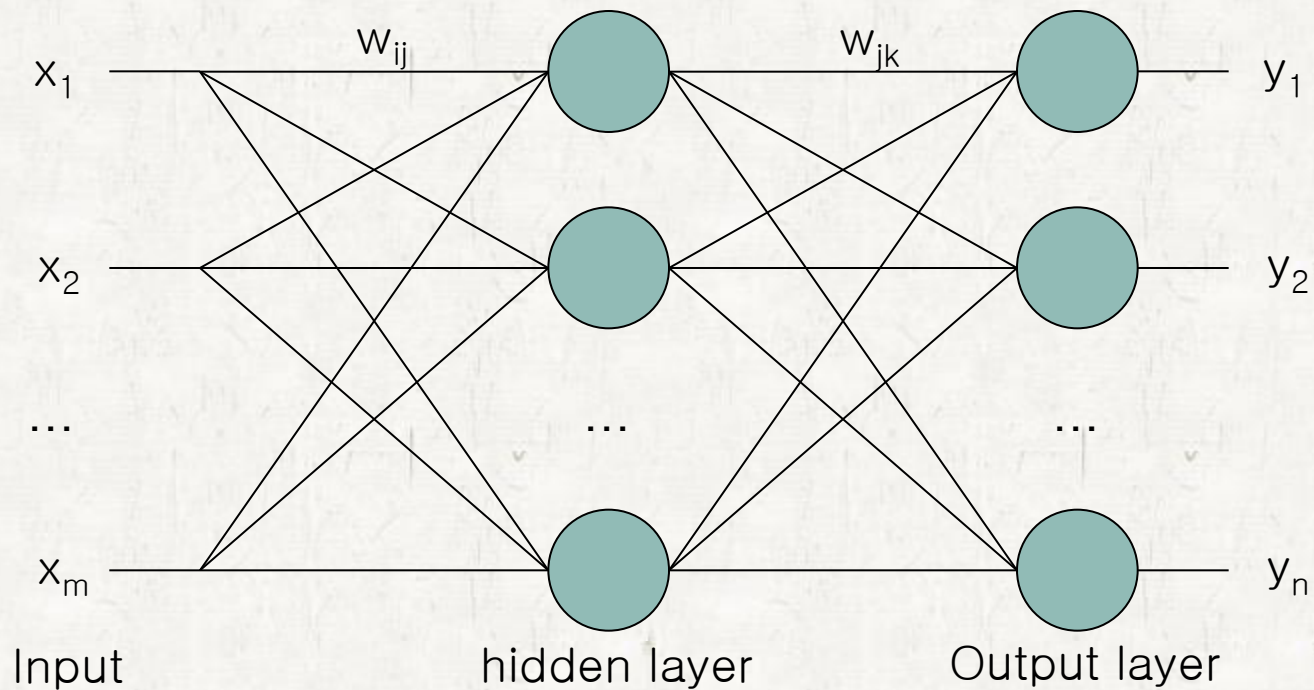# Introduction to Neural Networks

Introduction

Deep Learning = Deep Neural Network

- Deep? 그럼 Shallow Neural Network도 있겠네?

- Deep Neural Network 도 있고 Shallow Neural Network 도 있으면,
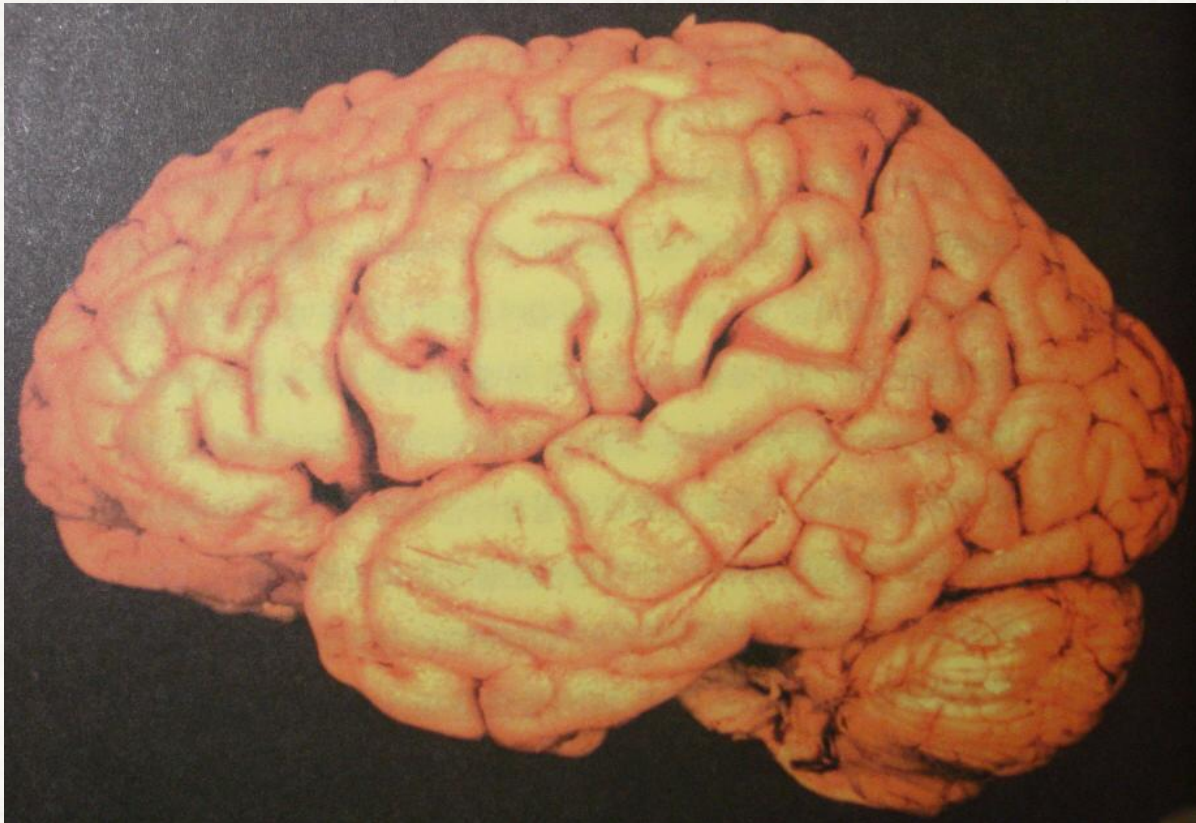
- 그럼, Neural Network은 뭐야?

- 왜, Neural 이야?

Introduction
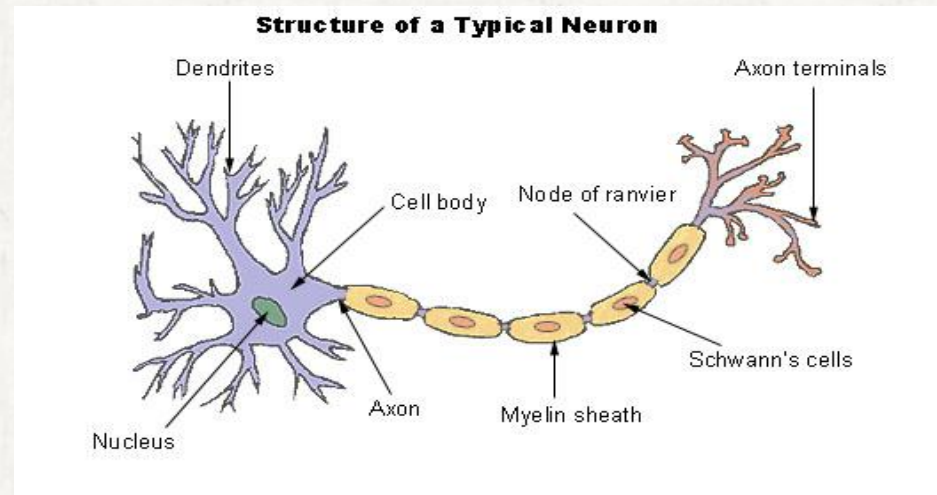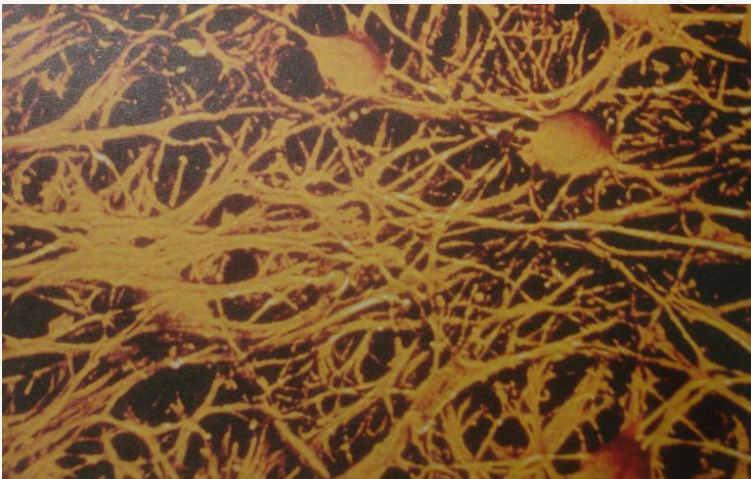
- Neural Network

