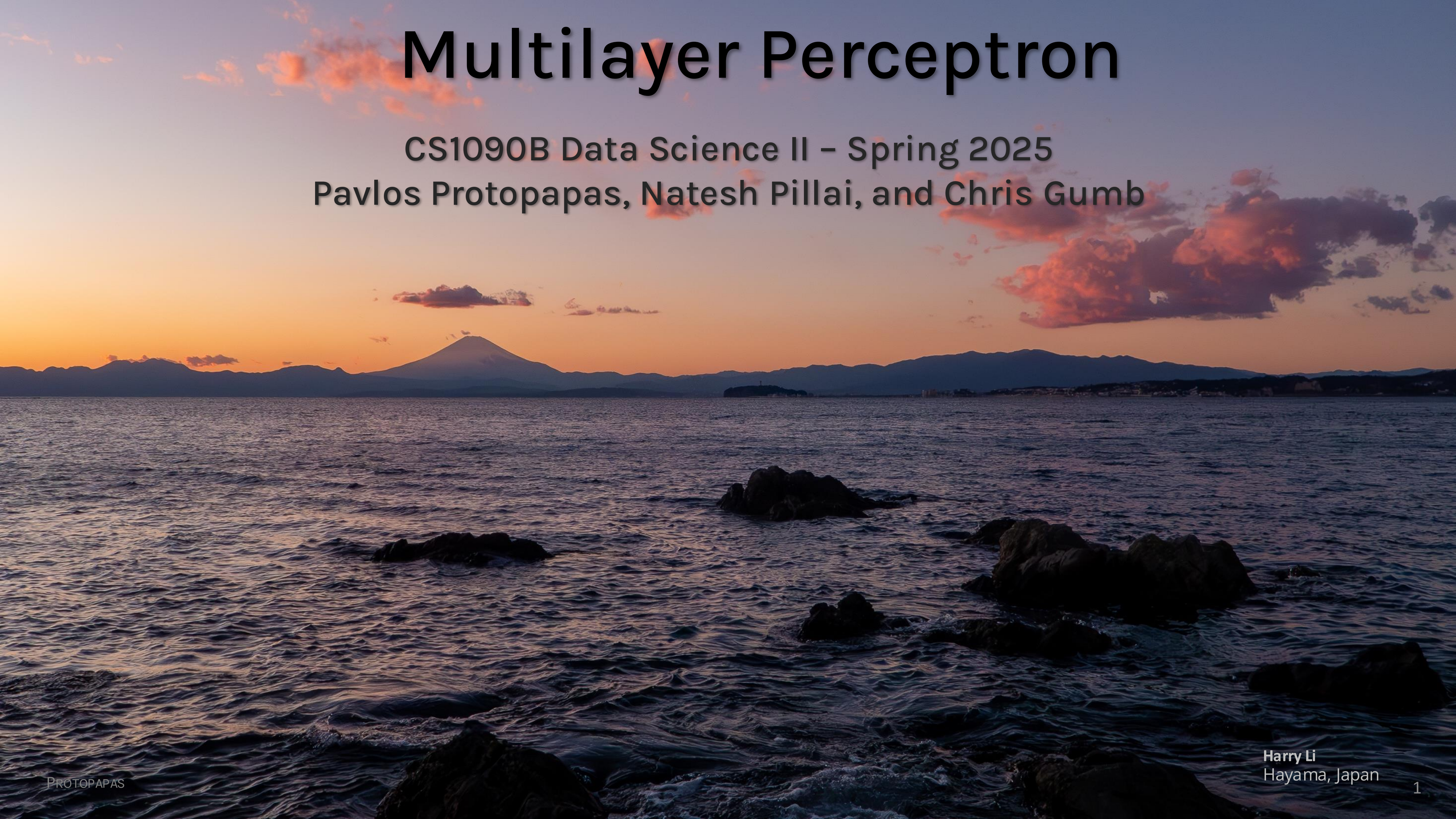
Multilayer Perceptron

CS1090B Data Science II – Spring 2025

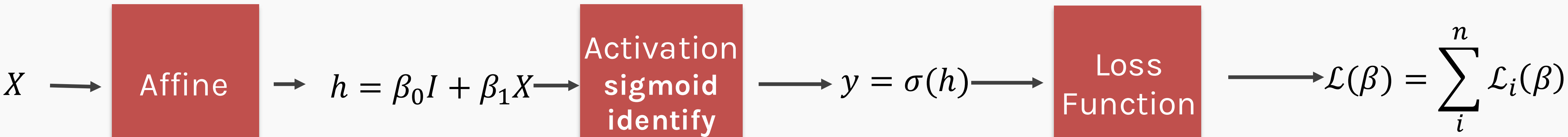
Pavlos Protopapas, Natesh Pillai, and Chris Gumb

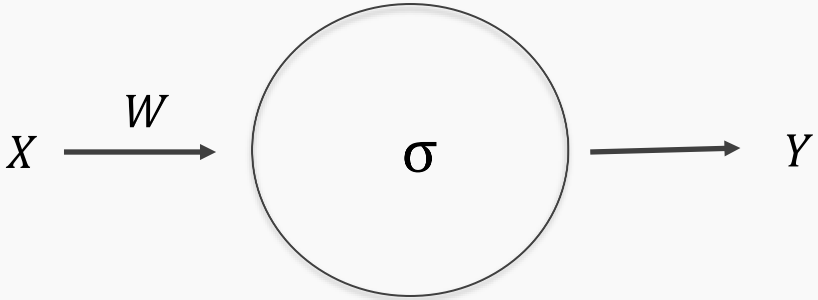


Harry Li
Hayama, Japan

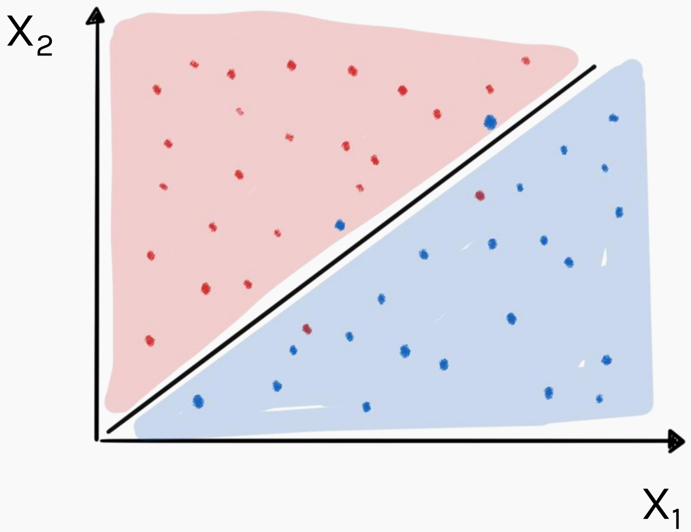
A single neuron

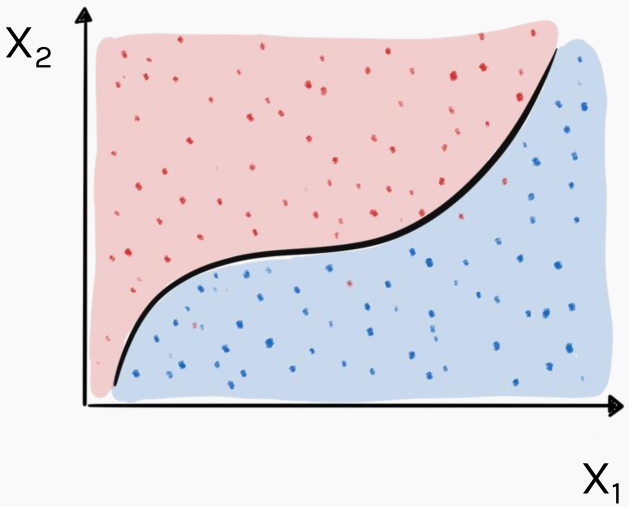
Up to this point we just re-branded logistic regression or linear regression to look like a neuron.

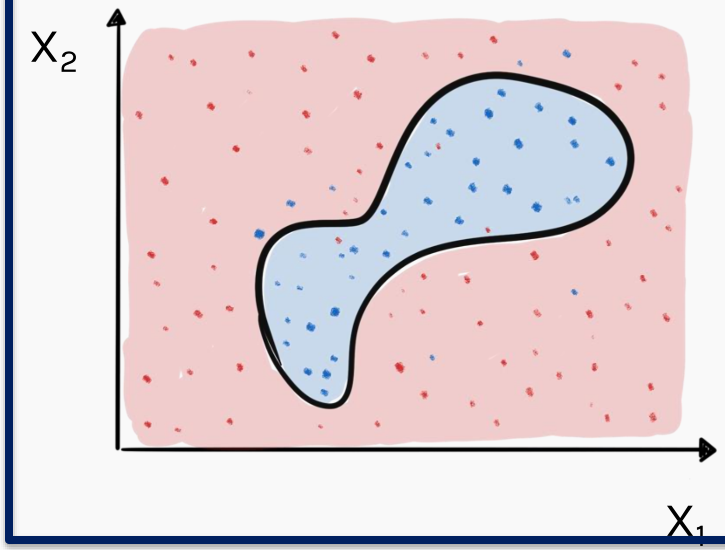


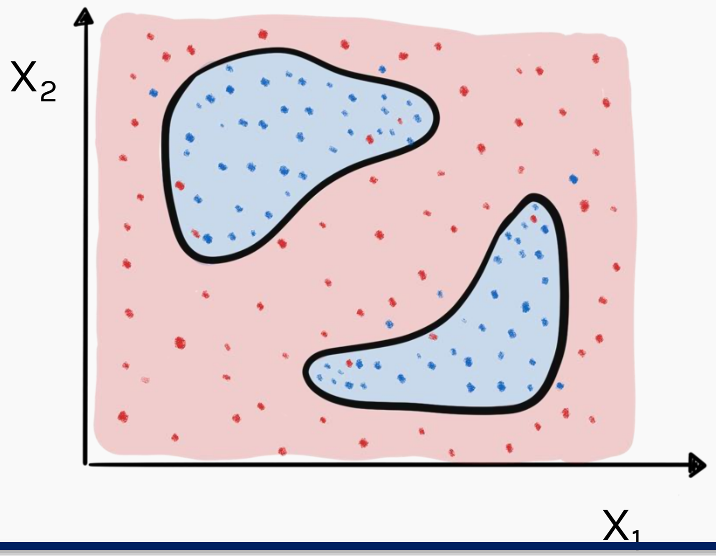


So, what's the big deal about Neural Networks?









