Deep learning

Episode 1

Basic neural networks

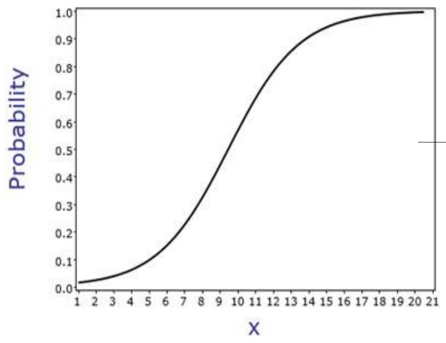
Yandex
Data Factory

LAMBDA

British Hedgehog
Preservation Society

Recap: logistic regression

$$\begin{tikzcd} X \arrow[r] & Wx + b \arrow[r] & {} \end{tikzcd}$$



$$\begin{tikzcd} {} \arrow[r] & P(y) \end{tikzcd}$$

Gradient descent

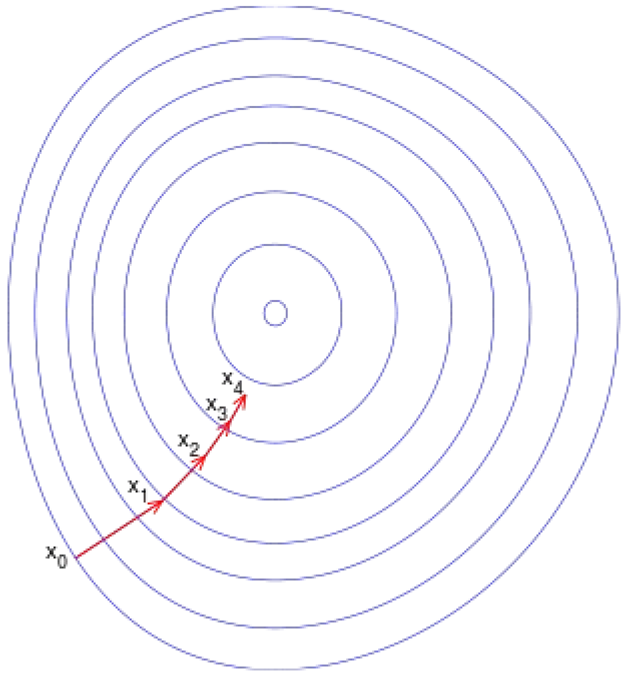
$$y_{pred}(\bar{x}) = \sigma(\bar{w} \cdot \bar{x} + b)$$

$$L(y, y_{pred}) = -(y \cdot \log y_{pred} + (1-y) \cdot \log(1 - y_{pred}))$$

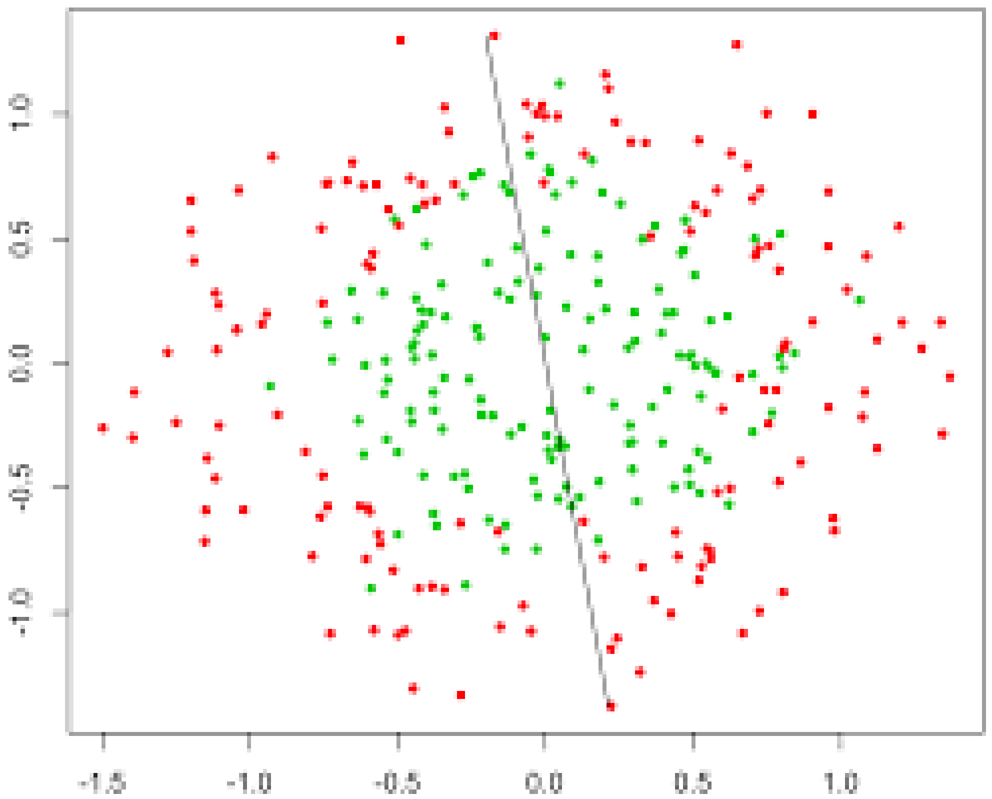
Repeat until convergence

$$\theta_j := \theta_j - \alpha \cdot \frac{\partial L(y, y_{pred})}{\partial \theta_j}$$