Introduction

- Brain
 - There are about 10^{11} neurons (brain cells)

Introduction

- Neurons
  - Shape: Cell body, Dendrite, Axon
  - Every neuron connects to 10^3 to 10^4 other neurons
  - A brain is a network of neurons

Structure of a Typical Neuron

Dendrites

Axon terminals

Cell body

Node of ranvier

Schwann's cells

Nucleus
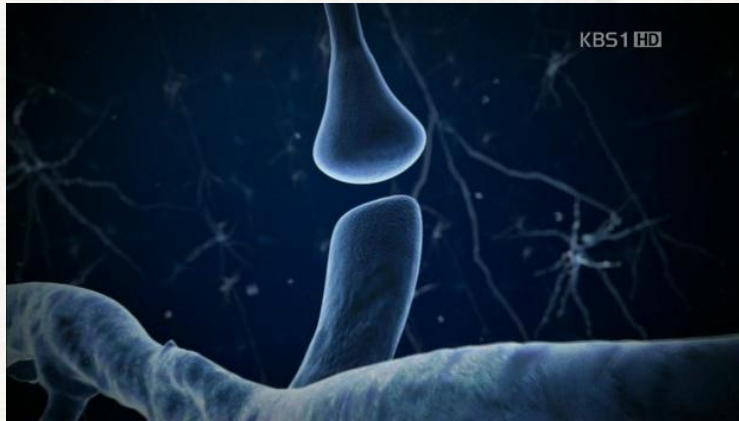
Axon

Myelin sheath

Introduction

- Connection between neuron
  - Synapse : Connection spot
  - Axon terminal : release neurotransmitter
  - Dendrite : receive neurotransmitter

Axon terminal

Dendrite
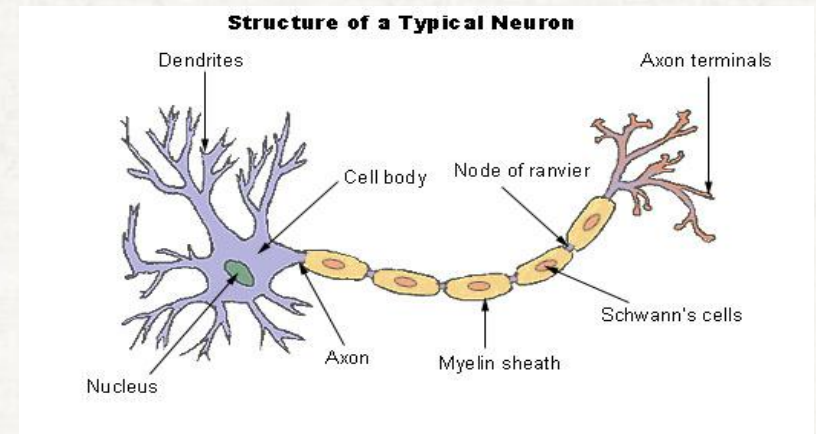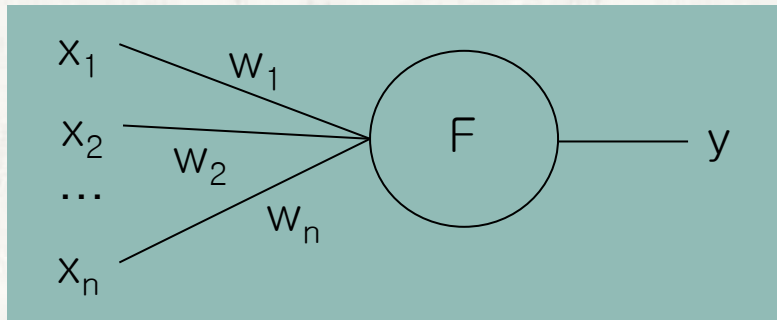
Synapse
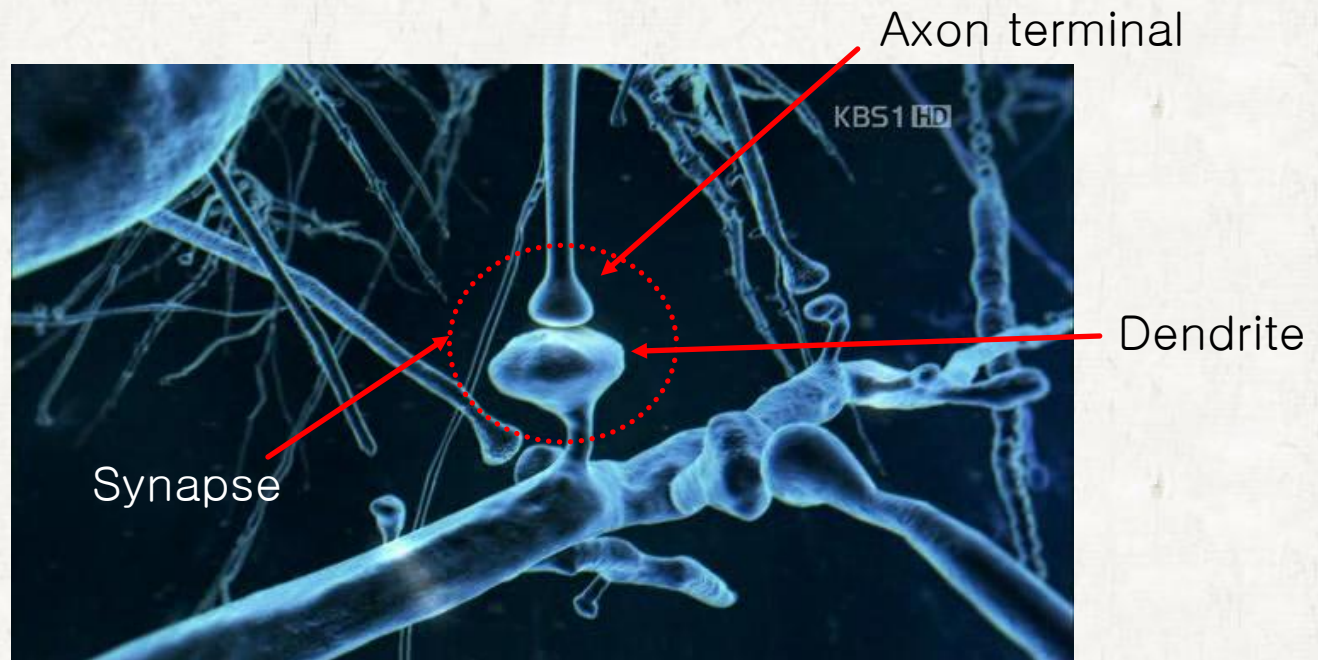
Introduction

