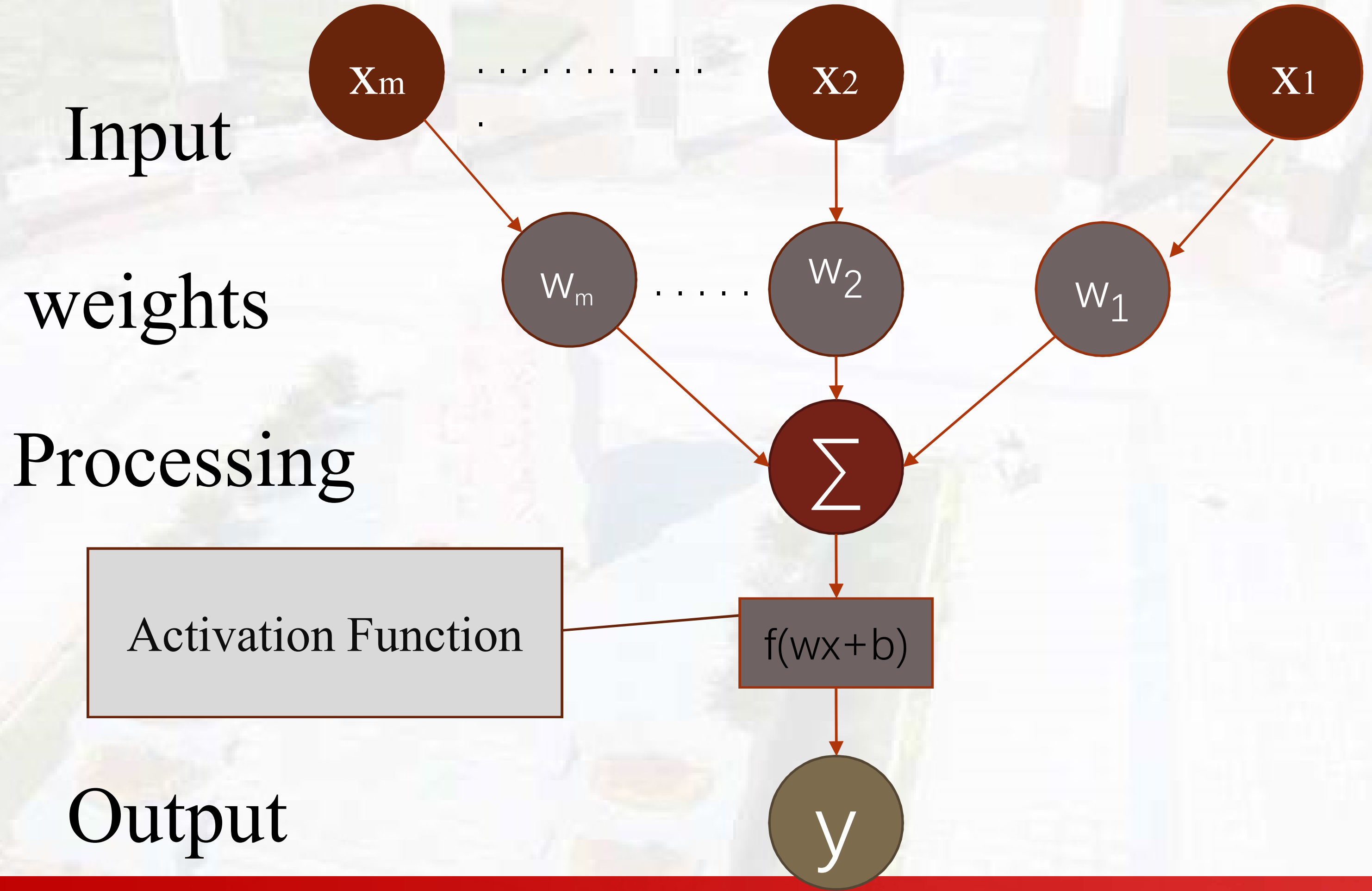
Not all inputs are equal



$$\sum = X_1w_1 + X_2w_2 + \ldots + X_mw_m = y$$

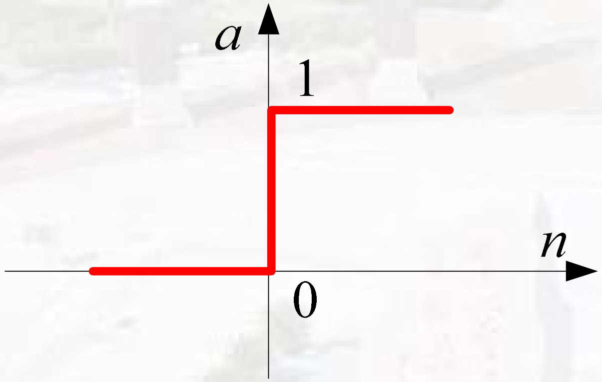
Artificial Neuron

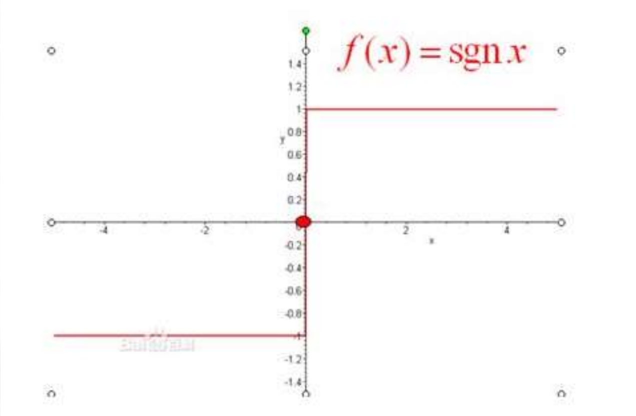
The signal is not passed down to the next neuron verbatim