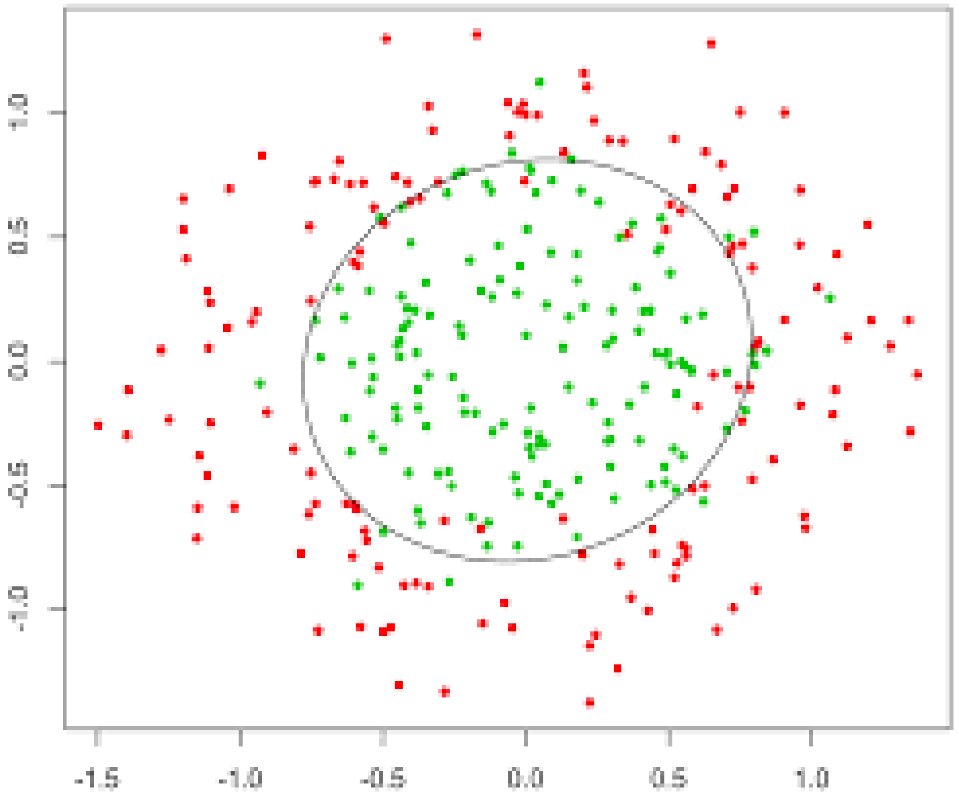
Θ~{W,b}



Nonlinear dependencies



What we have



What we want

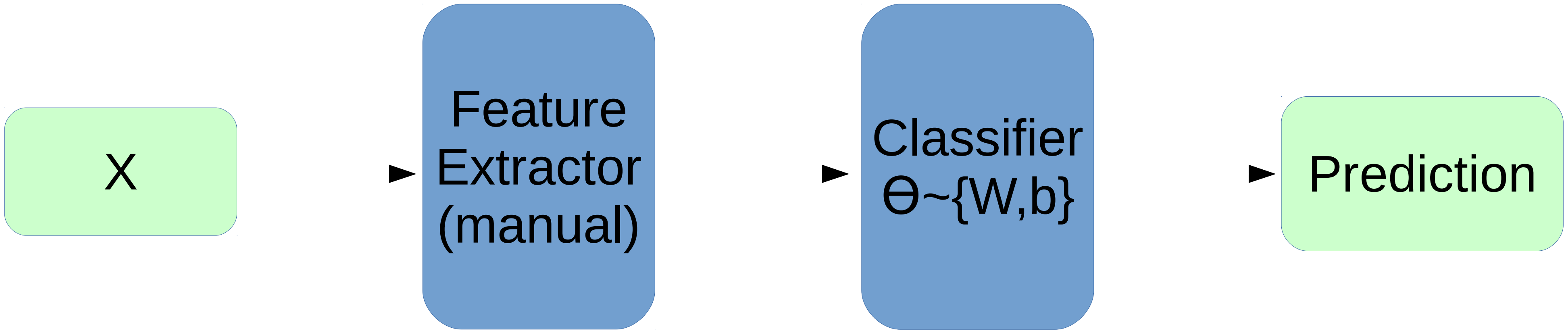
- How to get that?

Feature extraction

Loss, for example:

$$L(y, y_{pred}) = -(y \cdot \log y_{pred} + (1-y) \cdot \log(1-y_{pred}))$$

Model:



Training:

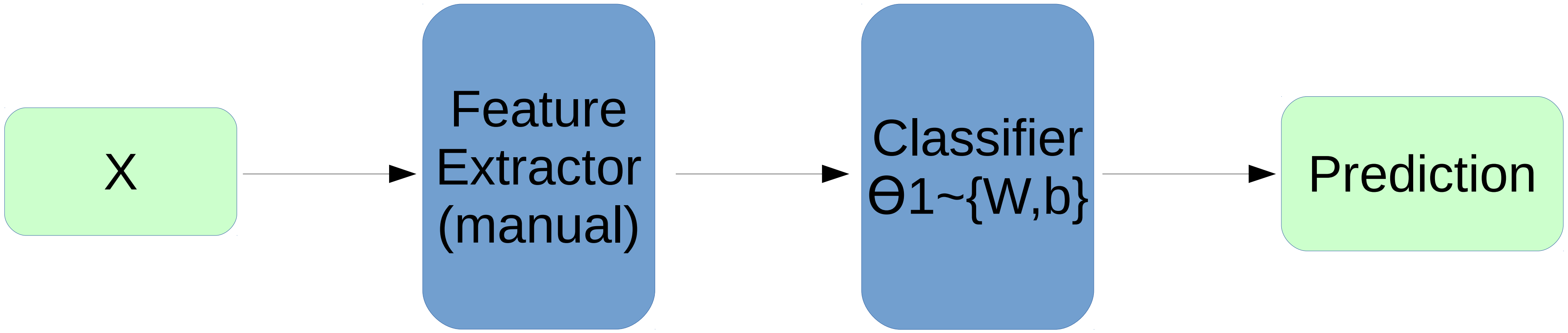
$$argmin_{\theta} L(y, y_{pred}(X, \theta))$$

Feature extraction

Loss, for example:

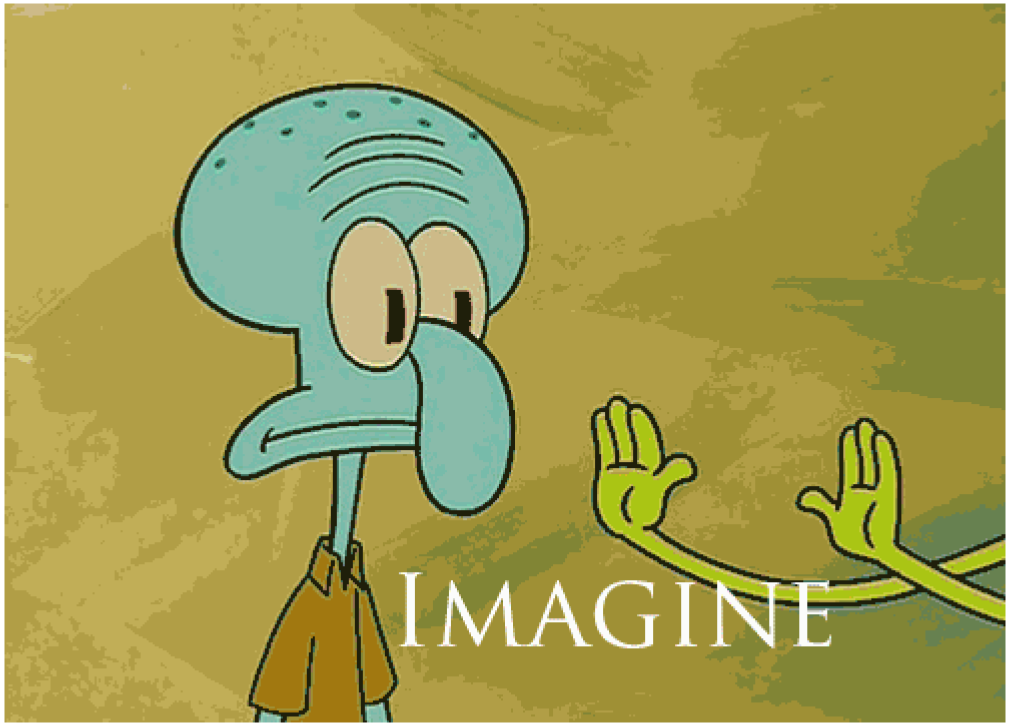
$$L(y, y_{pred}) = -(y \cdot \log y_{pred} + (1-y) \cdot \log(1-y_{pred}))$$

Model:



Gradient:

$$\frac{\delta L(y, y_{pred}(X, \theta 1))}{\delta \theta 1}$$



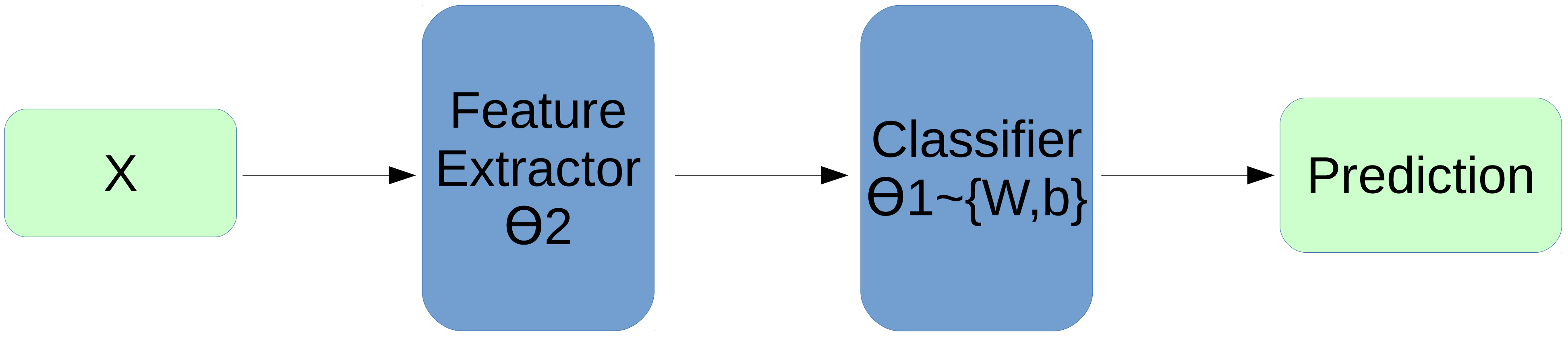
Features would tune to your problem automatically!