- Connection between neuron
  - Every connection does not have the same effect
  - Each connection has different strength
    - The more receptor a dendrite has (mushroom shape), the better it receives neurotransmitter
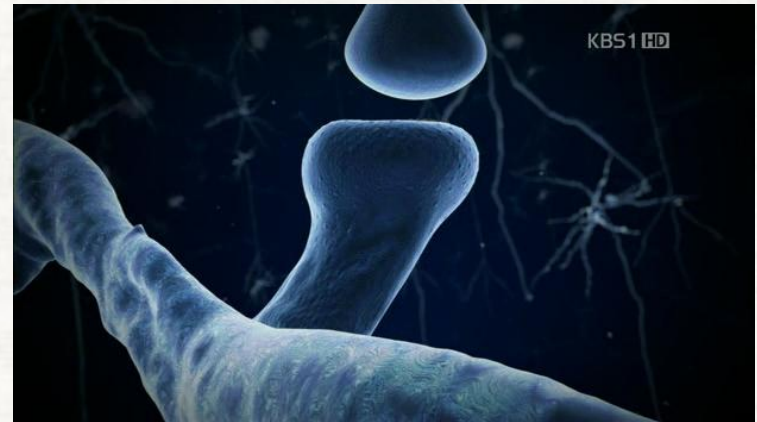
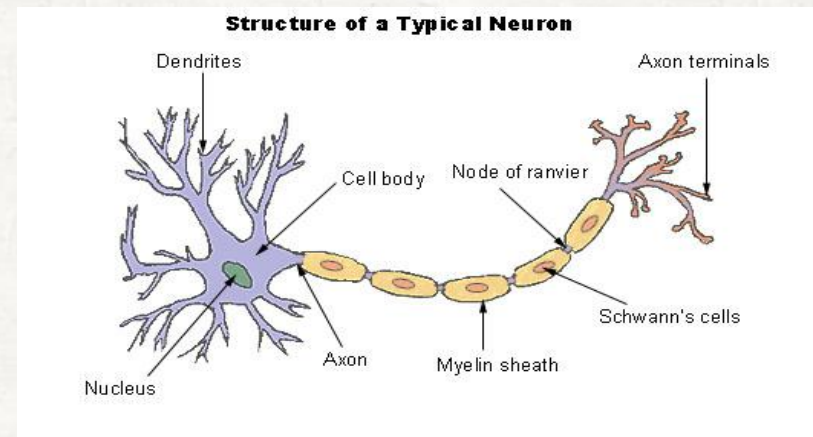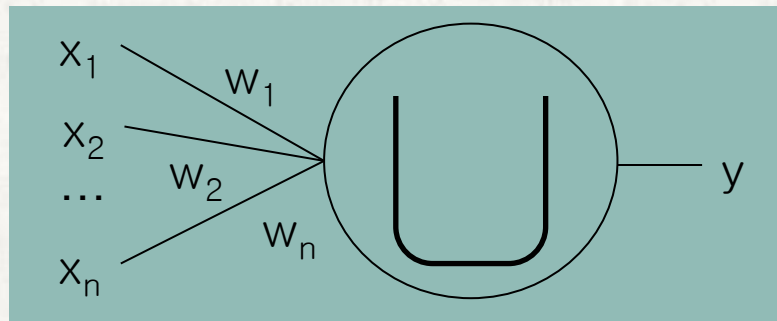# Simple Mathematical Model

- Simple representation of neurons

Structure of a Typical Neuron

- x : dendrites (input)
- w : amount of receptors in each dendrite (connection strength)
- F : cell body
- y : axon (output)

Simple Mathematical Model

- Abstract Behavior of Neuron
  - Neuron is a cell not a computer
  - When signals come in, it just absorbs them.

Structure of a Typical Neuron

- When signals come in, a neuron collects them in the bucket
  - If the amount of signal reaches the threshold, it allows the signals to flow out
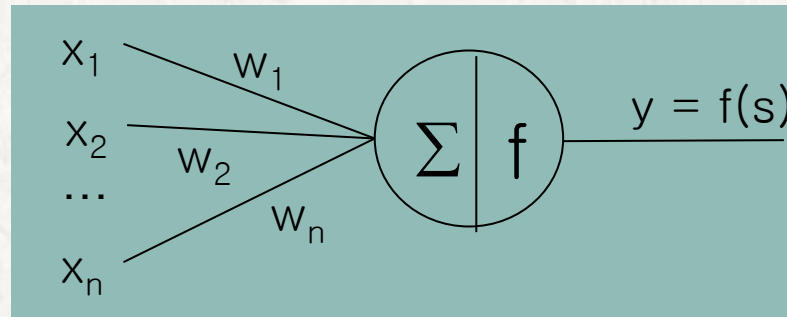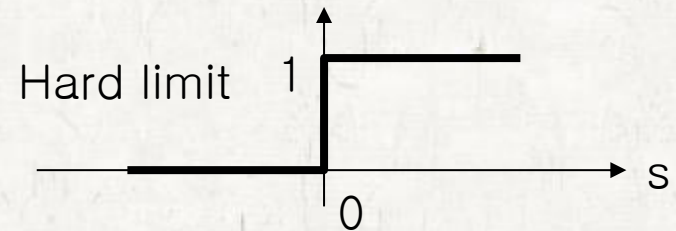 - Otherwise, it does not output

Simple Mathematical Model

- Simple mathematical model of neurons-con'd
  - First function: Weighted summation of inputs

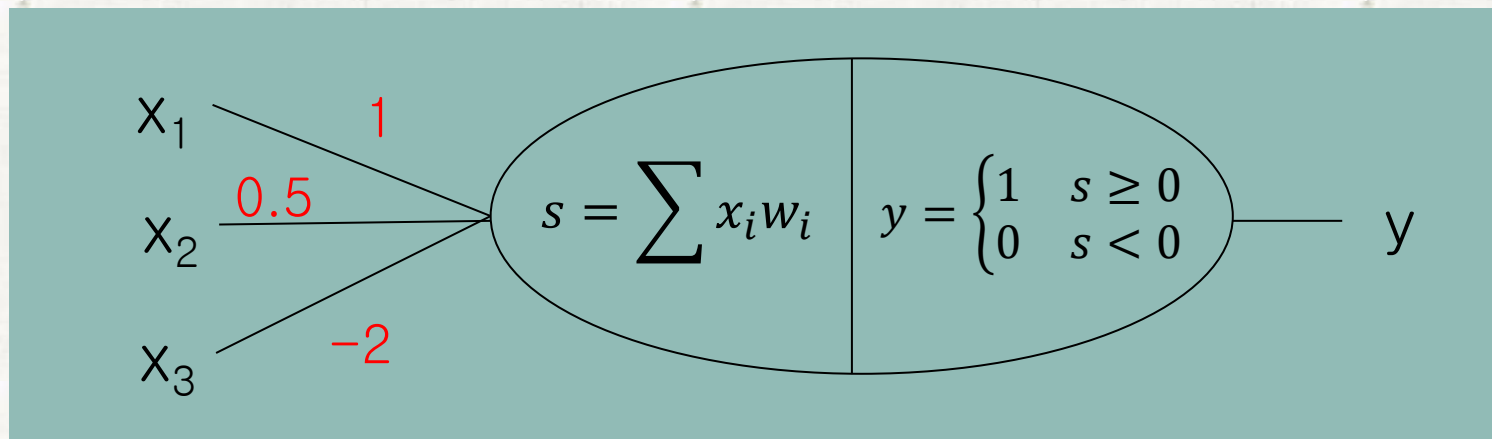$$s = x_1 w_1 + x_2 w_2 + \ldots + x_n w_n$$

  - Second function: Non-linear threshold

$$y = \begin{cases} 1 & s \geq 0 \\ 0 & s < 0 \end{cases}$$

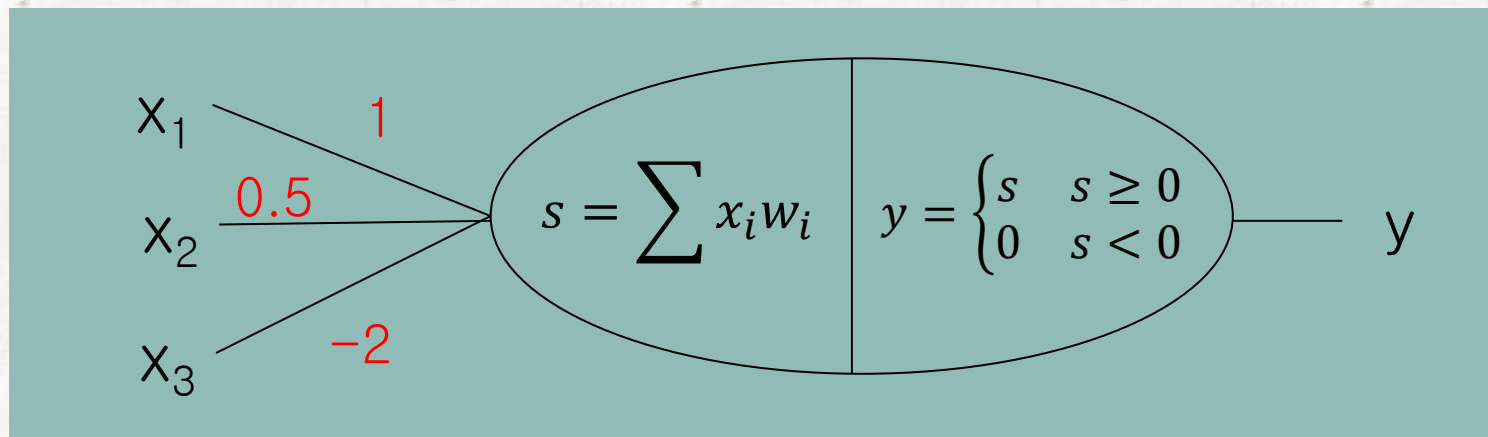Hard limit

Simple Mathematical Model

- Simple mathematical model of neurons−con'd

x_1	x_2	x_3	Σ	y
0	0	1	$0 \cdot 1 + 0 \cdot 0.5 + 1 \cdot (-2) = -2$	0
−0.5	3	1	$(-0.5) \cdot 1 + 3 \cdot 0.5 + 1 \cdot (-2) = -1$	0
0.5	1	−0.5	$0.5 \cdot 1 + 1 \cdot 0.5 + (-0.5) \cdot (-2) = 2$	1
2	1	0.6	$2 \cdot 1 + 1 \cdot 0.5 + 0.6 \cdot (-2) = 0.3$	1