Artificial Neuron

Activation Function(1) – Step Function



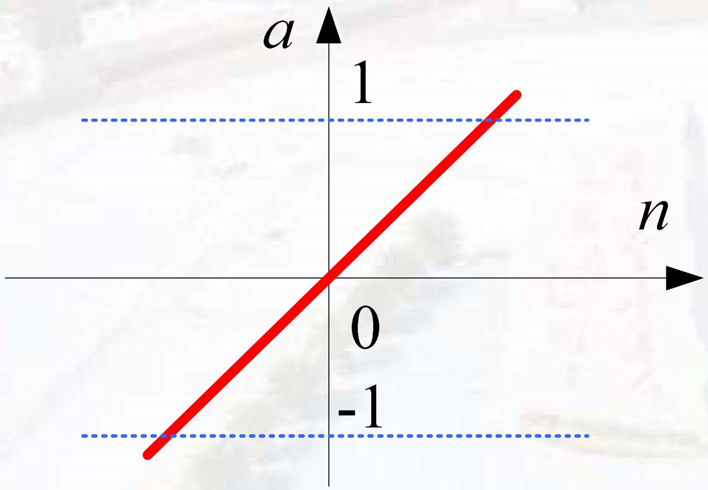


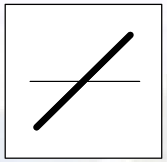
•Step Function

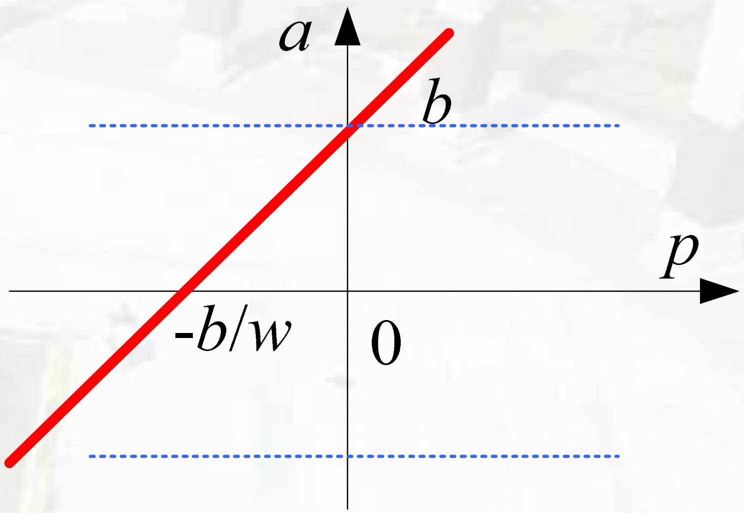
$$y=f(x)=\begin{cases}1, & x\geq 0\\ 0, & x<0\end{cases}$$