What do we want, exactly?

Loss, for example:

$$L(y, y_{pred}) = -(y \cdot \log y_{pred} + (1-y) \cdot \log(1-y_{pred}))$$

Model:



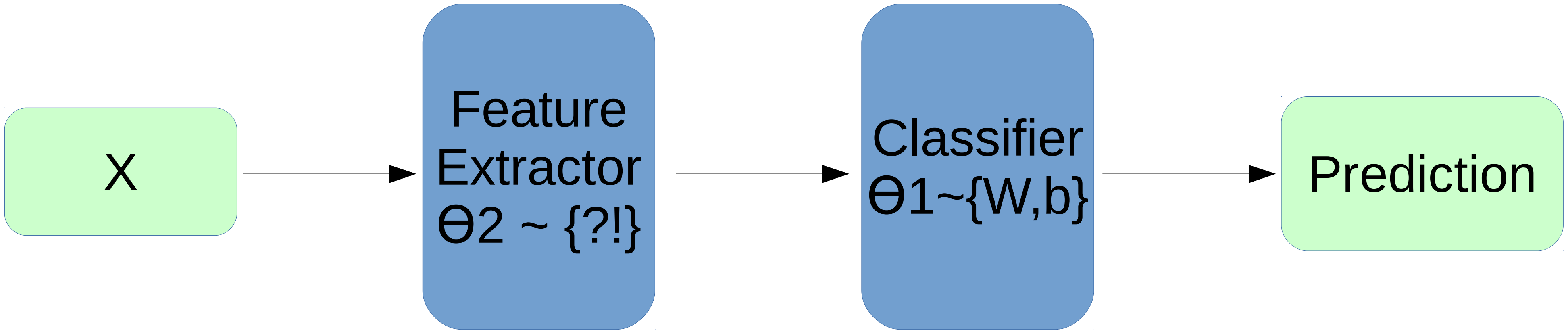
Training: ? $argmin_{\theta_1} L(y, y_{pred}(X, \theta_{1,} \theta_2))$

What do we want, exactly?

Loss, for example:

$$L(y, y_{pred}) = -\left(y \cdot \log y_{pred} + (1-y) \cdot \log(1-y_{pred})\right)$$

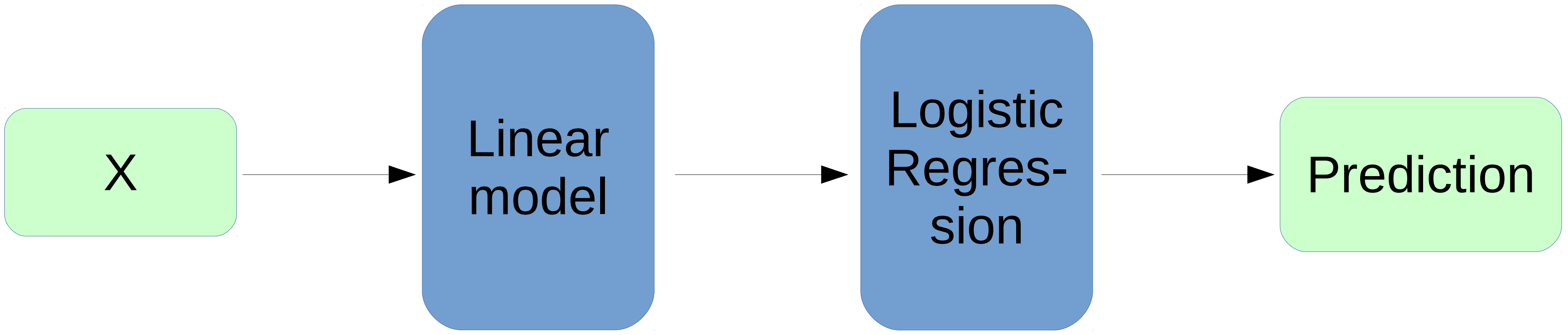
Model:



Gradients: $\frac{\delta L(y, y_{pred}(X, \theta_{1,} \theta_2))}{\delta \theta_2}$ $\frac{\delta L(y, y_{pred}(X, \theta_{1,} \theta_2))}{\delta \theta_1}$

Try linear

Model:

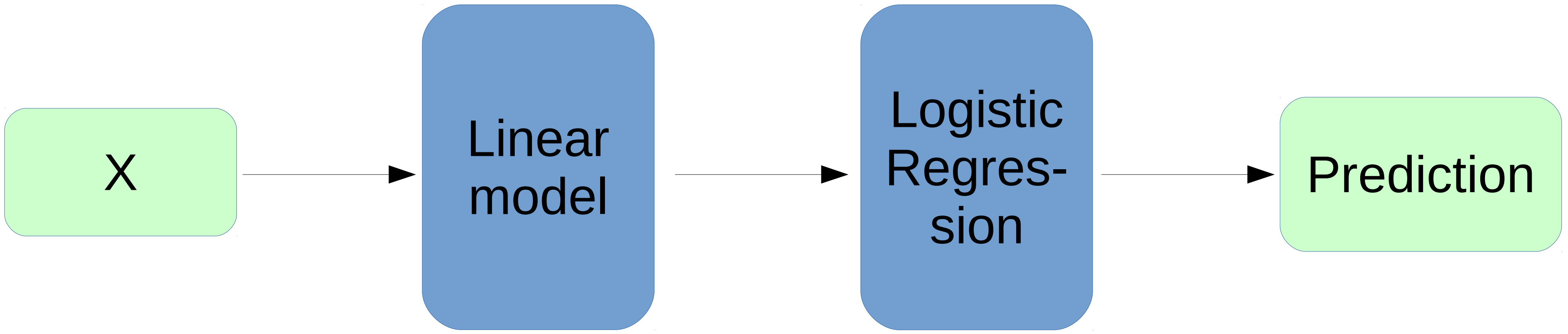


$$h_j = \sum_i w_{ij}^h x_i + b_j^h \quad j \in \{1,2,\ldots,n\}$$

$$y_{pred} = \sigma\left(\sum_j w_j^o h_j + b^o\right)$$

Try linear

Model:



$$h_j = \sum_i w_{ij}^h x_i + b_j^h \qquad y_{pred} = \sigma\left(\sum_j w_j^o h_j + b^o\right)$$
$$j \in \{1, 2, \ldots, n\}$$

Output:

$$y_{pred} = \sigma\left(\sum_j w_j^o \left(\sum_i w_{ij}^h x_i + b_j^h\right) + b^o\right)$$

Is it any better than logistic regression?

Try linear

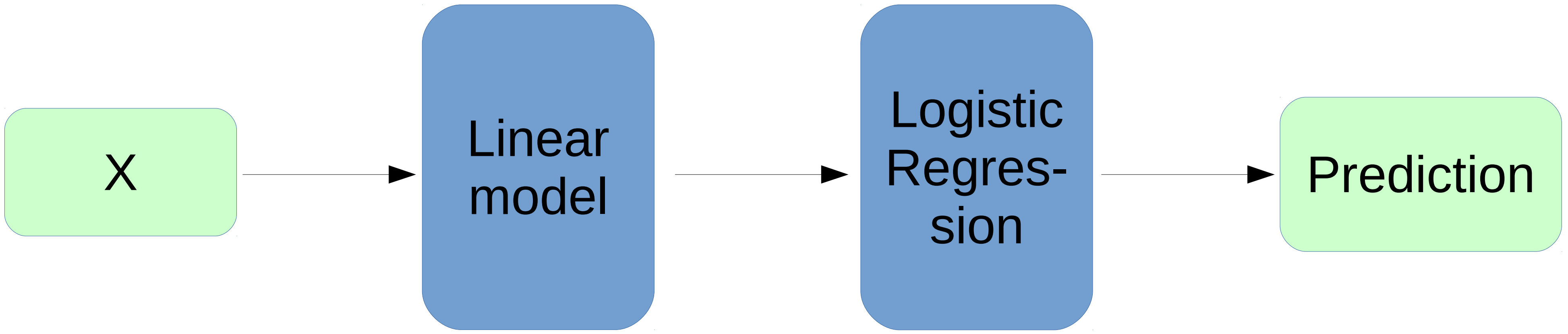
$$y_{pred} = \sigma\left(\sum_j w_j^o \left(\sum_i w_{ij}^h x_i + b_j^h\right) + b^o\right)$$