Simple Mathematical Model
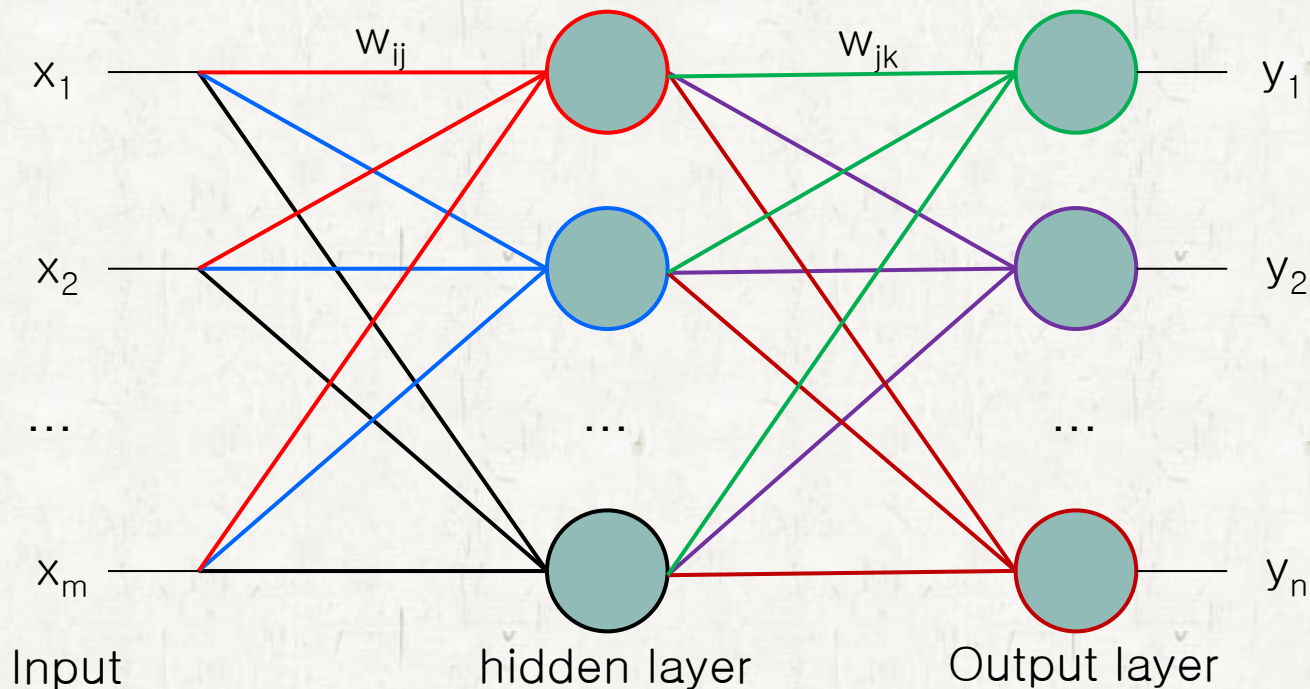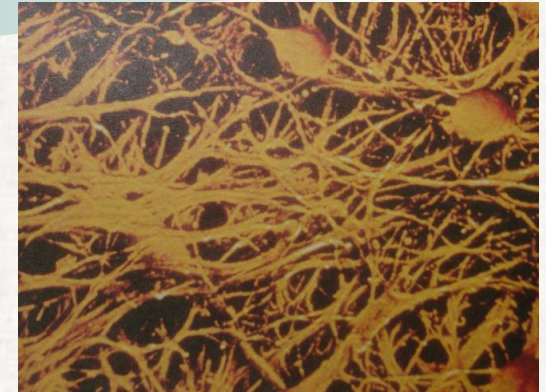
- Simple mathematical model of neurons−con'd

$$x_1 \xrightarrow{1} \quad x_2 \xrightarrow{0.5} \quad x_3 \xrightarrow{-2}$$

$$s = \sum x_i w_i \qquad y = \begin{cases} s & s \geq 0 \\ 0 & s < 0 \end{cases} \longrightarrow y$$

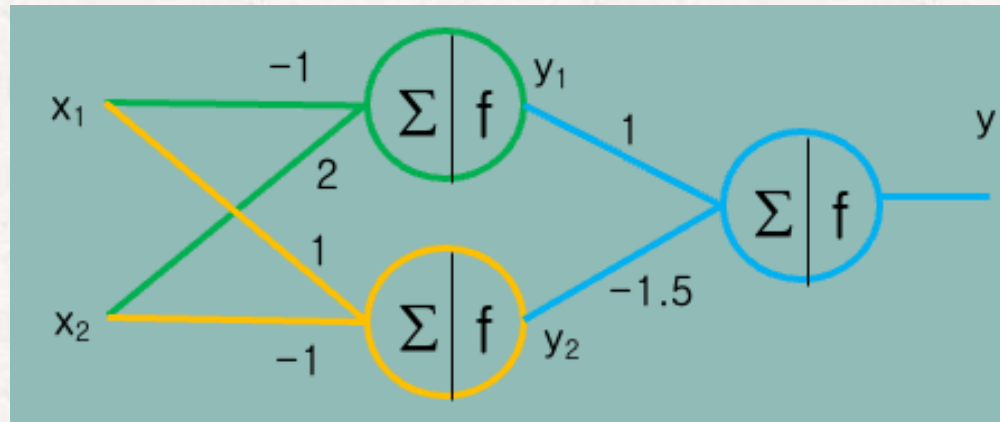| x_1	x_2	x_3	Σ	y
0	0	1	$0 \cdot 1 + 0 \cdot 0.5 + 1 \cdot (-2) = -2$	0
−0.5	3	1	$(-0.5) \cdot 1 + 3 \cdot 0.5 + 1 \cdot (-2) = -1$	0
0.5	1	−0.5	$0.5 \cdot 1 + 1 \cdot 0.5 + (-0.5) \cdot (-2) = 2$	2
2	1	0.6	$2 \cdot 1 + 1 \cdot 0.5 + 0.6 \cdot (-2) = 0.3$	0.3

Neural Network

- Structure of Neural Network
  - Brain is a network of neurons
  - So, let's simply connects artificial neurons and call it artificial neural network

$$w_{ij} \qquad w_{jk}$$

$x_1 \qquad\qquad y_1$

$x_2 \qquad\qquad y_2$

... ...

$x_m \qquad\qquad y_n$

Input   hidden layer   Output layer

Neural Network

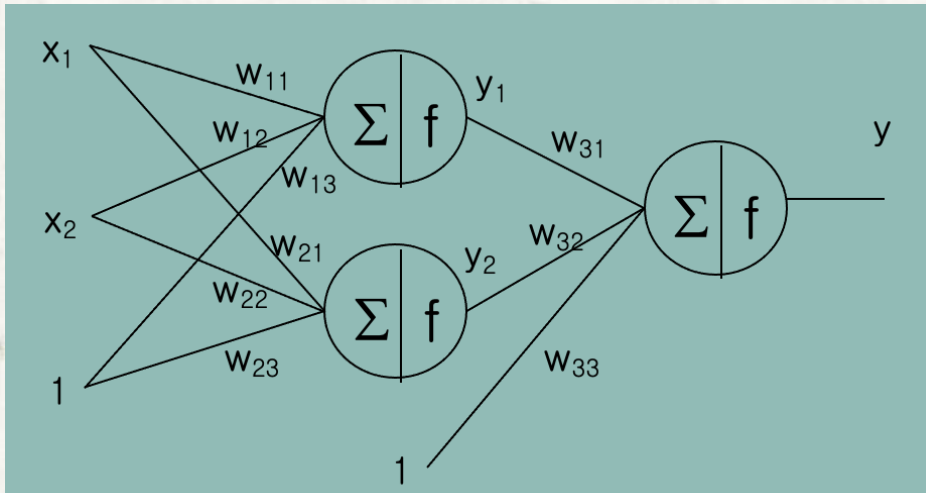- What a neural network can do– con'd

x_1	x_2	s_1	y_1
0	1	2	1
2.5	1	−0.5	0
−1	0.5	1	1
2	1.5	1	1

x_1	x_2	s_2	y_2
0	1	−1	0
2.5	1	1.5	1
−1	0.5	−0.5	0
2	1.5	0.5	1

y_1	y_2	s	y
1	0	1	1
0	1	−1.5	0
1	0	1	1
1	1	−0.5	0

What a Neural Network Can Do? (2)