Very hard to express boundaries like these with logistic regression

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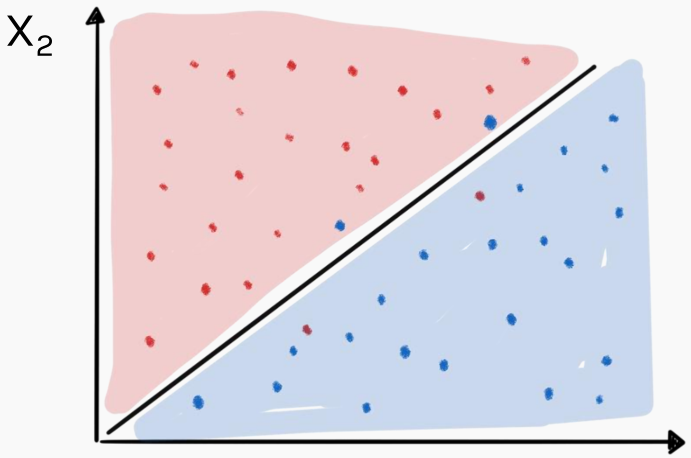
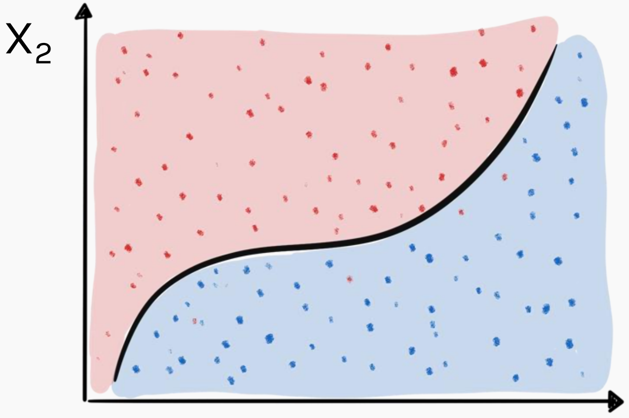
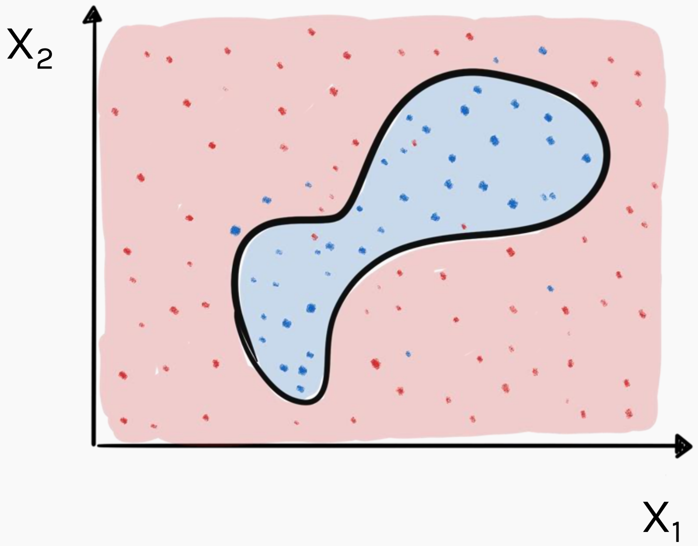
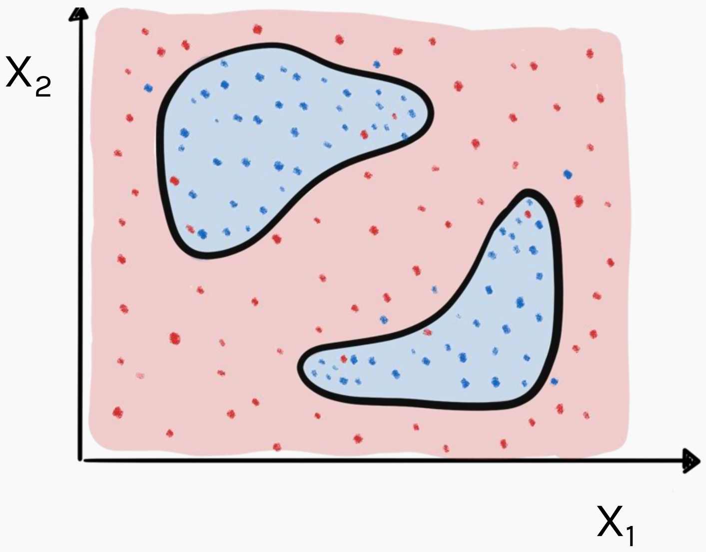




No Linear Boundaries!





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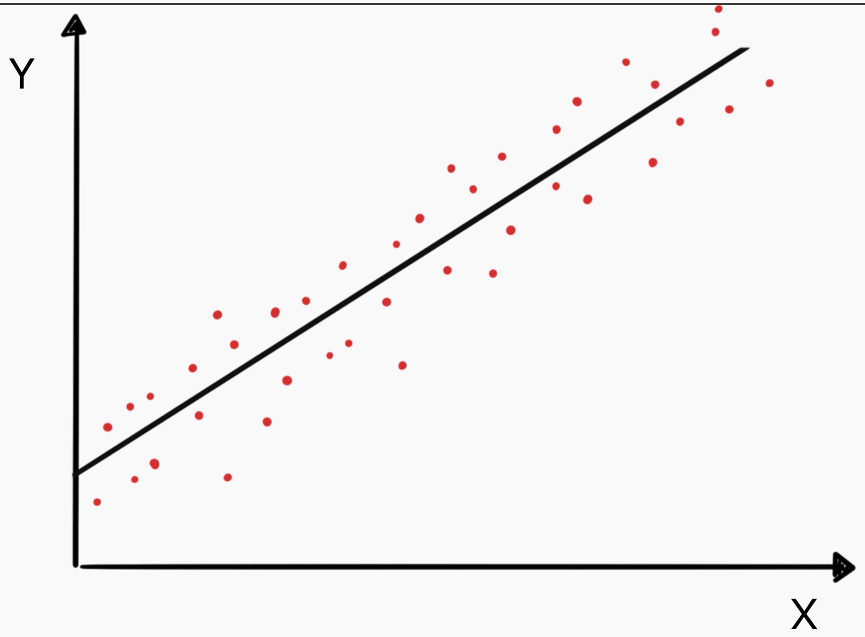