$$w'_i = \sum_j w_j^o w_{ij}^h \qquad b' = \sum_j w_j^o b_j^h + b^o$$

$$y_{pred} = \sigma\left(\sum_i w'_i x_i + b'\right)$$

Try linear

Model:



$$h_j = \sum_i w^h_{ij} x_i + b^h_j \qquad y_{pred} = \sigma\left(\sum_j w^o_j h_j + b^o\right)$$

$$j \in \{1,2,\ldots,n\}$$

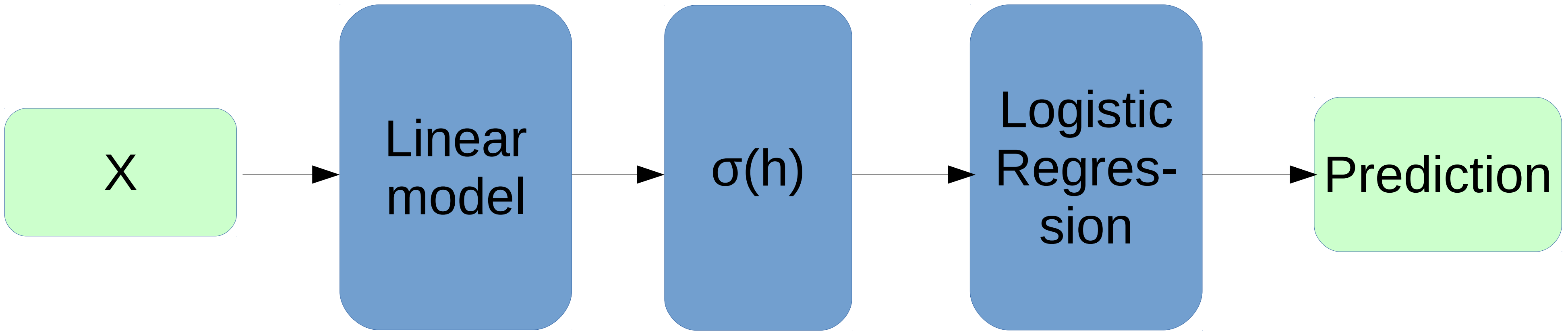
Output:

$$y_{pred} = \sigma\left(\sum_j w^o_j \left(\sum_i w^h_{ij} x_i + b^h_j\right) + b^o\right)$$

Is it any better than logistic regression?

Nonlinearity

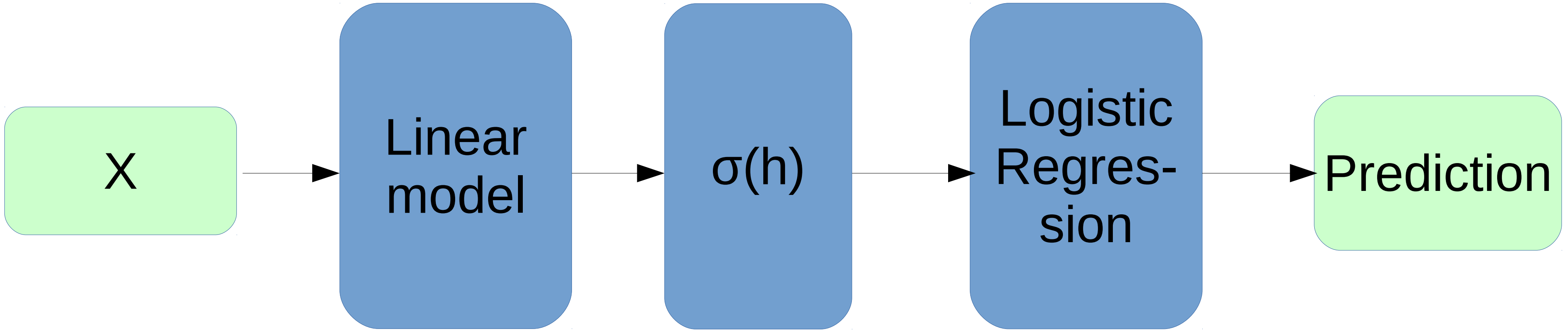
Model:



$$h_j = \sigma\left(\sum_{\substack{i \\ j \in \{1,2,\ldots,n\}}} w_{ij}^h x_i + b_j^h\right) \qquad y_{pred} = \sigma\left(\sum_j w_j^o h_j + b^o\right)$$

Nonlinearity

Model:



$$h_j = \sigma\left(\sum_{\substack{i \\ j \in \{1,2,\ldots,n\}}} w_{ij}^h x_i + b_j^h\right) \qquad y_{pred} = \sigma\left(\sum_j w_j^o h_j + b^o\right)$$

Output:

$$y_{pred} = \sigma\left(\sum_j w_j^o \sigma\left(\sum_i w_{ij}^h x_i + b_j^h\right) + b^o\right)$$

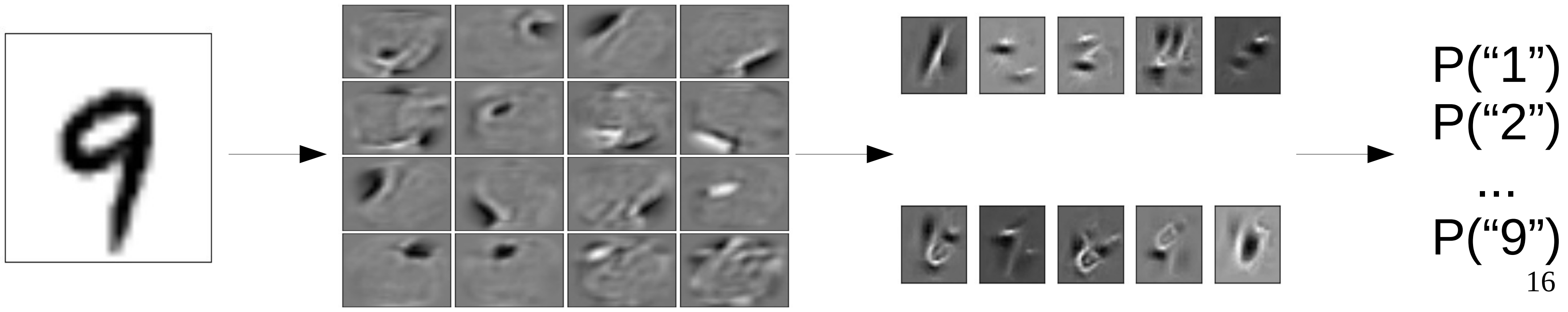
Nonlinearity

Model:

$$\begin{tikzcd}
\text{X} \arrow[r] & \text{Linear model} \arrow[r] & \sigma(h) \arrow[r] & \text{Logistic Regres-sion} \arrow[r] & \text{Prediction}
\end{tikzcd}$$