- What a neural network can do– con'd

w_{11}=1.0, w_{12}=1.0, w_{13}=−1.5

w_{21}=1.0, w_{22}=1.0, w_{23}=−0.5

w_{31}=−1.0, w_{32}=1.0, w_{33}=−0.5

x_1	x_2	Σ	y_1
0	0	−1.5	0
0	1	−0.5	0
1	0	−0.5	0
1	1	0.5	1

x_1	x_2	Σ	y_2
0	0	−0.5	0
0	1	0.5	1
1	0	0.5	1
1	1	1.5	1

y_1	y_2	Σ	y
0	0	−0.5	0
0	1	0.5	1
0	1	0.5	1
1	1	−0.5	0

What a Perceptron Can Do?

- What a perceptron can do
  - And operation

OR operation

x_1 w_1 Σ | f y
x_2 w_2
1 w_3

x_1 w_1 Σ | f y
x_2 w_2
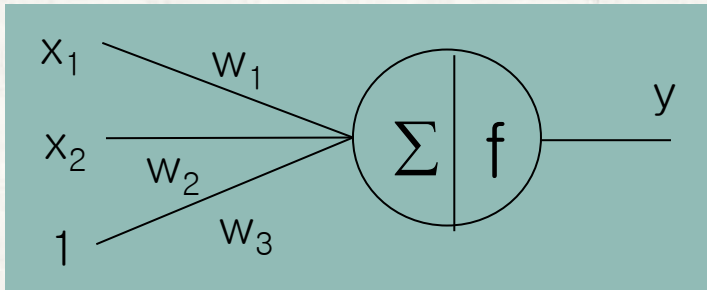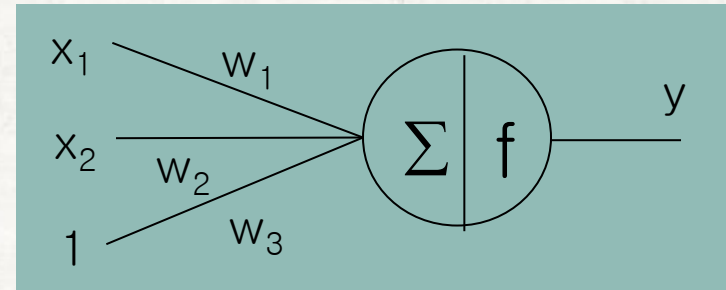1 w_3

w1=1.0, w2=1.0, w3=−1.5

w1=1.0, w2=1.0, w3=−0.5

x_1	x_2	Σ	y
0	0	−1.5	0
0	1	−0.5	0
1	0	−0.5	0
1	1	0.5	1

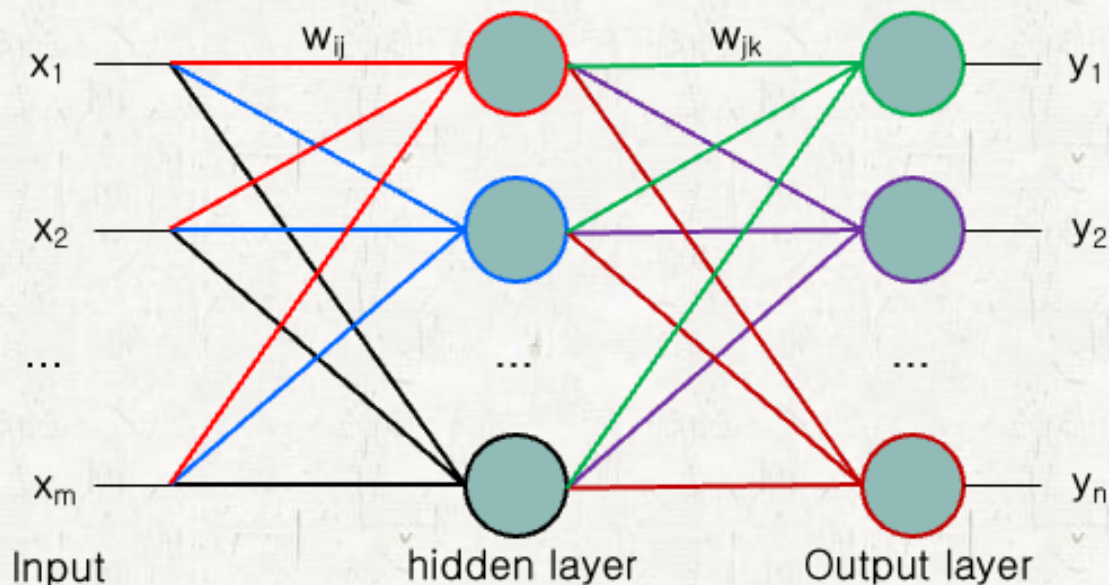| x_1	x_2	Σ	y
0	0	−0.5	0
0	1	0.5	1
1	0	0.5	1
1	1	1.5	1

What a Neural Network Can Do?

- Simple mathematical model of brains-con'd

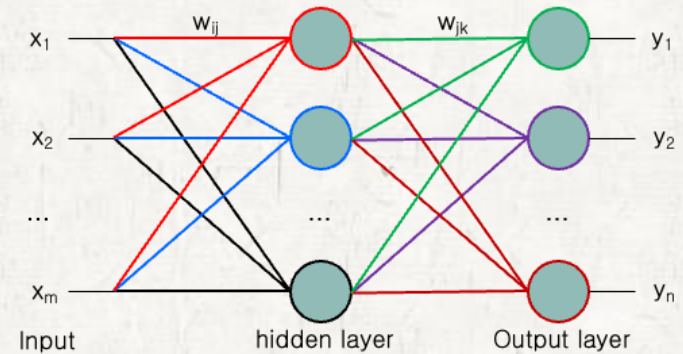- How stupid it is!!
- What can it do?
  - Everything a computer can do!!

What a Neural Network Can Do?

- Simple mathematical model of brains-con'd
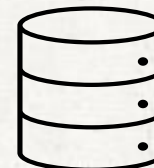

=

x_1 w_{ij} w_{jk} y_1

x_2 y_2

... ...

x_m y_n

Input   hidden layer   Output layer

Program   **=**   Connection weights in NN
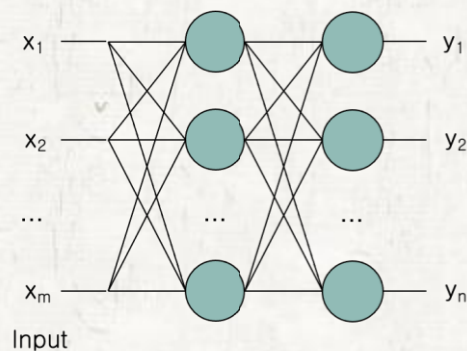
Programming by Human   **=**   Training with Data

What a Neural Network Can Do?