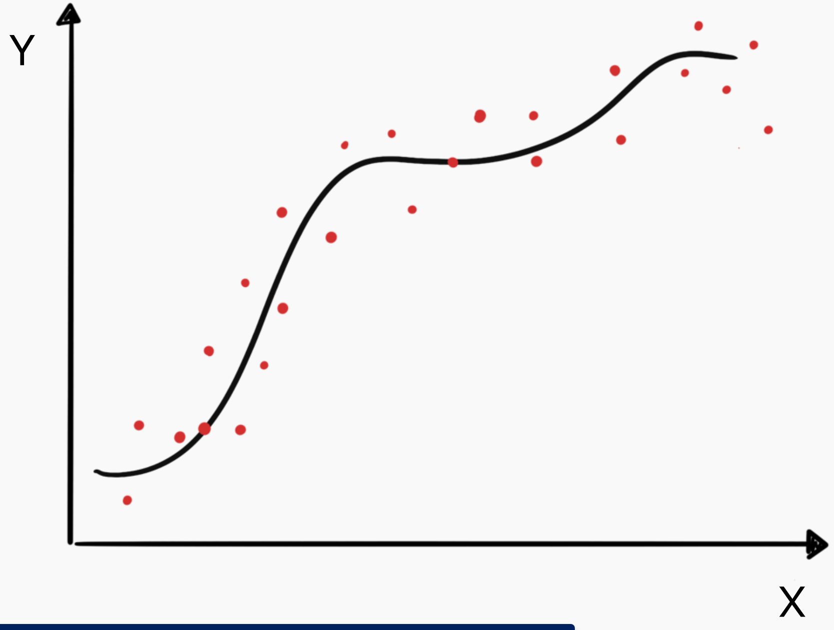

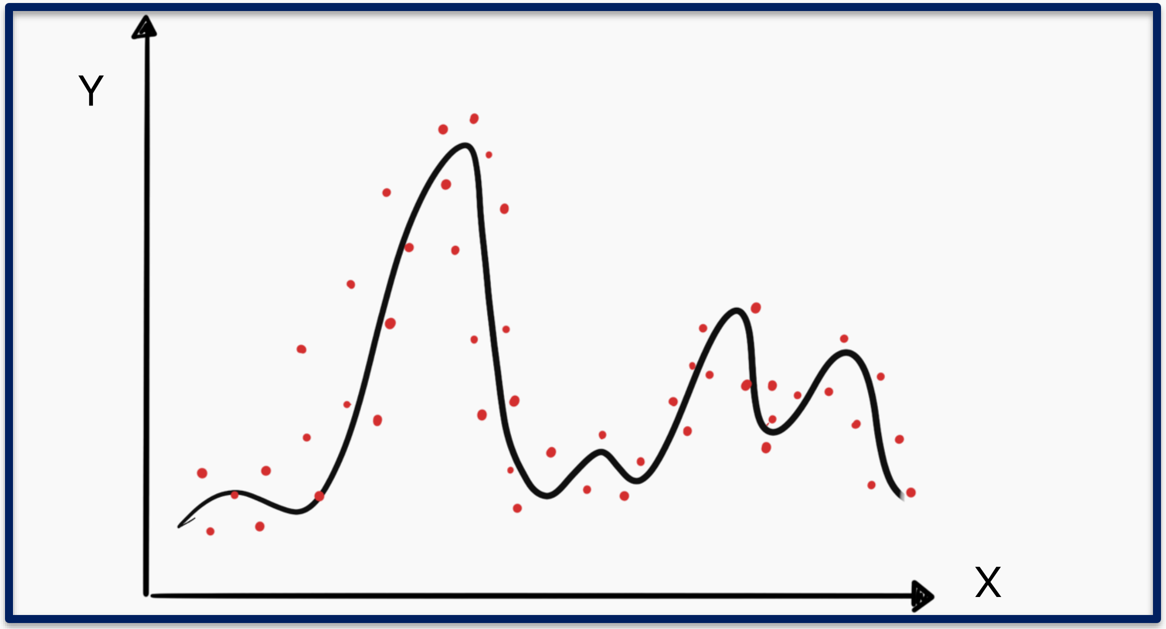

Very hard to express functions like these with polynomial regression

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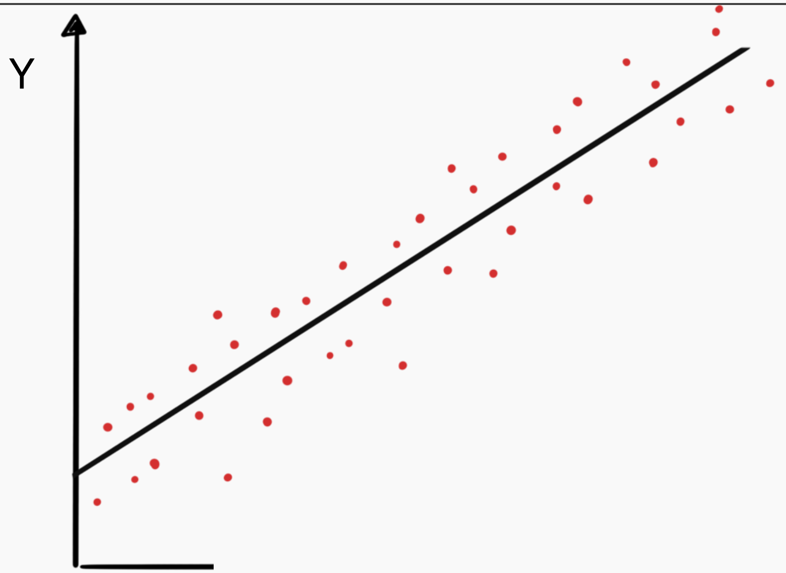
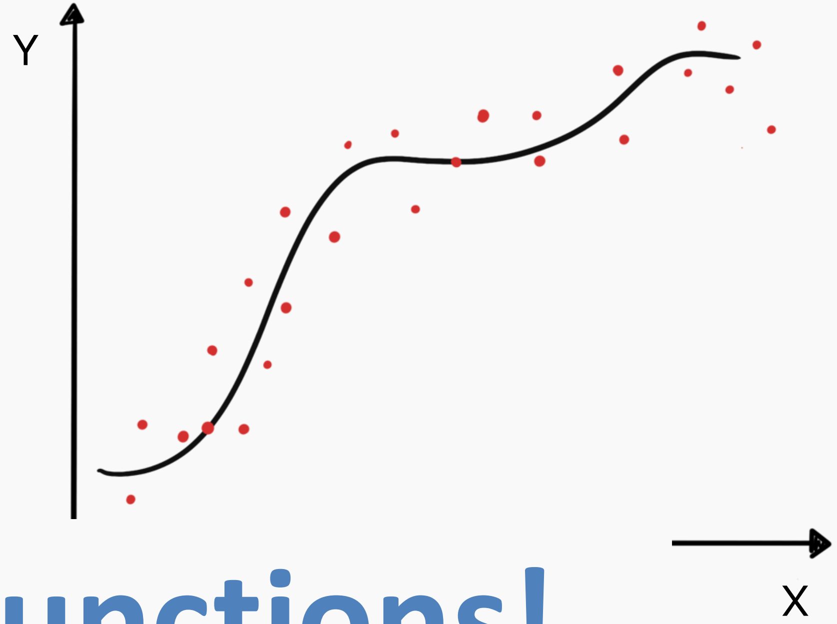
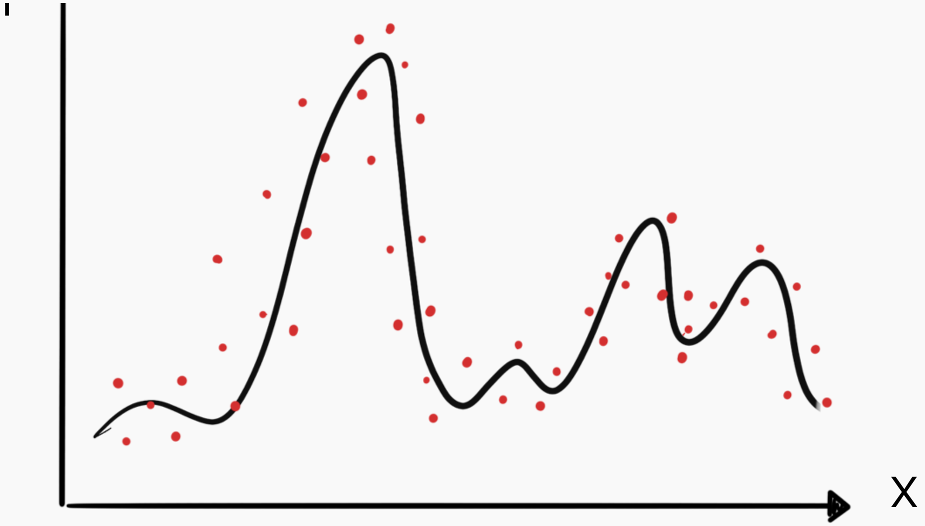




No Linear Functions!



Outline

- Introduction
- Review of basic concepts
- Linear to Logistic Regression
- Logistic Regression to ANN
- Perceptron - Single neuron network
- **Multi-Layer Perceptron (MLP)**

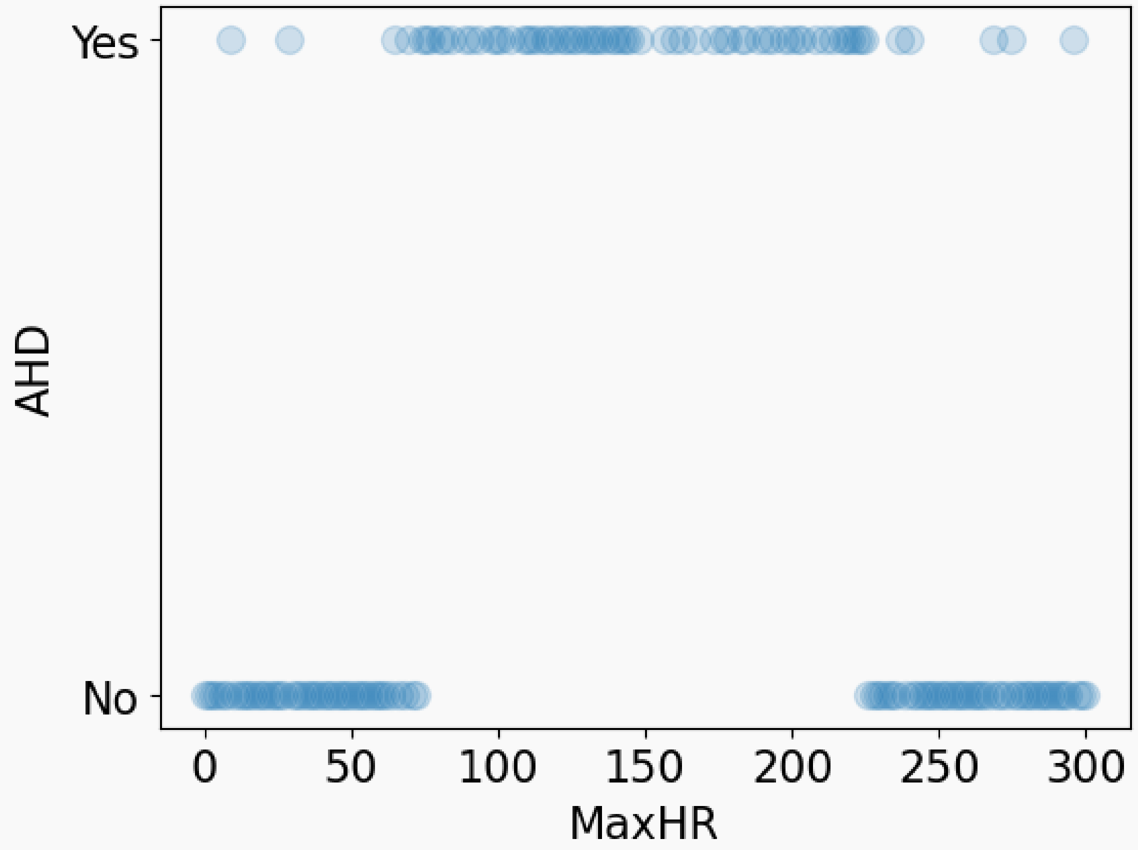
Example Using Heart Data

Consider a dataset that contains a binary outcome AHD for 303 patients who presented with chest pain.

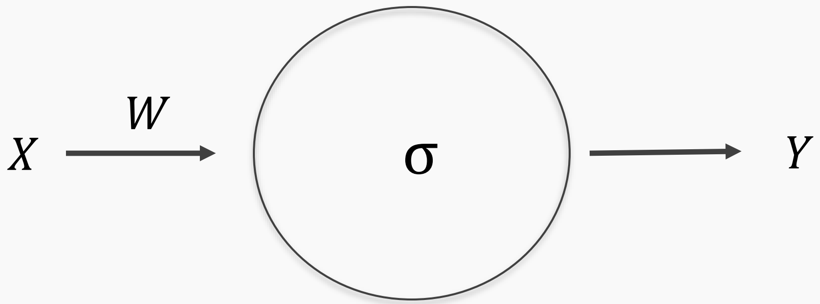
Age	Sex	ChestPain	RestBP	Chol	MaxHR	ExAng	Thal	AHD
63	1	typical	145	233	150	0	fixed	No
67	1	asymptomatic	160	286	108	1	normal	Yes
67	1	asymptomatic	120	229	129	1	reversable	Yes
37	1	nonanginal	130	250	187	0	normal	No