$$y=f(x)=\begin{cases}1, & x>0\\ -1, & x\leq 0\end{cases}$$

Activation Function(2) – Linear Function

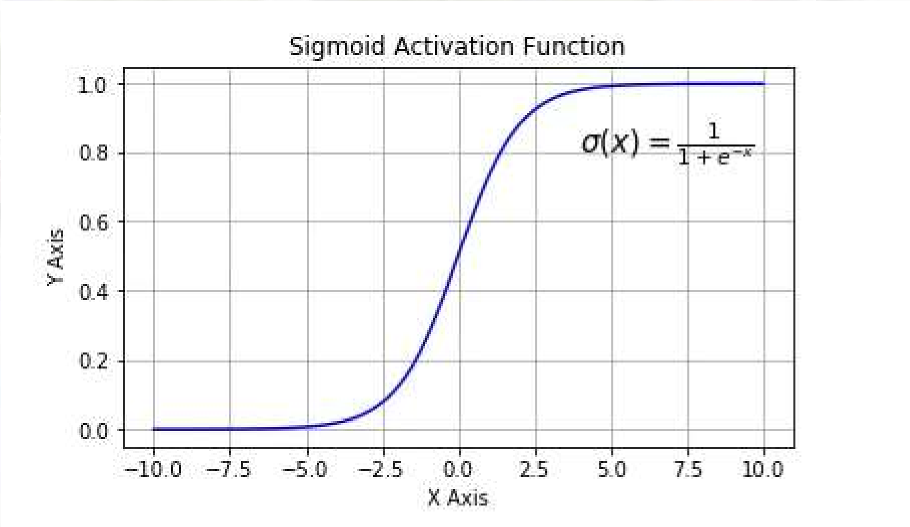


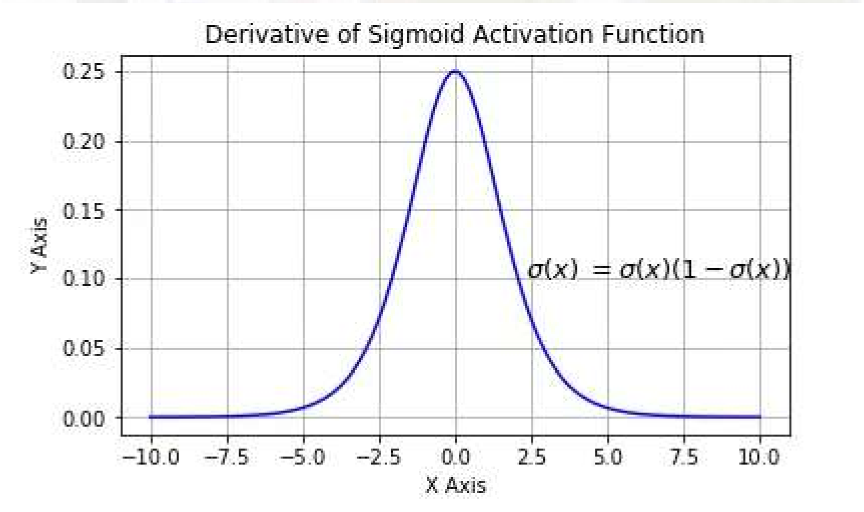




$$f(x) = kx + b$$

Activation Function(3) – Sigmoid Function