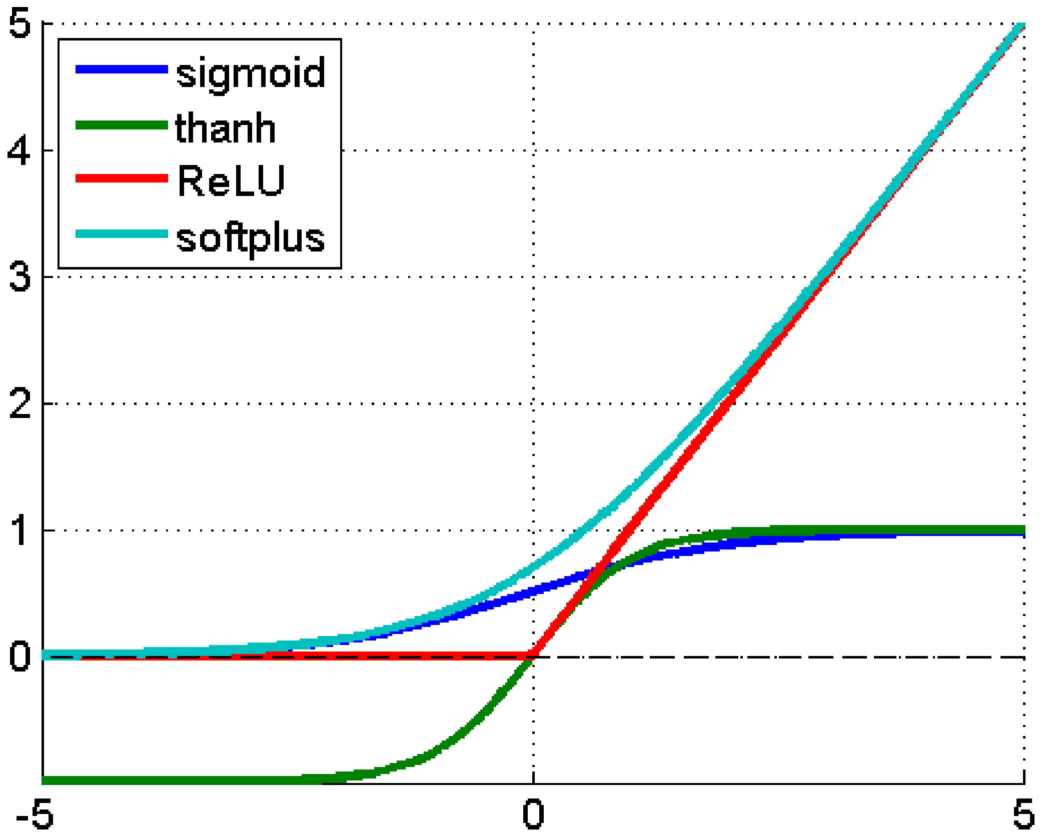
$$h_j = \sigma\left(\sum_{i \in \{1, 2, \ldots, n\}} w_{ij}^h x_i + b_j^h\right)$$

$$y_{pred} = \sigma\left(\sum_j w_j^o h_j + b^o\right)$$

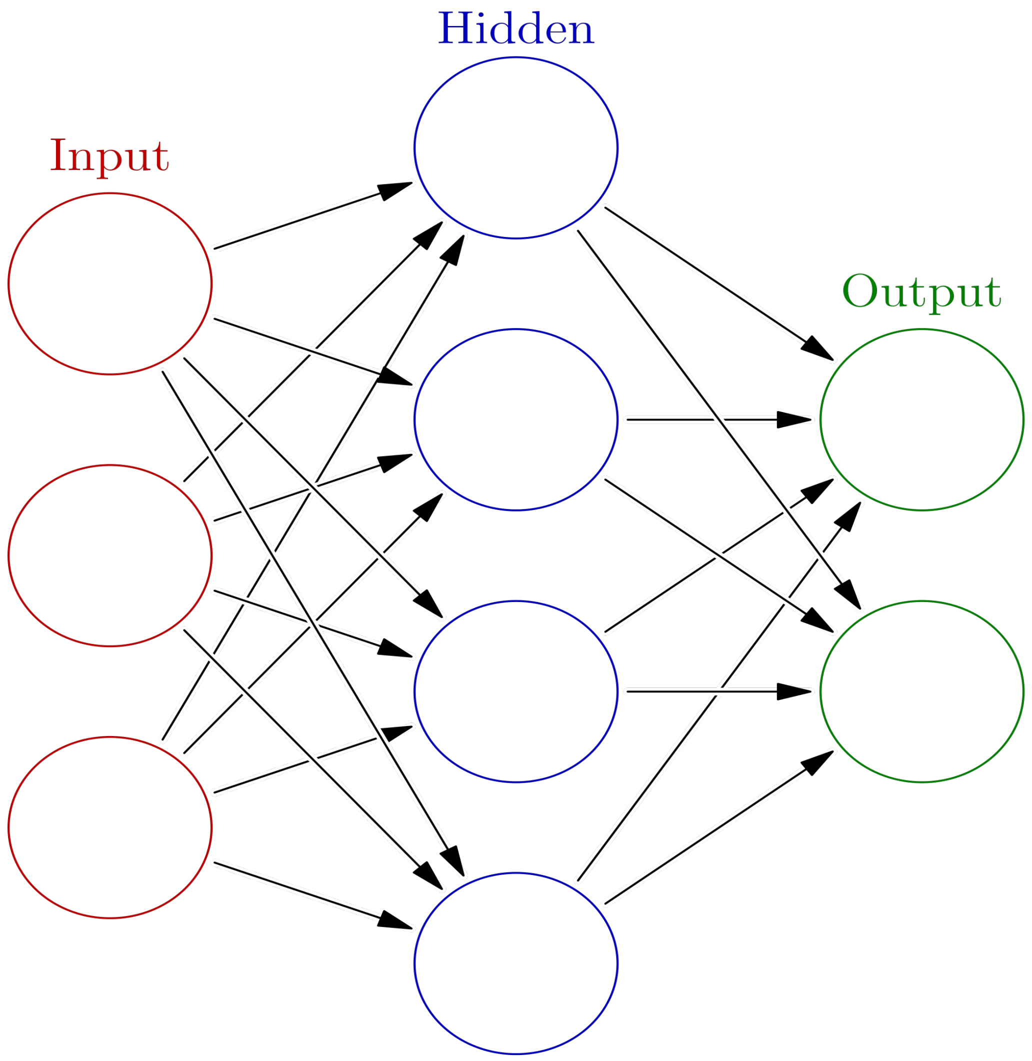


Nonlinearity

- f(a) = 1/(1+e^a)
- f(a) = tanh(a)
- f(a) = max(0,a)
- f(a) = log(1+e^x)