Example Using Heart Data

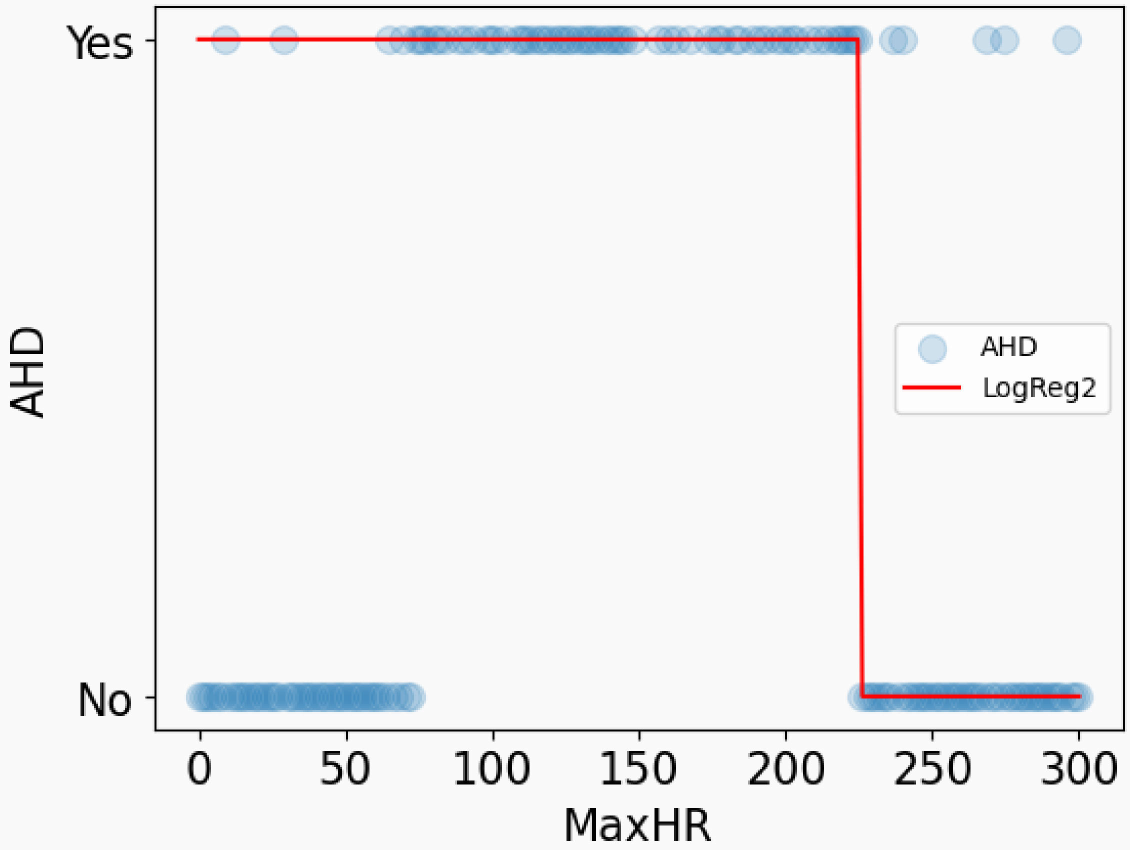
Slightly modified data to illustrate concepts.



Example Using Heart Data



Choose W such as **right** part of data is fitted well



Game Time

What would be the expected behavior of the logistic regression function below if we increase the bias (b or W_0)?

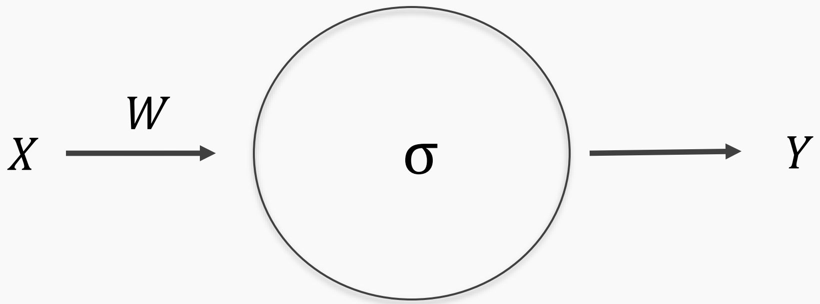
A. The curve will shift upwards

B. The curve will shift downwards

C. The curve will shift to the left

D. The curve's slope will become steeper

Example Using Heart Data



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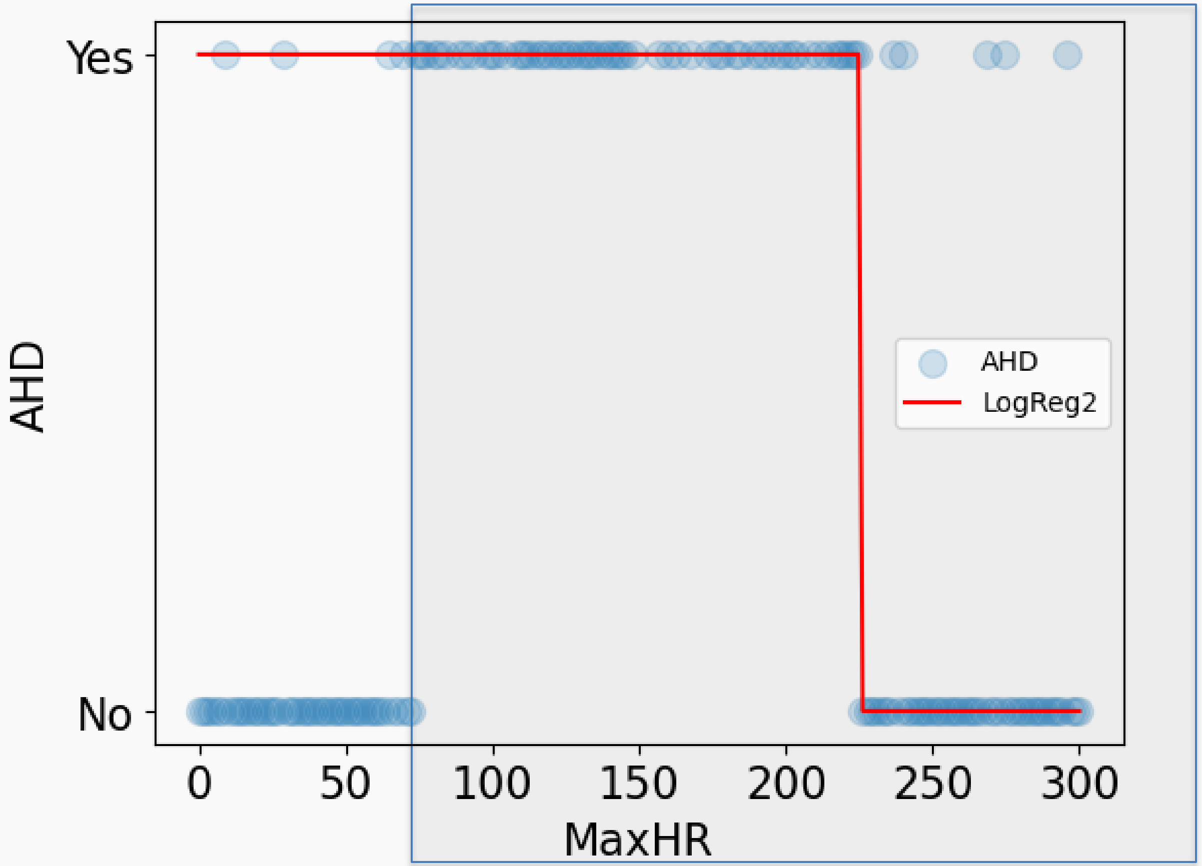

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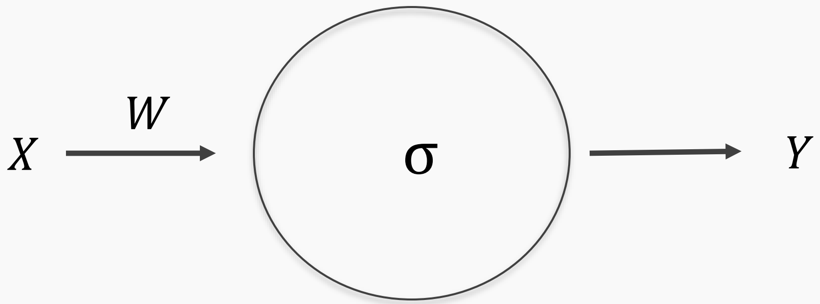
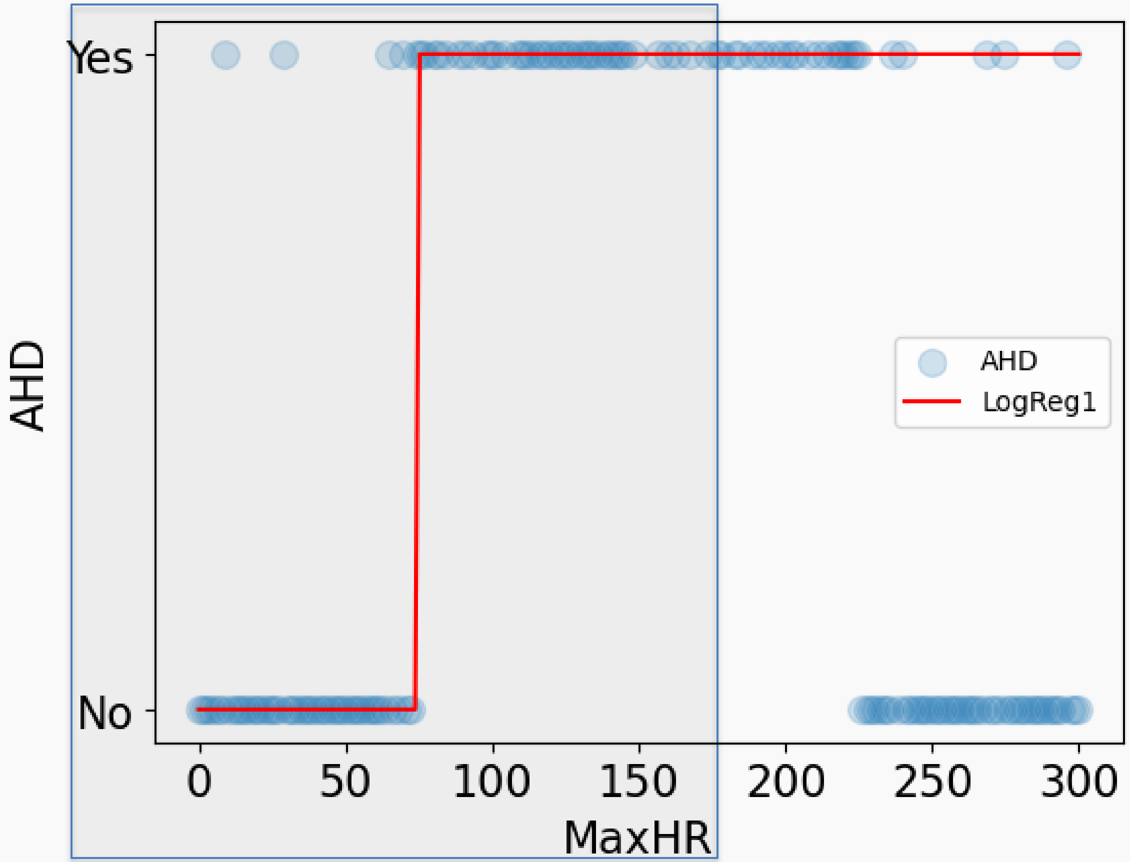
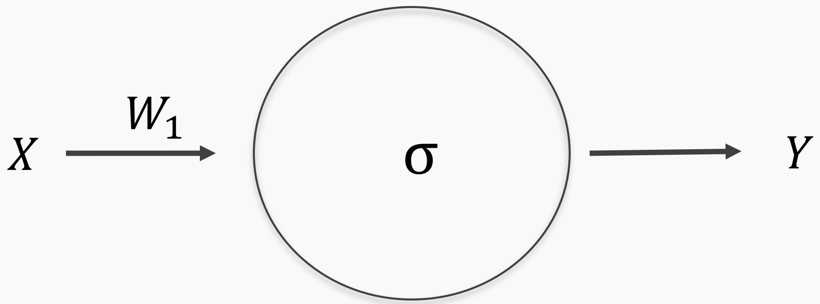