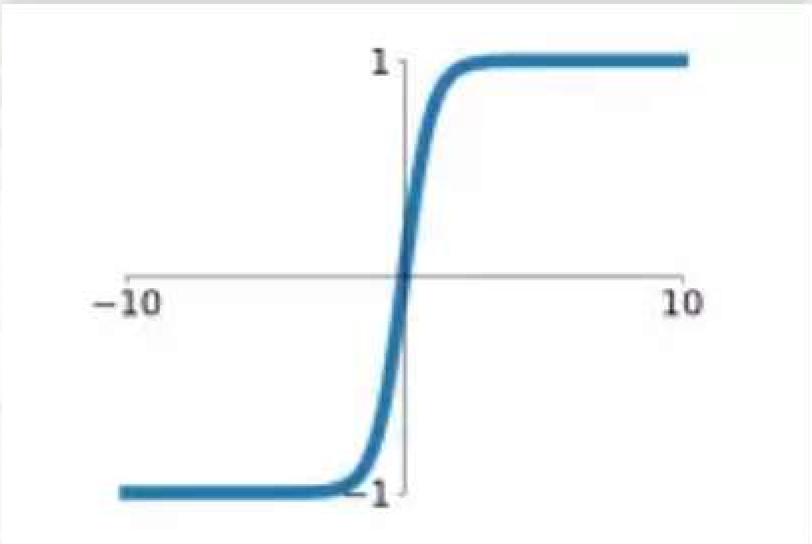




$$f(x) = \frac{1}{1+e^{-kx}}$$

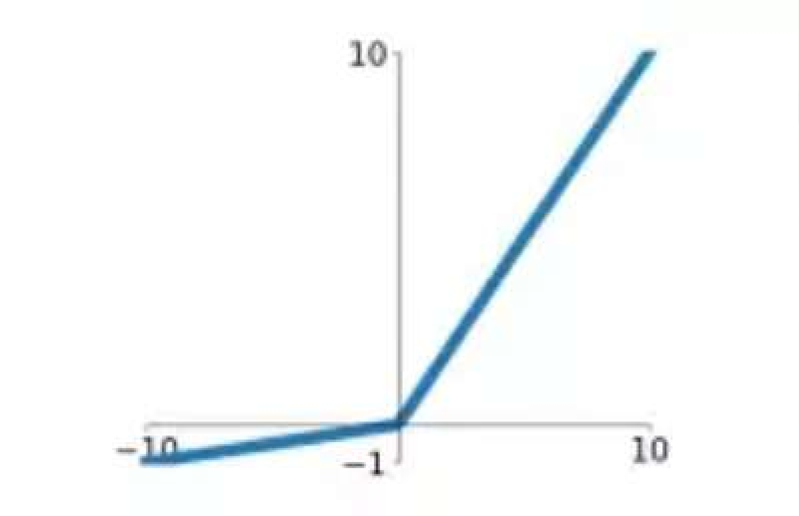
$$f'(x) = kf(x)\left[1 - f(x)\right]$$

Activation Function(4) – Tanh Function



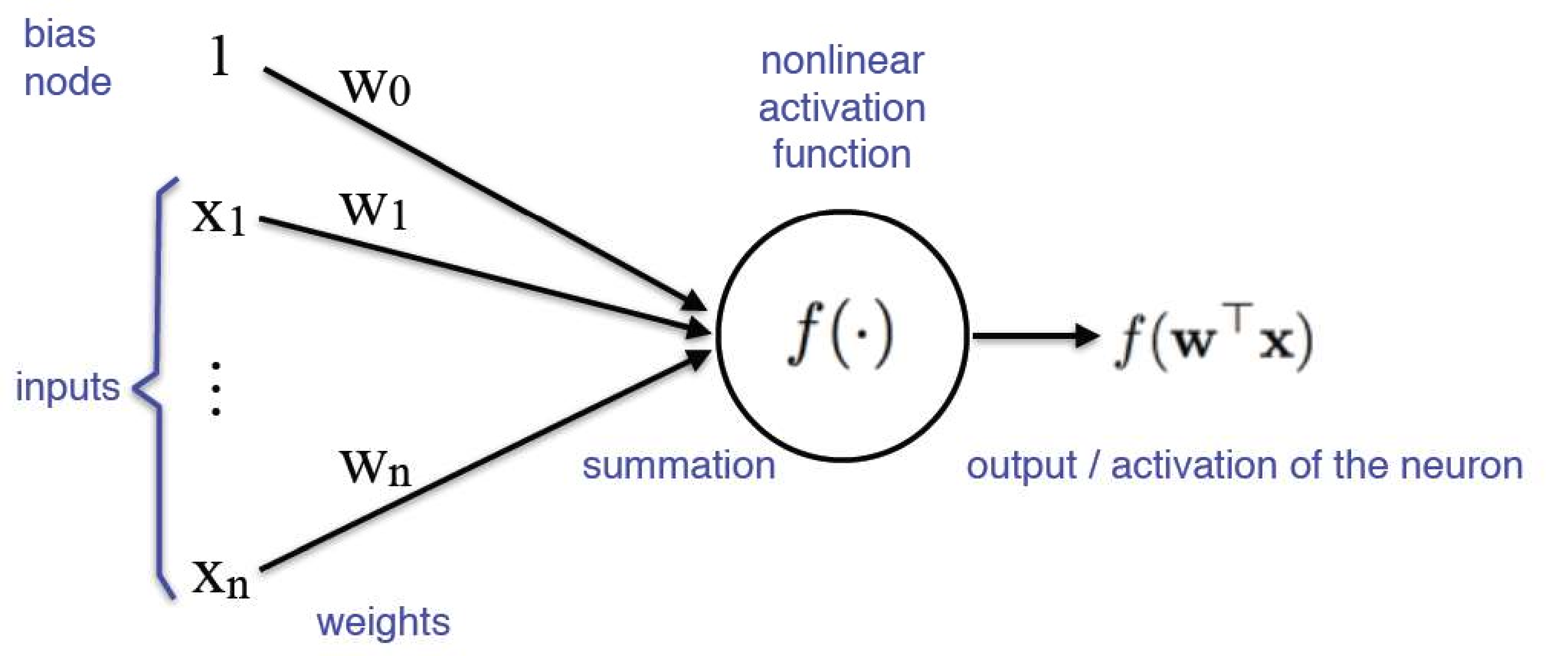
$$f(x) = \frac{1 - e^{-kx}}{1 + e^{-kx}}$$