Initialization, symmetry problem

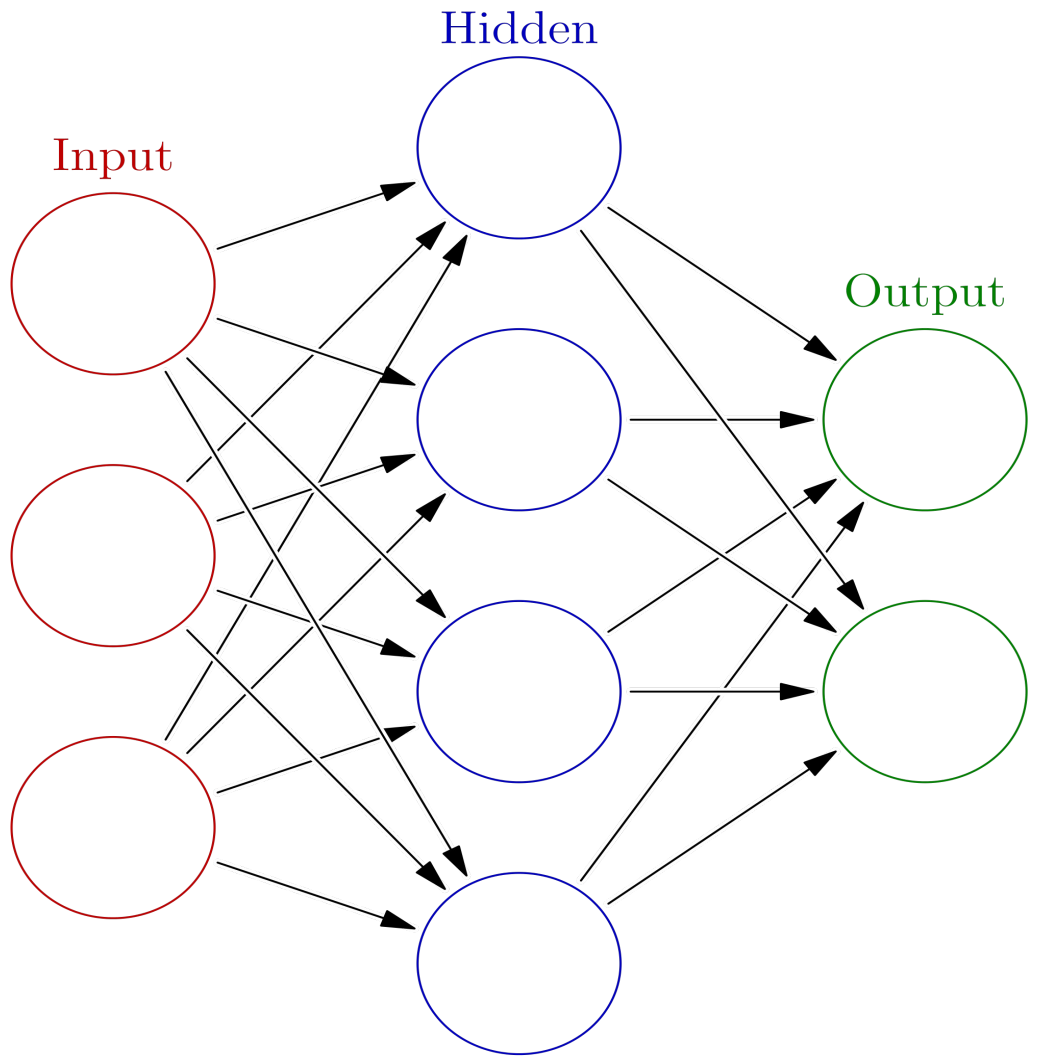


- Initialize with zeros

  $W \leftarrow 0$

- What will the first step look like?

Initialization, symmetry problem

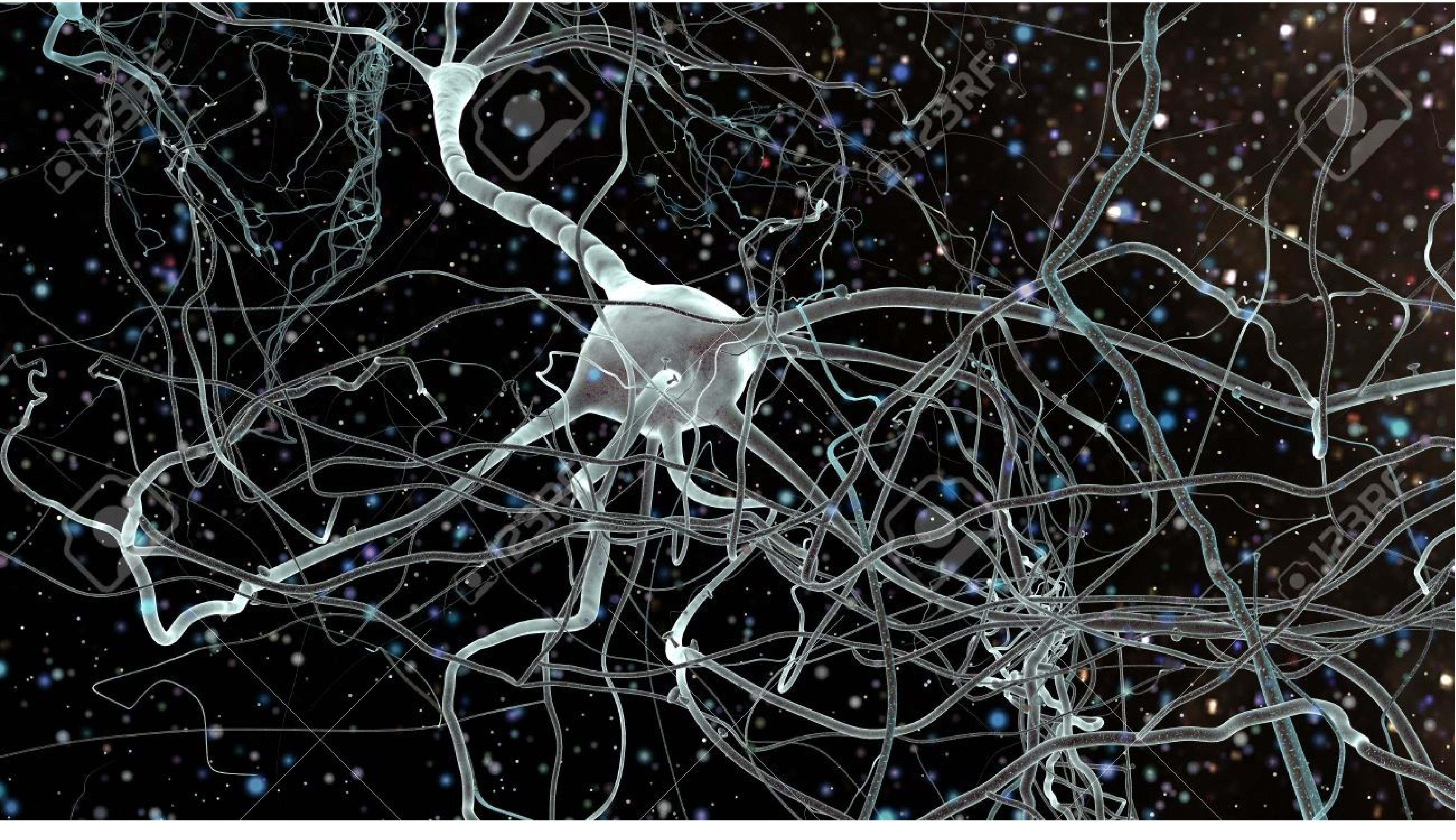


- Break the symmetry!
- Initialize with random numbers!

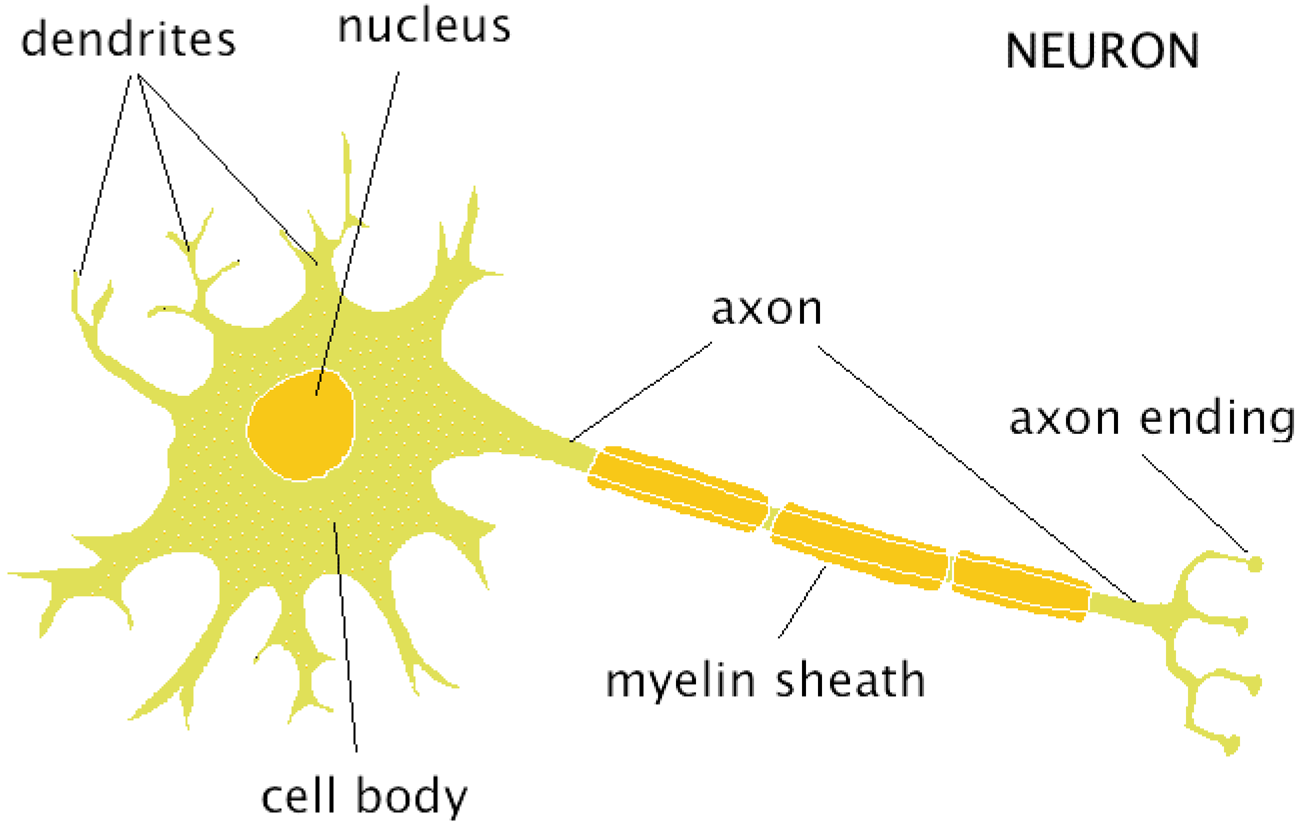
  $W \leftarrow N(0,0.01)$?