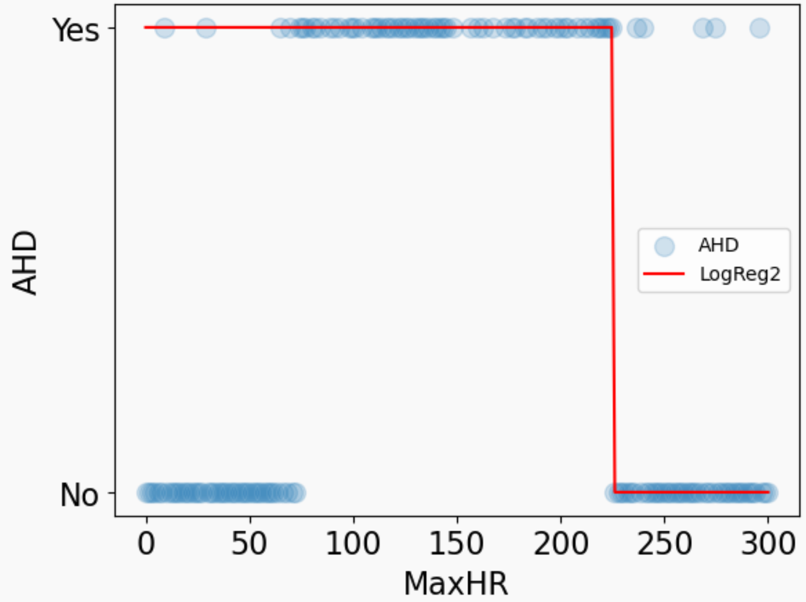
Choose W such as **left** part of data is fitted well

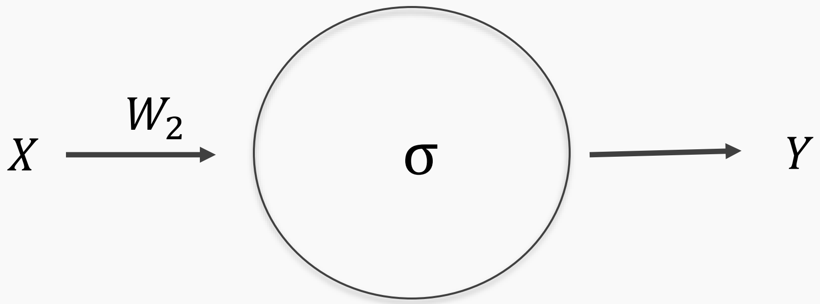


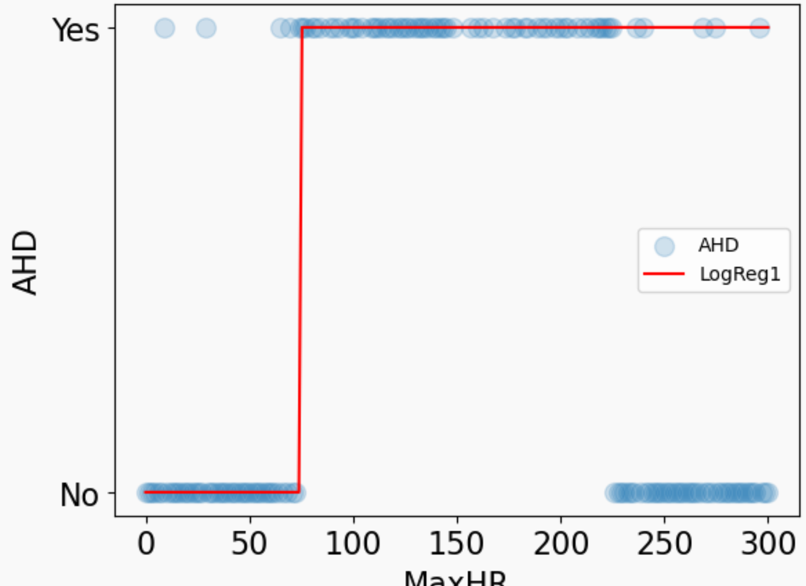
Example Using Heart Data

Two regions, two nodes

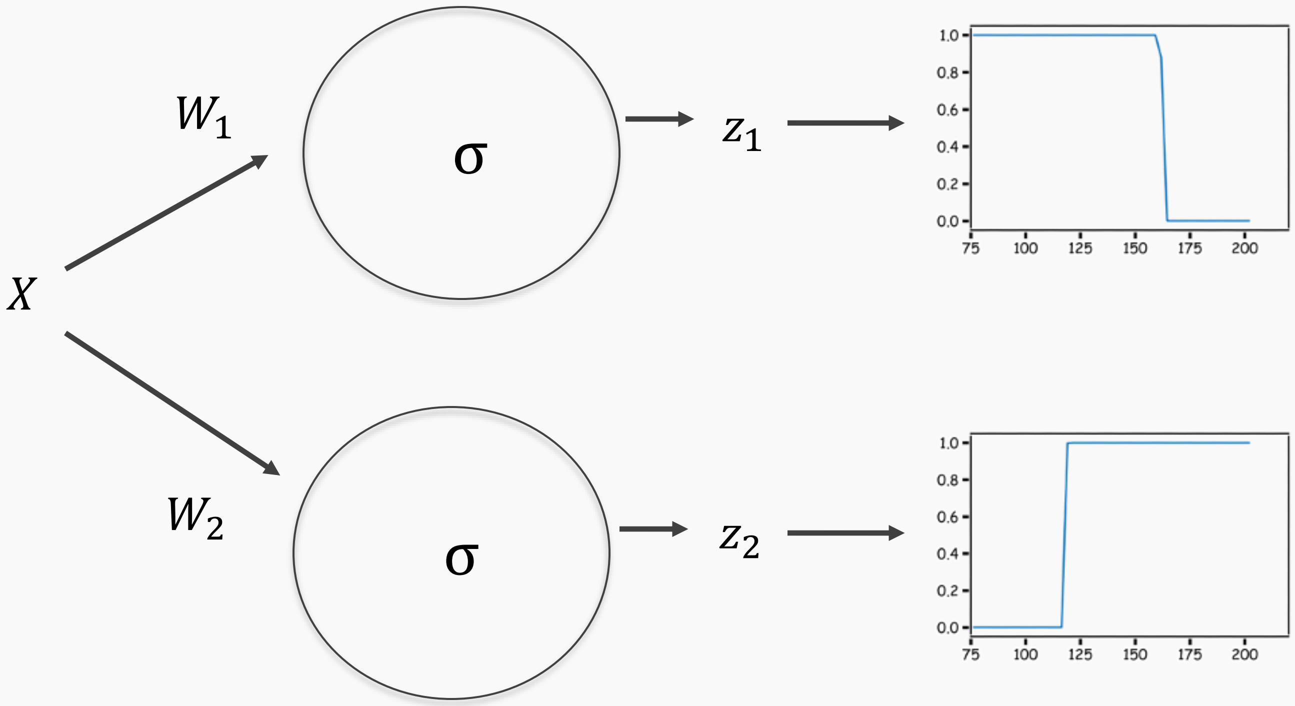








Combining Neurons



Game Time

How shall we combine these results?