- History of Neural Network

ChatGPT
by OpenAI

Transformer
by Google

학습알고리즘 제안
by Rumelhart, **Hinton** & Williams

AlphaGo
by Google

Deep
Network

AlexNet
by Hinton

Perceptron
한계지적
by Minsky & Papert

Deep Belief Networks
by **Hinton**

Shallow Network

Perceptron
제안

Popularity

1958   1969   1986   2000쯤   2006   2012   2016 2017   2022   Time
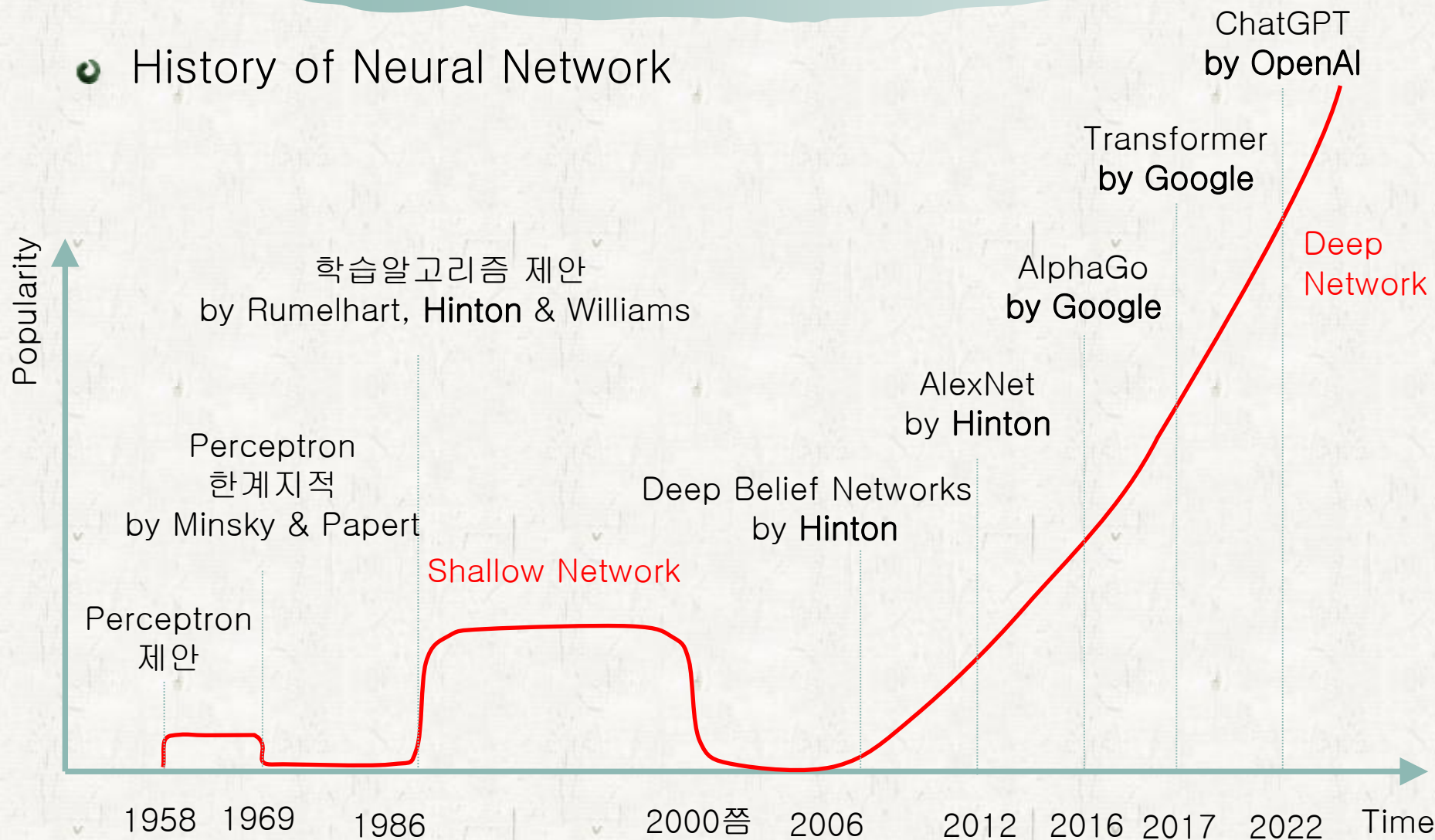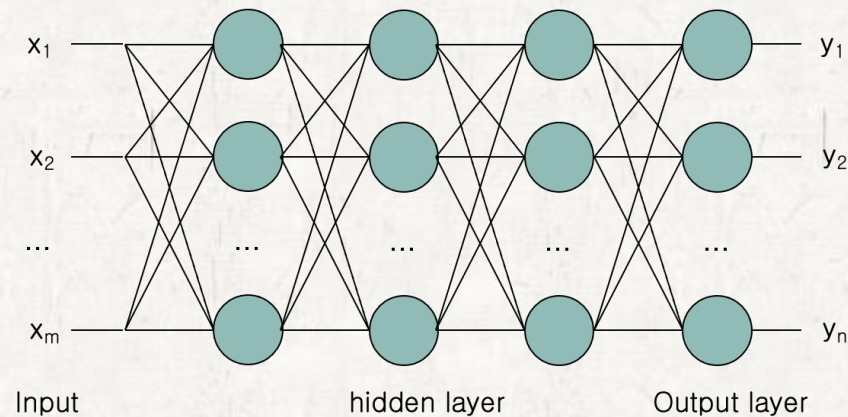
Neural Network

- Why deep?
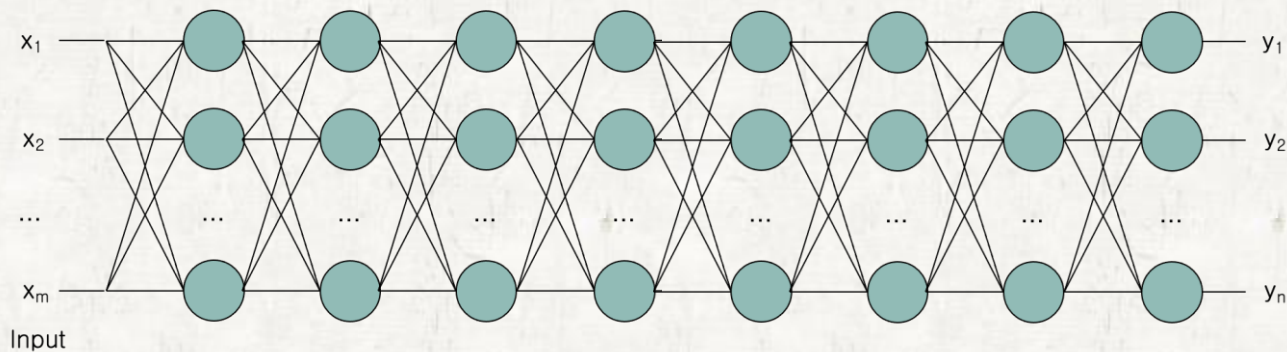
Neural Network Design

- Neural Network Structure
  - How many inputs?
  - How many outputs?
  - How many hidden layers?
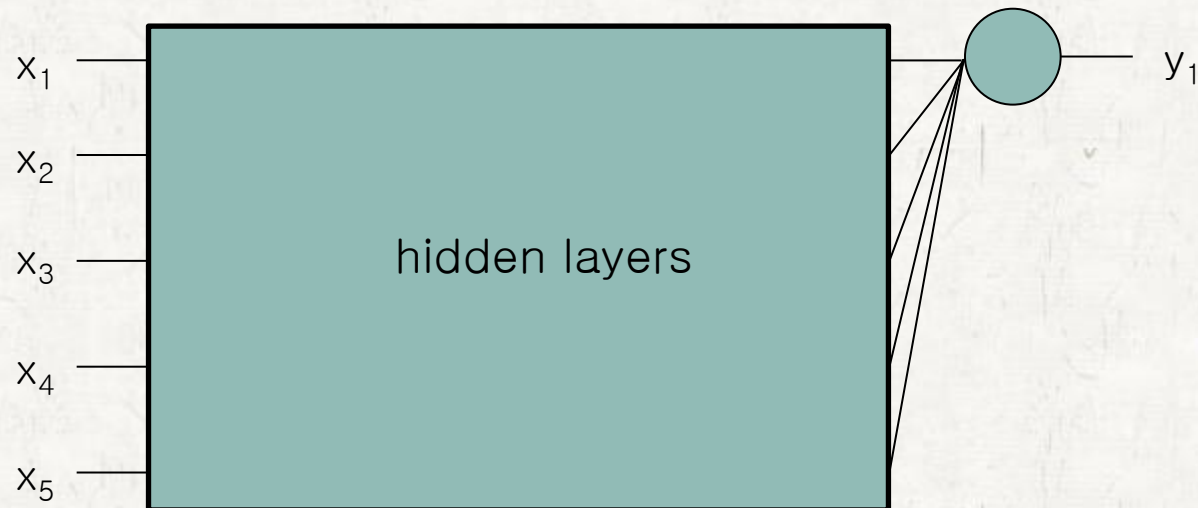 - How many nodes in hidden layers?