  $W \leftarrow U(0,0.1)$?
- Can get a bit better for deep NNs

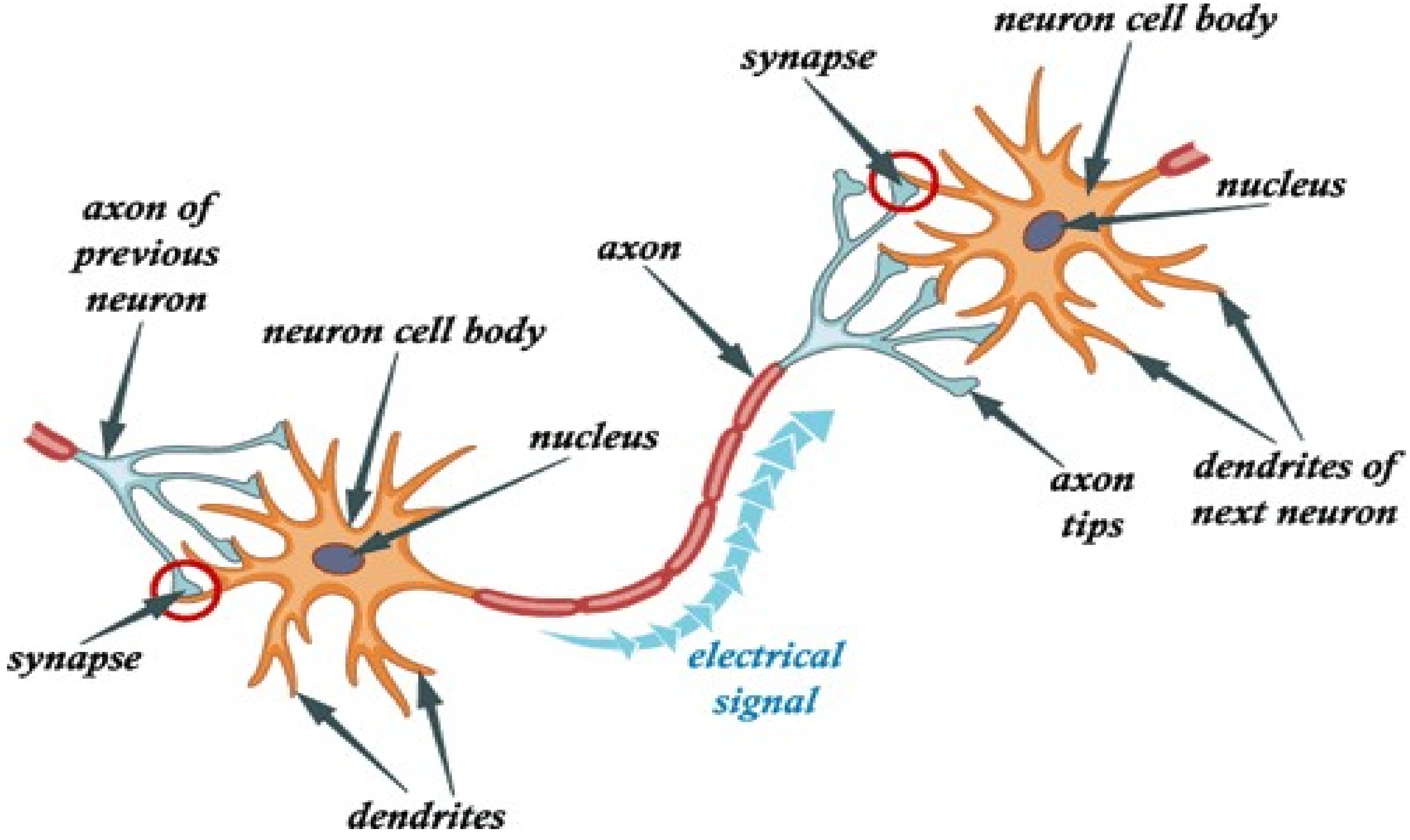
Biological inspiration



Biological inspiration

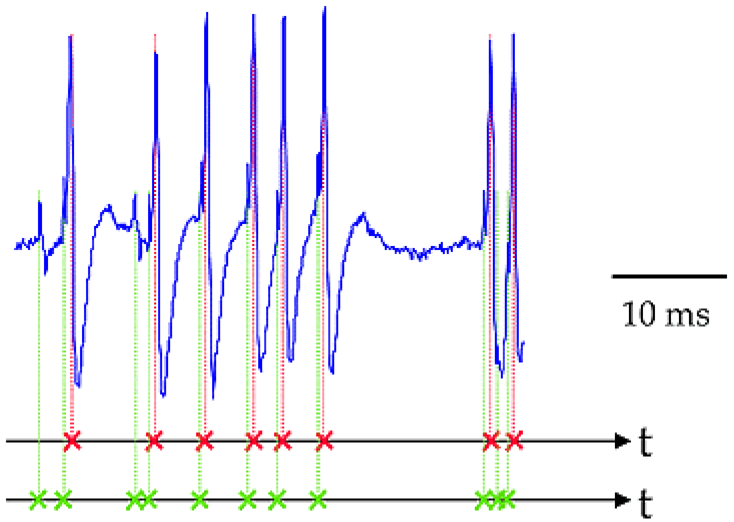


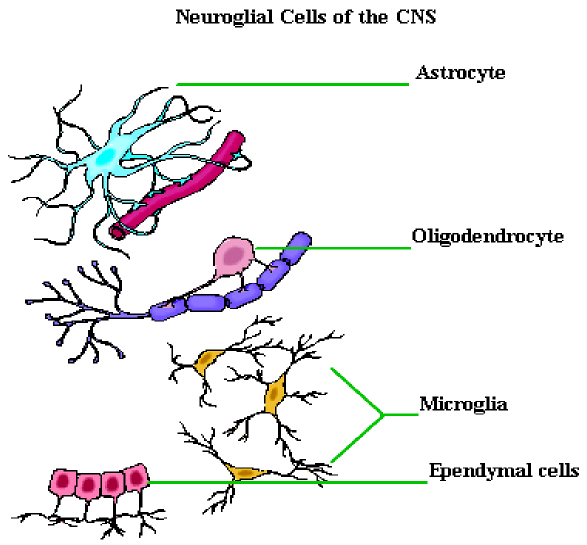
Biological inspiration



Not actual neurons :)

- Neurons react in “spikes”, not real numbers
- Neurons maintain/change their states over time
- No one knows for sure how they “train”
- Neuroglial cells are important But noone knows, why