A. Multiply z_1 and z_2

B. Add z_1 and z_2

C. $\sigma(z_1) + \sigma(z_2)$

D. Convolve z_1 with z_2

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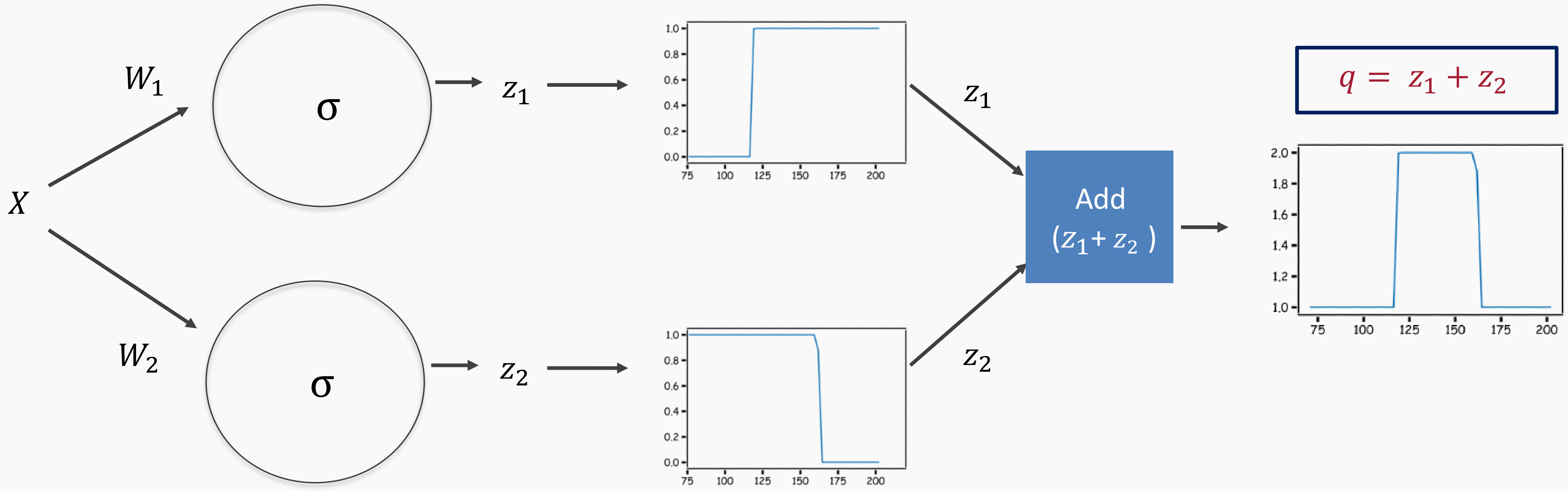
Combining Neurons



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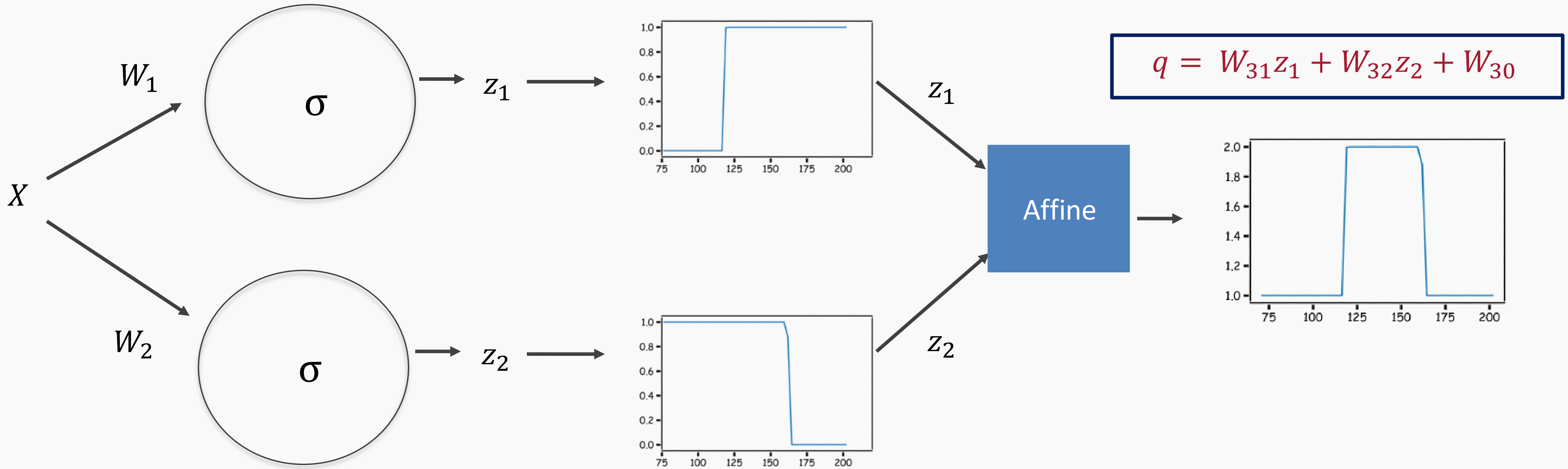

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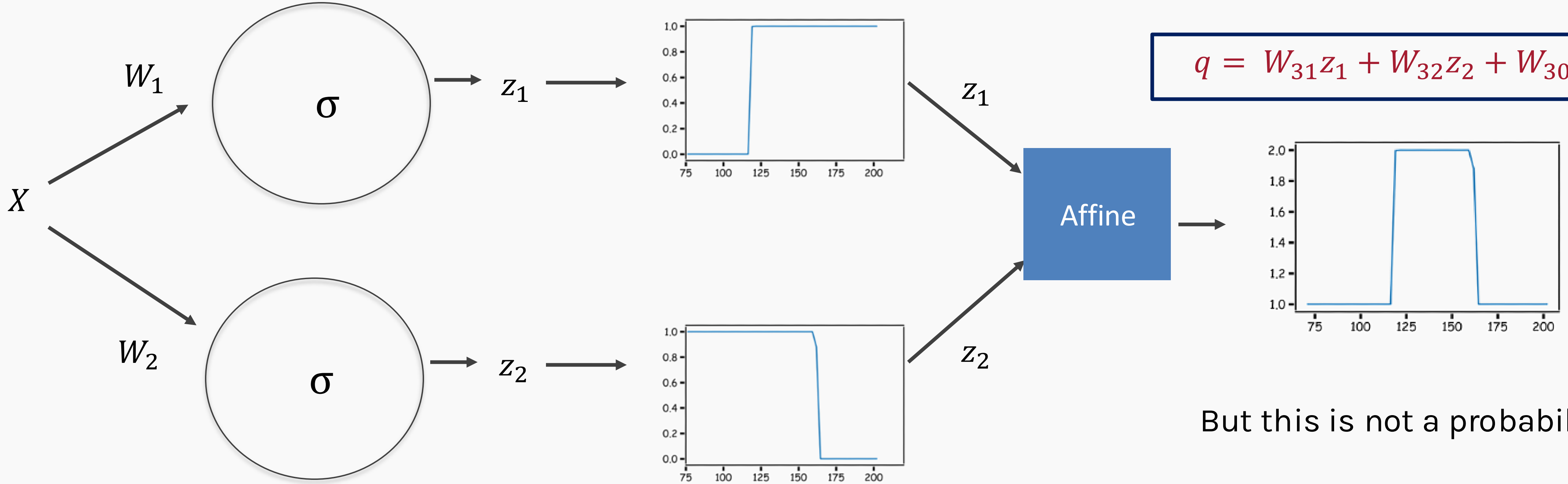


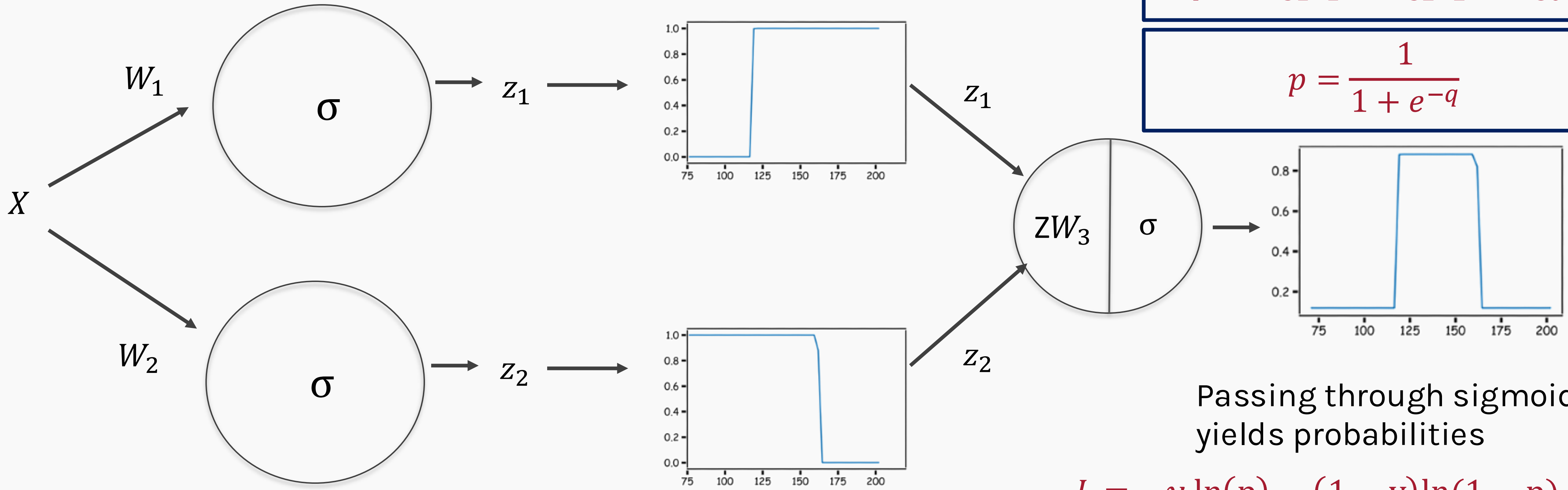
$$q = W_{31}z_1 + W_{32}z_2 + W_{30}$$

But this is not a probability

Combining Neurons

$$q = W_{31}z_1 + W_{32}z_2 + W_{30}$$

$$p = \frac{1}{1+e^{-q}}$$



Passing through sigmoid yields probabilities

$$L = -y\ln(\mathrm{p}) - (1-\mathrm{y})\ln(1-\mathrm{p})$$

Combining Neurons

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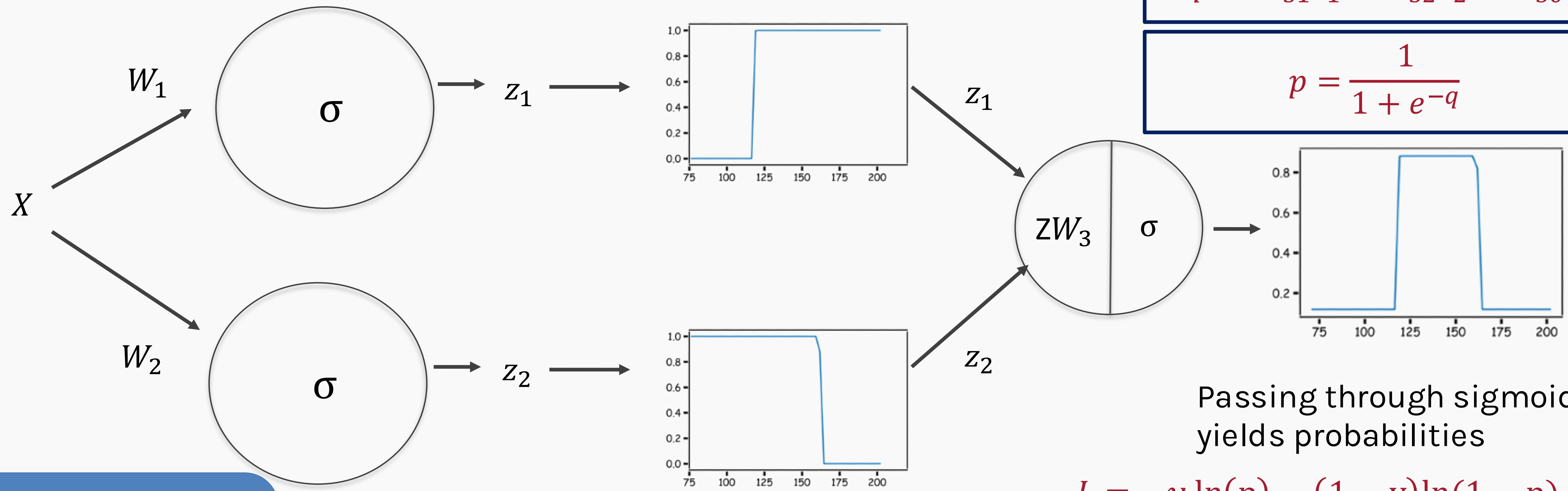