Activation Function(5) – Leaky Relu Function

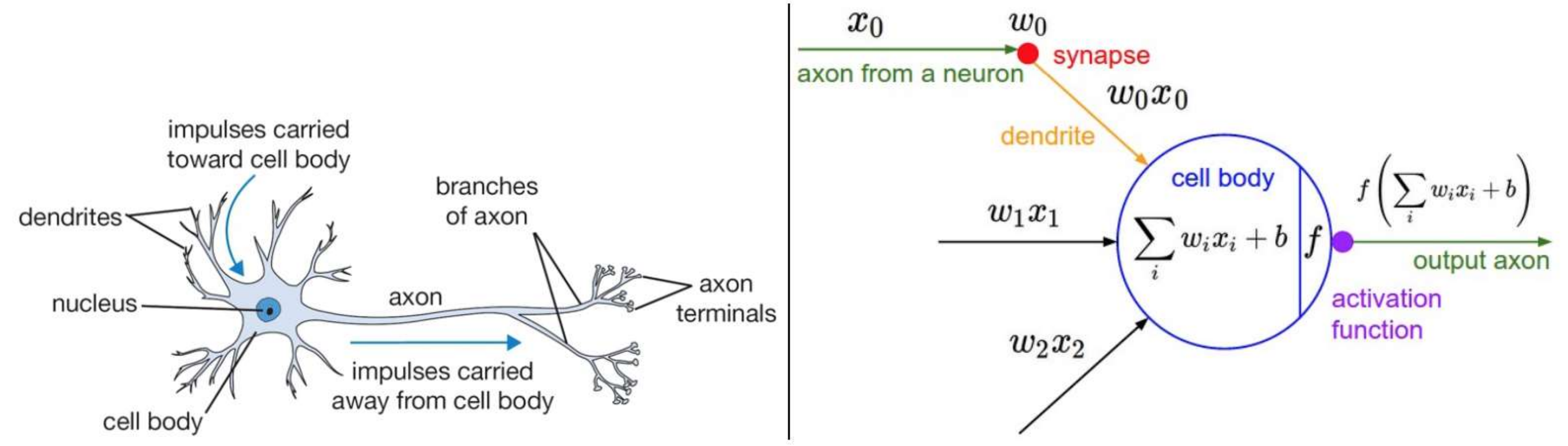


$$f(x) = \max(0.01x, x)$$

The Structure of Artificial Neuron



Mathematics formulation of Neuron (数学建模)



A cartoon drawing of a biological neuron (left) and its mathematical model (right).

THANK YOU

谢谢！