Neural Network Design

- How many inputs? How many outputs?
  - Stock Index Prediction

$(2500, 2550, 2530, 2540, 2550) \rightarrow 2600$

$(2400, 2410, 2420, 2430, 2440) \rightarrow 2450$

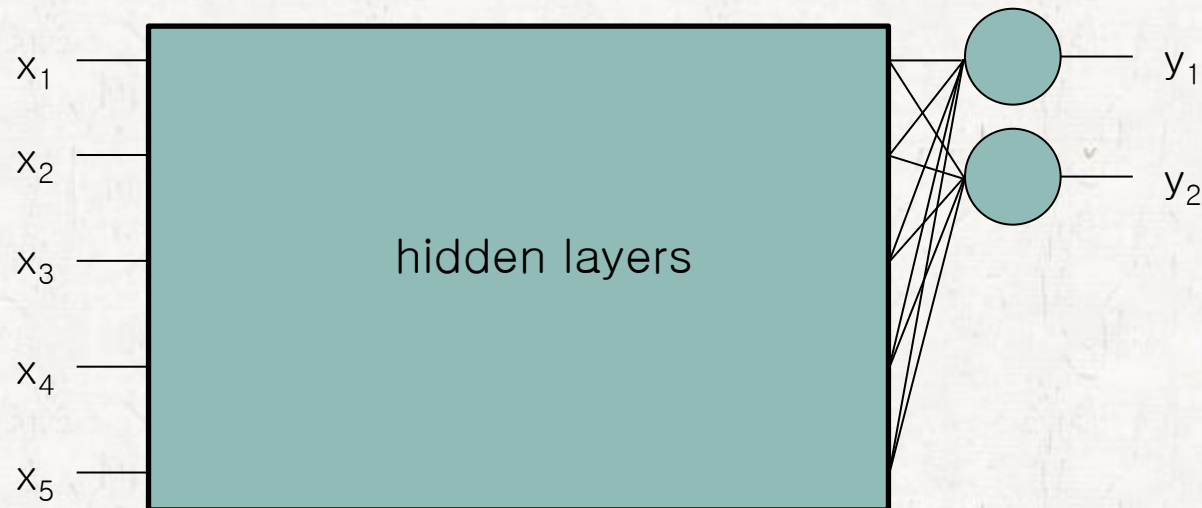$(2470, 2460, 2450, 2470, 2480) \rightarrow 2470$

Neural Network Design

How many inputs? How many outputs?

- Stock Index Prediction

$(2500, 2550, 2530, 2540, 2550) \rightarrow (2600, 2580)$

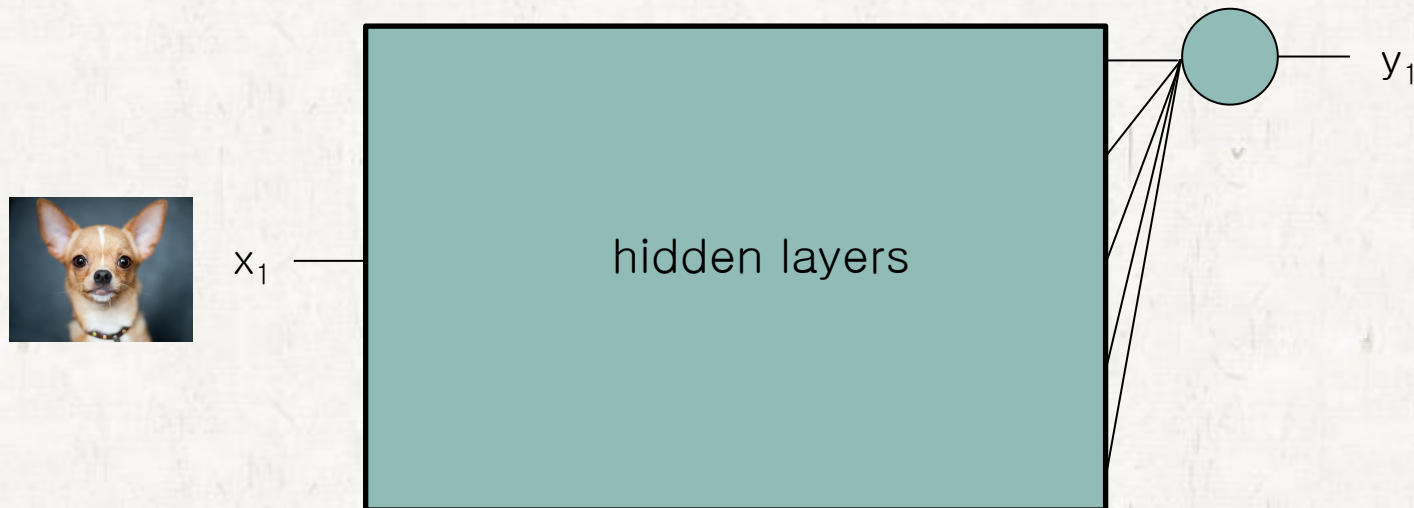$(2400, 2410, 2420, 2430, 2440) \rightarrow (2450, 2460)$

$(2470, 2460, 2450, 2470, 2480) \rightarrow (2470, 2460)$

Neural Network Design

- How many inputs? How many outputs?
  - Image Classification

$$\left(\text{} , 1 \right) \left(\text{} , 0 \right)$$

x_1 ——— hidden layers ———< y_1

Neural Network Design

- How many inputs? How many outputs?
  - Image Classification

Neural Network Design

- How many inputs? How many outputs?
  - Image Classification

$$\left(\text{[dog image]}, 1 \right) \quad \left(\text{[cat image]}, 0 \right)$$

x_1

x_2

x_3

$\vdots$

$x_{100만}$

hidden layers

y_1

Neural Network Design

○ How many hidden layers?
  How many nodes in hidden layers?
  - 음.. 원하시는대로 하시면 돼요. 그러나
  - 쉬운 문제면, layer 조금 node 조금
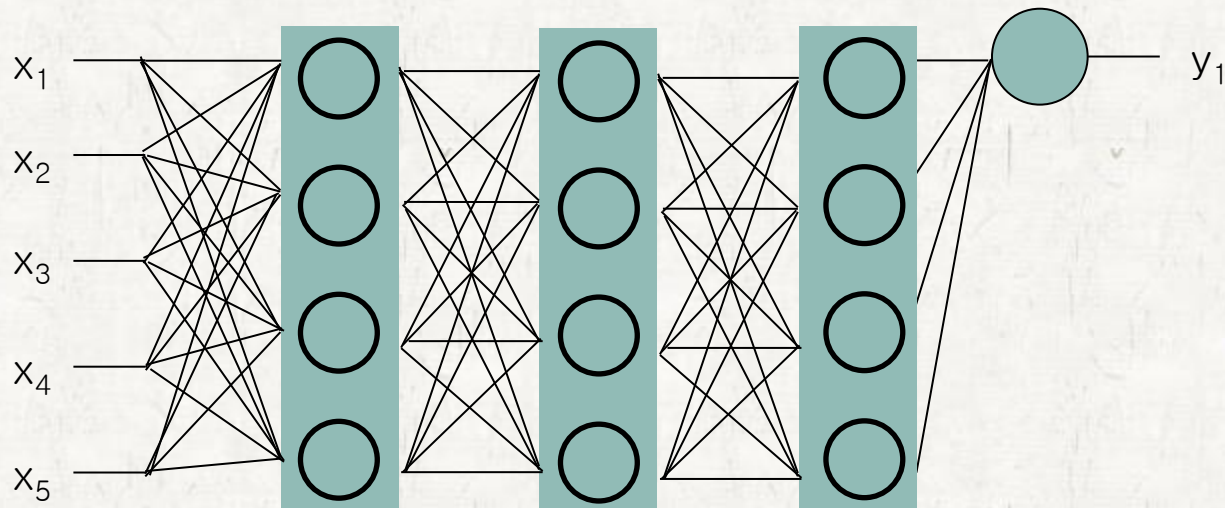 - 어려운 문제면, layer 많이 node 많이
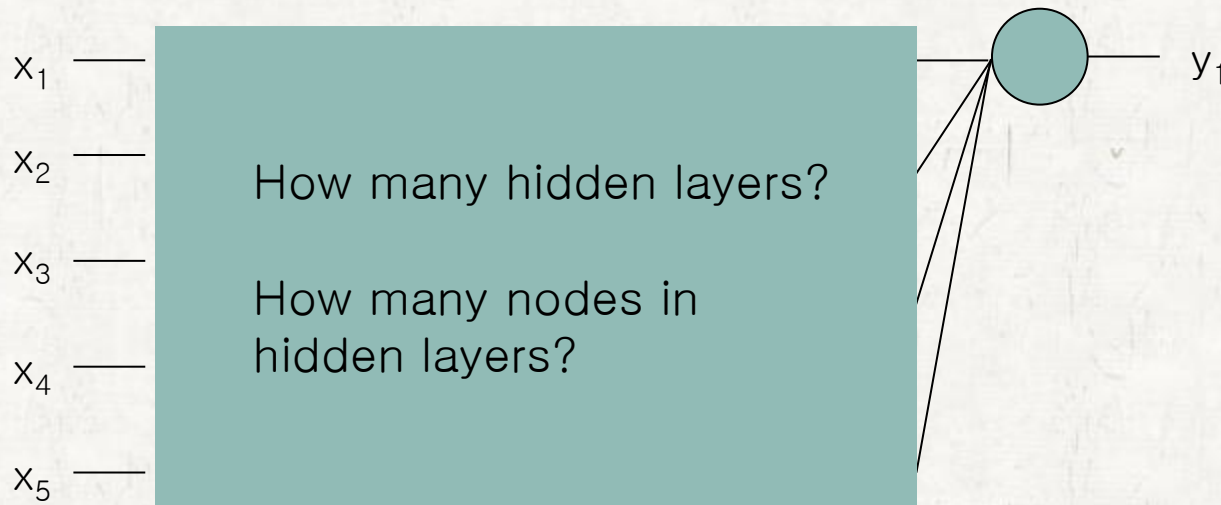
x_1 ——