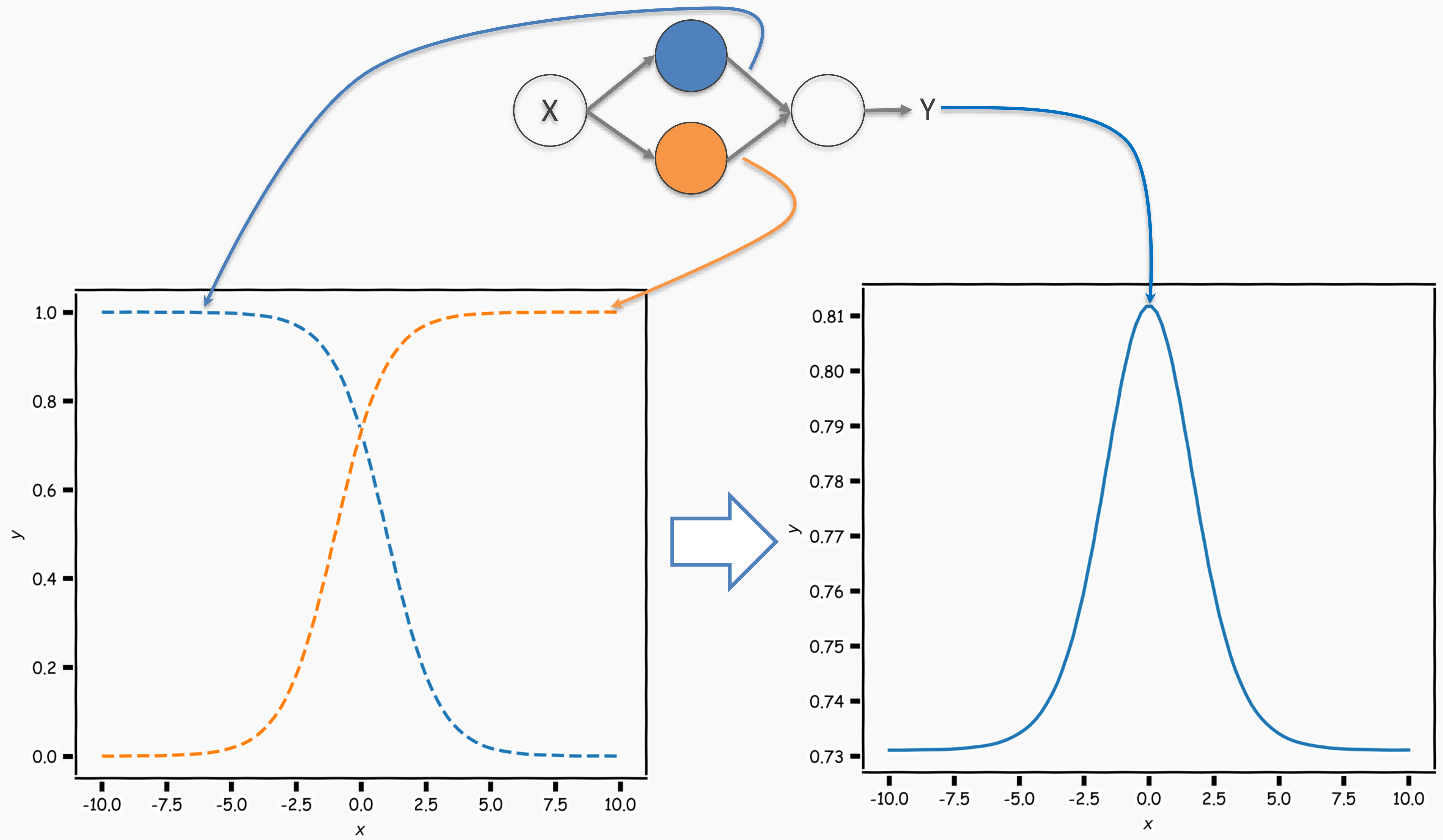
Passing through sigmoid yields probabilities

$$L = -y \ln(\mathrm{p}) - (1 - \mathrm{y}) \ln(1 - \mathrm{p})$$

We will talk about this in the coming lectures

Need to learn W_1 ,W_2 and W_3

Combining neurons allows us to model interesting functions



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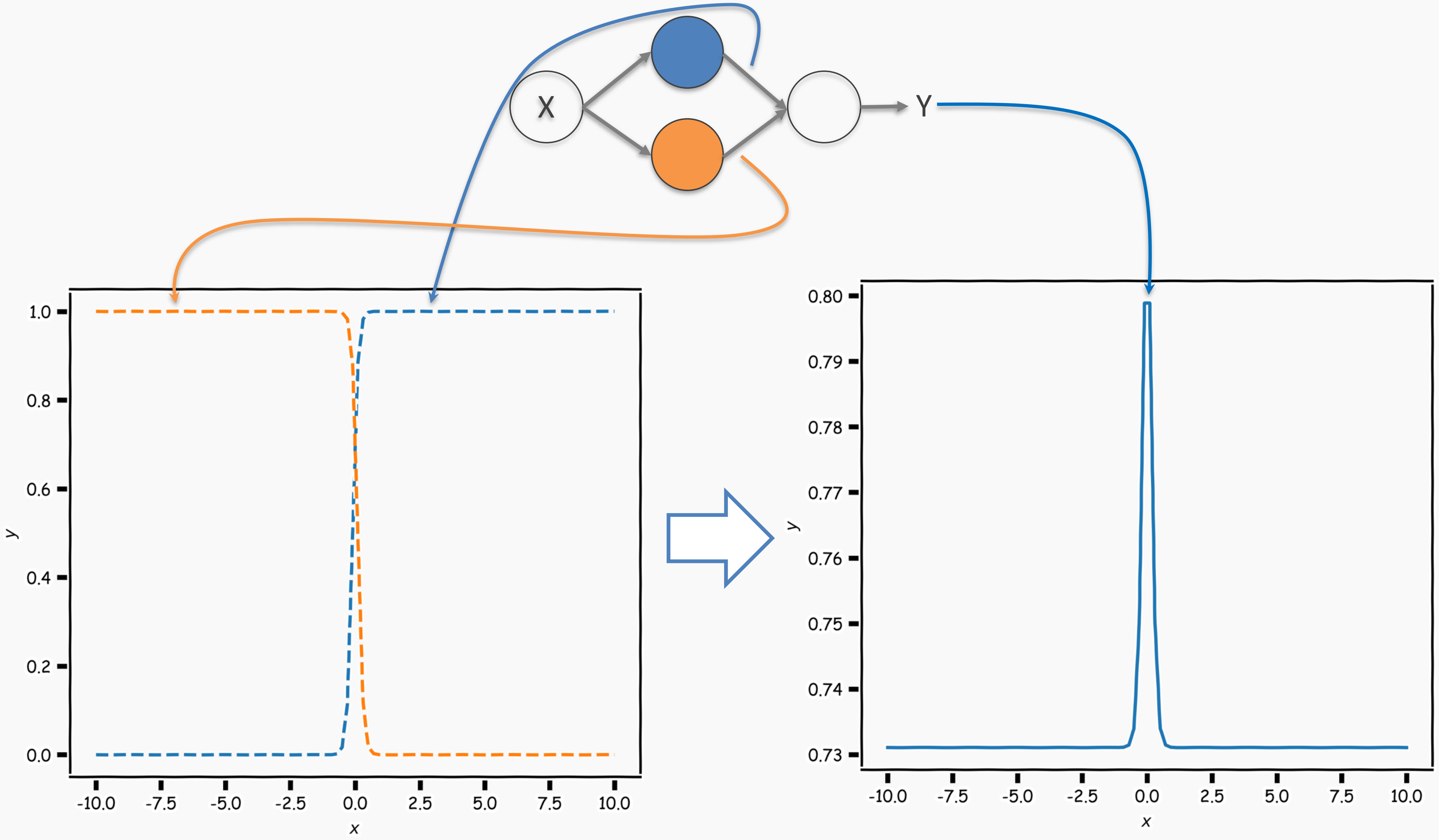

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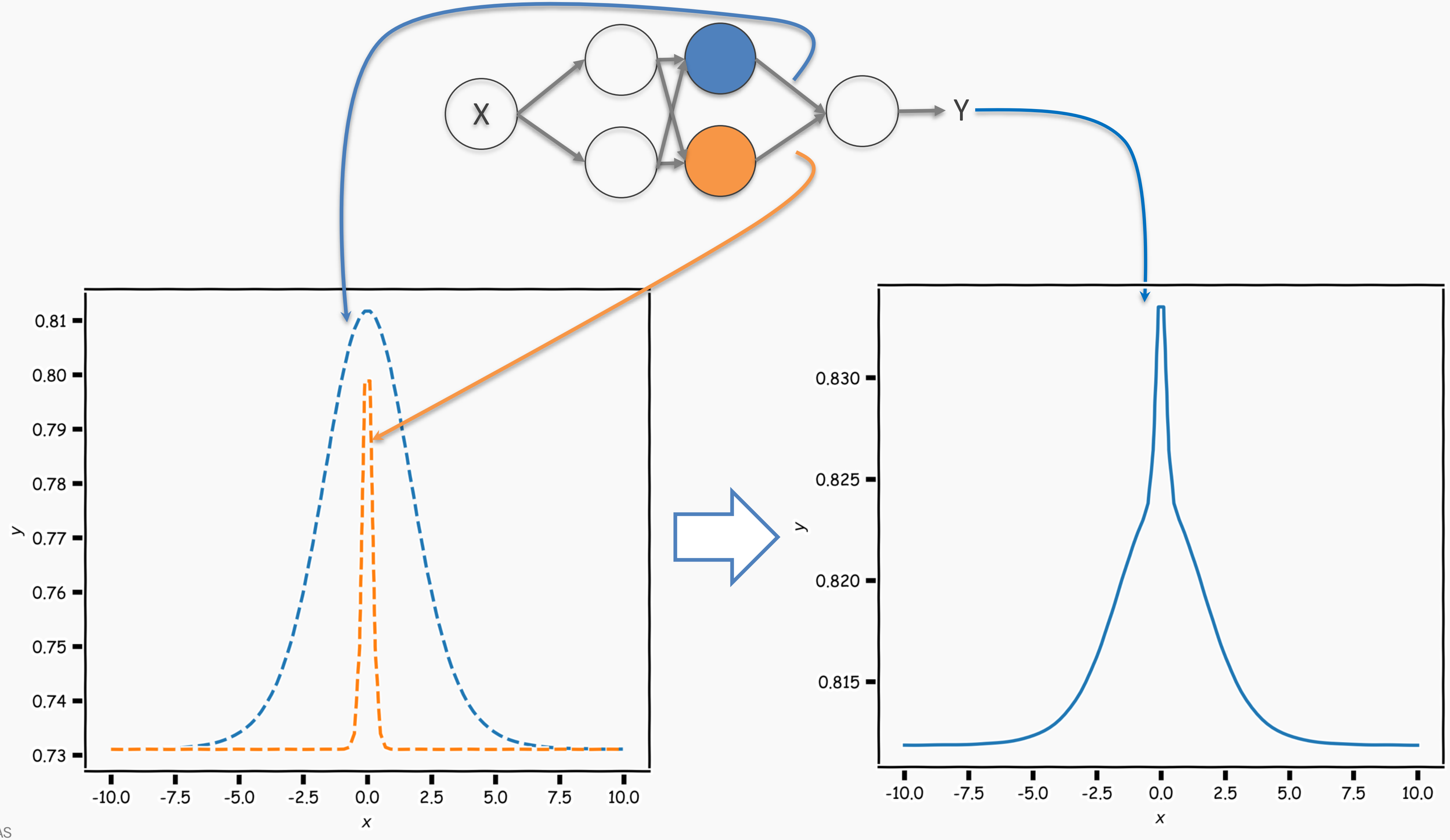

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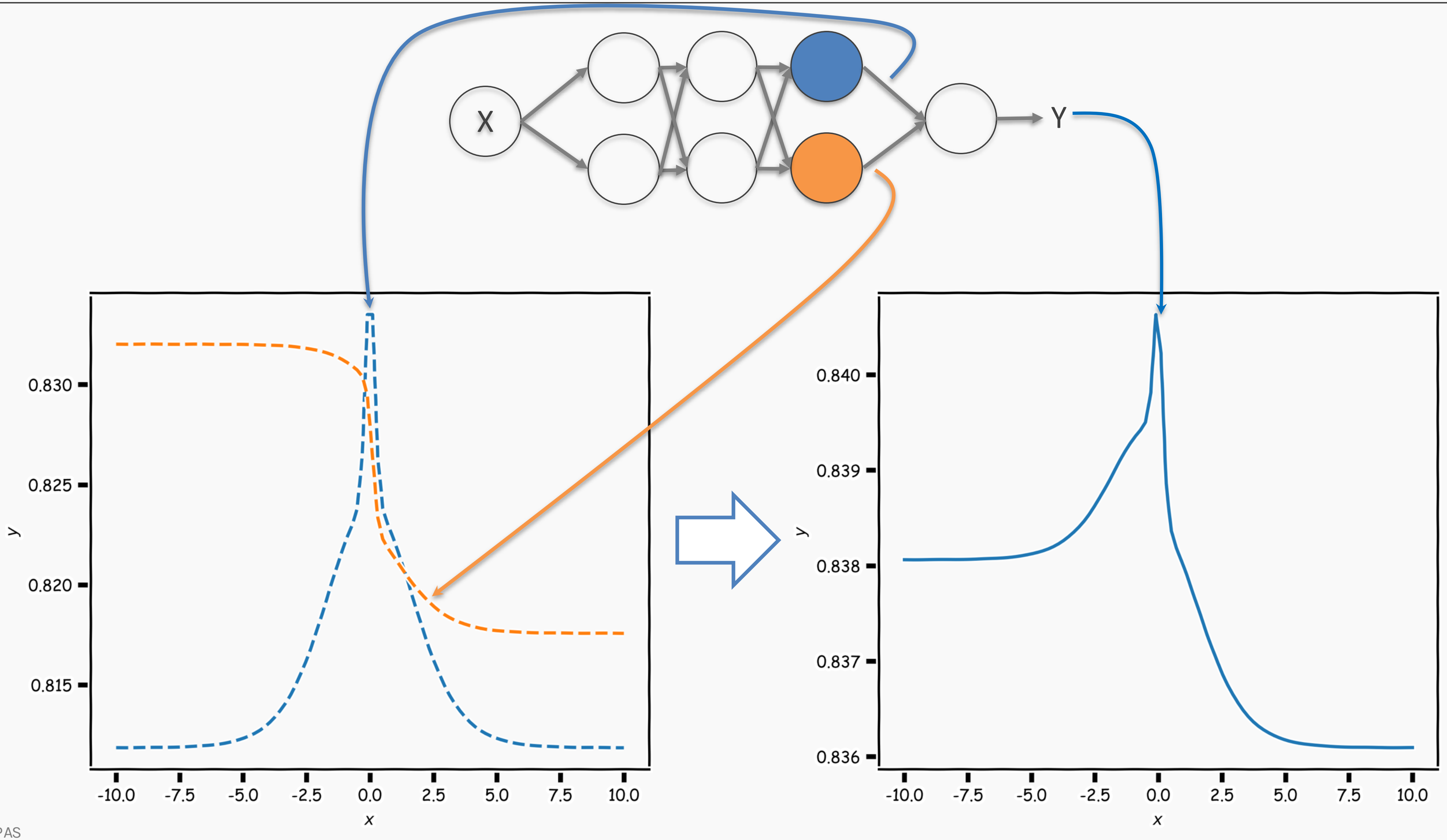
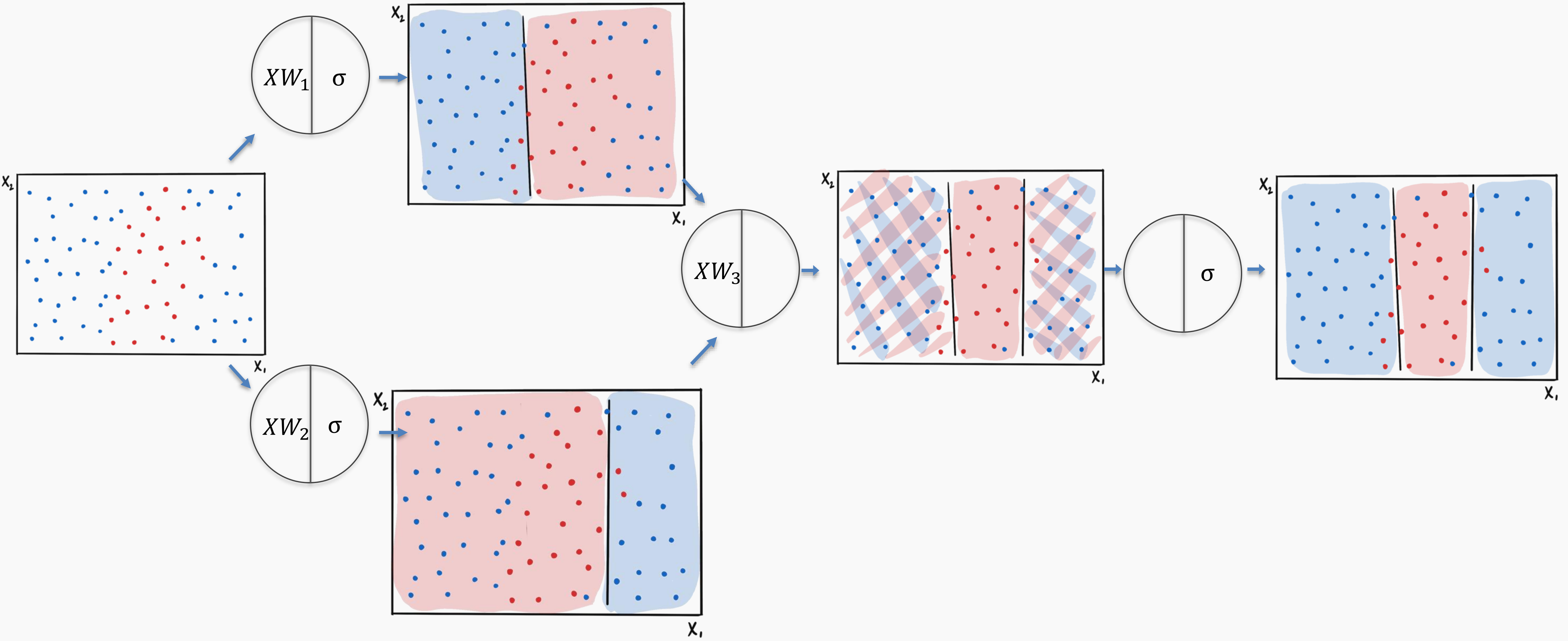


For 2-D input the same idea applies



Summary

So far:

- A single neuron is simply an affine transformation followed by an activation function.
- A single neuron can function either as a logistic regression unit or linear unit. We will soon see other choices of activation functions.
- A neural network is a combination of neurons units.
- A neural network can approximate non-linear functions either for regression or classification.

Summary

Next:

- What kind of activations, how many neurons, how many layers, how to construct the output unit and what loss functions are appropriate