x_2 —— How many hidden layers?

x_3 —— How many nodes in
hidden layers?

x_4 ——

x_5 ——

y_1

Neural Network Design

○ How many hidden layers?
   How many nodes in hidden layers?
   ● Stock Index Prediction

$$(2500, 2550, 2530, 2540, 2550) \rightarrow 2600$$

$$(2400, 2410, 2420, 2430, 2440) \rightarrow 2450$$

$$(2470, 2460, 2450, 2470, 2480) \rightarrow 2470$$
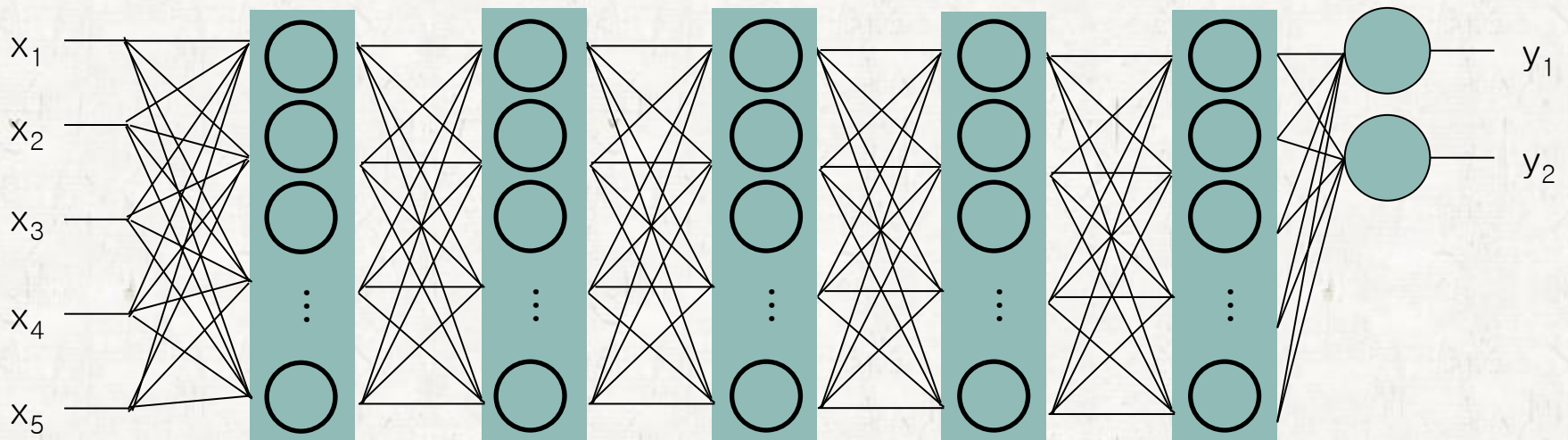
Neural Network Design

- How many hidden layers?
  How many nodes in hidden layers?
  - Stock Index Prediction

    (2500,2550, 2530, 2540, 2550) -> (2600,2580)

    (2400,2410, 2420, 2430, 2440) -> (2450,2460)

    (2470,2460, 2450, 2470, 2480) -> (2470,2460)

Neural Network Design

- How many hidden layers?
  How many nodes in hidden layers?
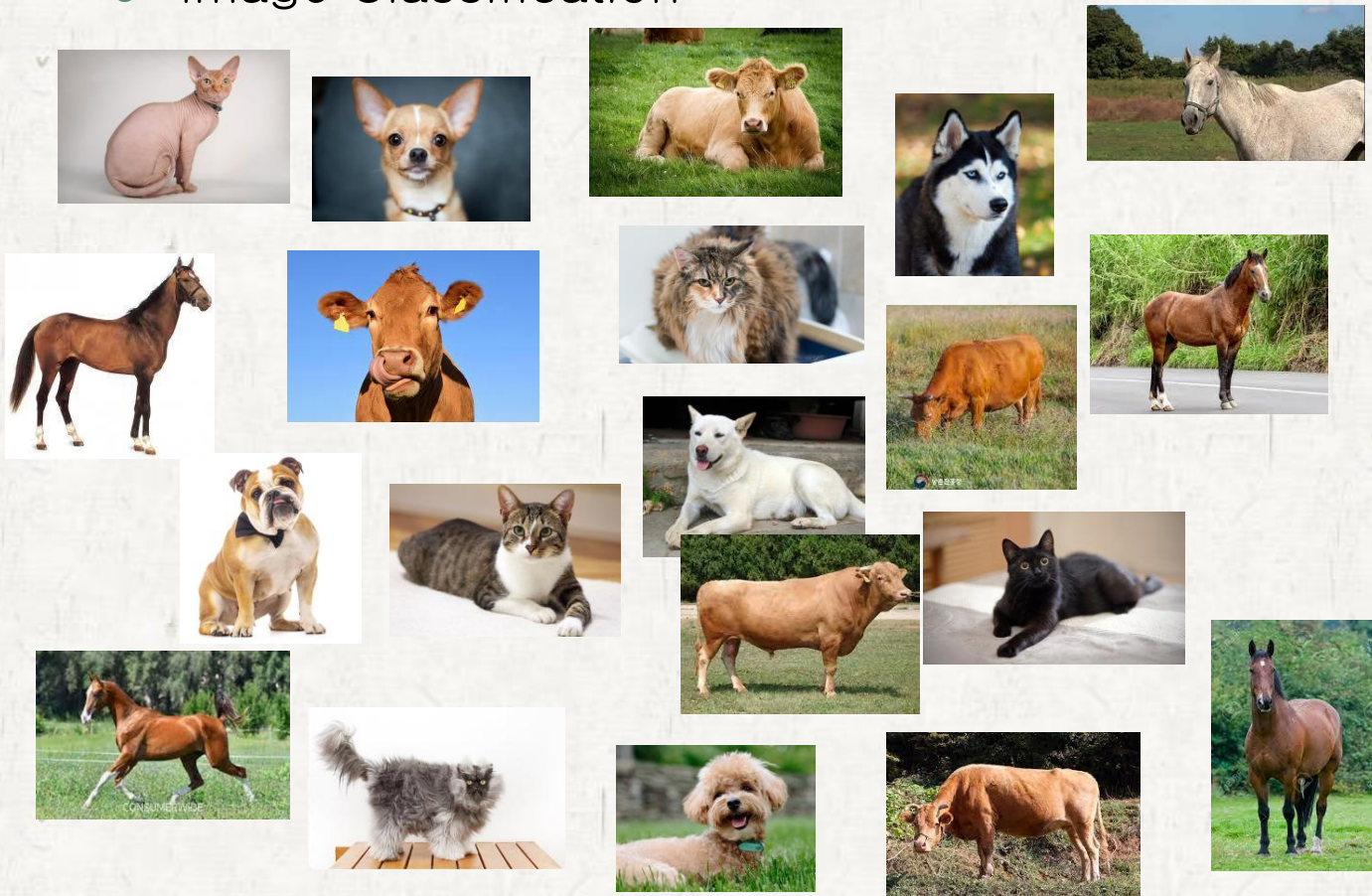 - Image Classification

개

고양이

Neural Network Design

- How many hidden layers?
  How many nodes in hidden layers?
  - Image Classification

개

고양이

말

소