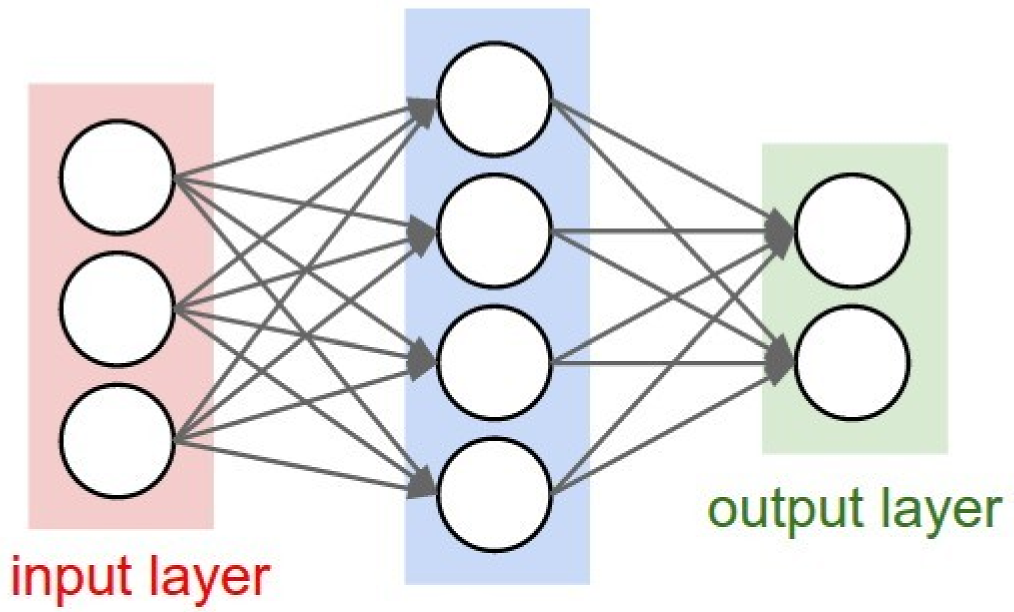
Connectionist phrasebook

- Layer – a building block for NNs :
  - “Dense layer”: $f(x) = Wx+b$
  - “Nonlinearity layer”: $f(x) = \sigma(x)$
  - Input layer, output layer
  - A few more we gonna cover later

- Activation – layer output
  - i.e. some intermediate signal in the NN

- Backpropagation – a fancy word for “chain rule”

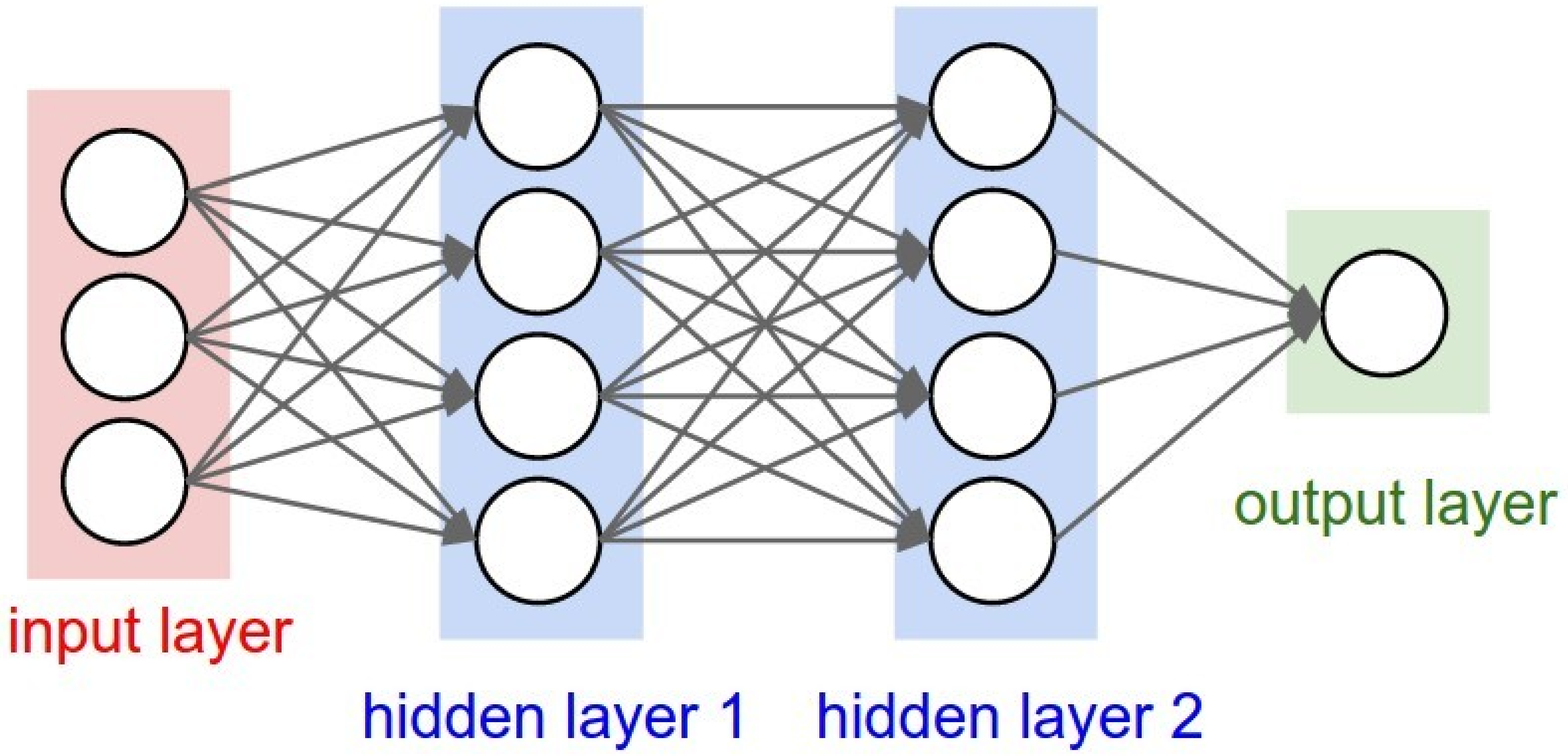
Connectionist phrasebook



Dense layer
with a nonlinearity

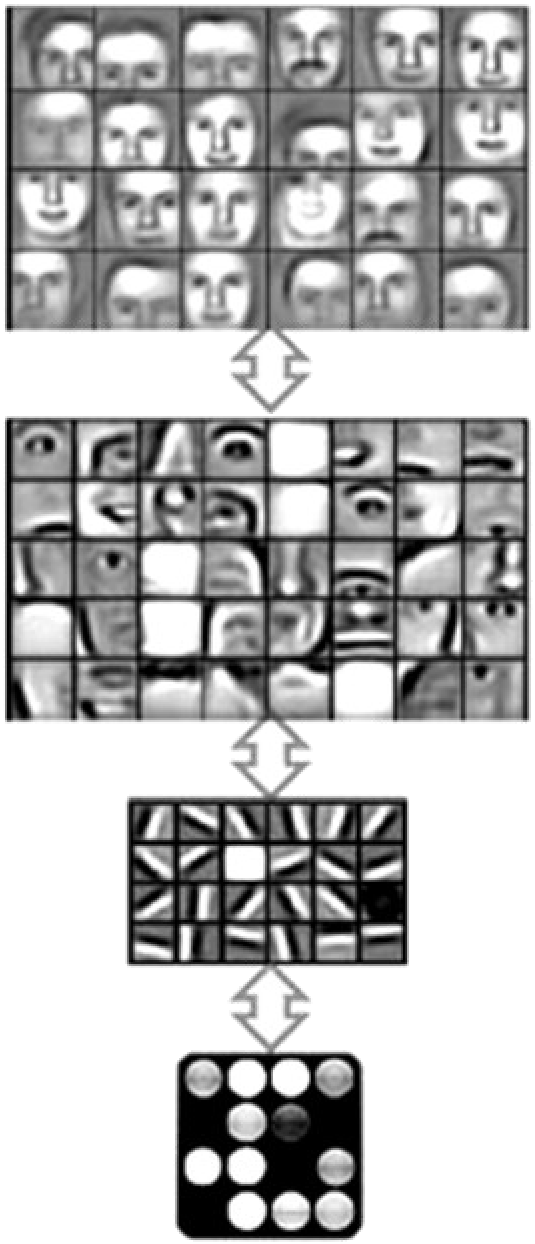
- “Train it via backprop!”

Connectionist phrasebook



How do we train it?

Potential caveats?



Discrete Choices

⋮

Layer 2 Features

Layer 1 Features

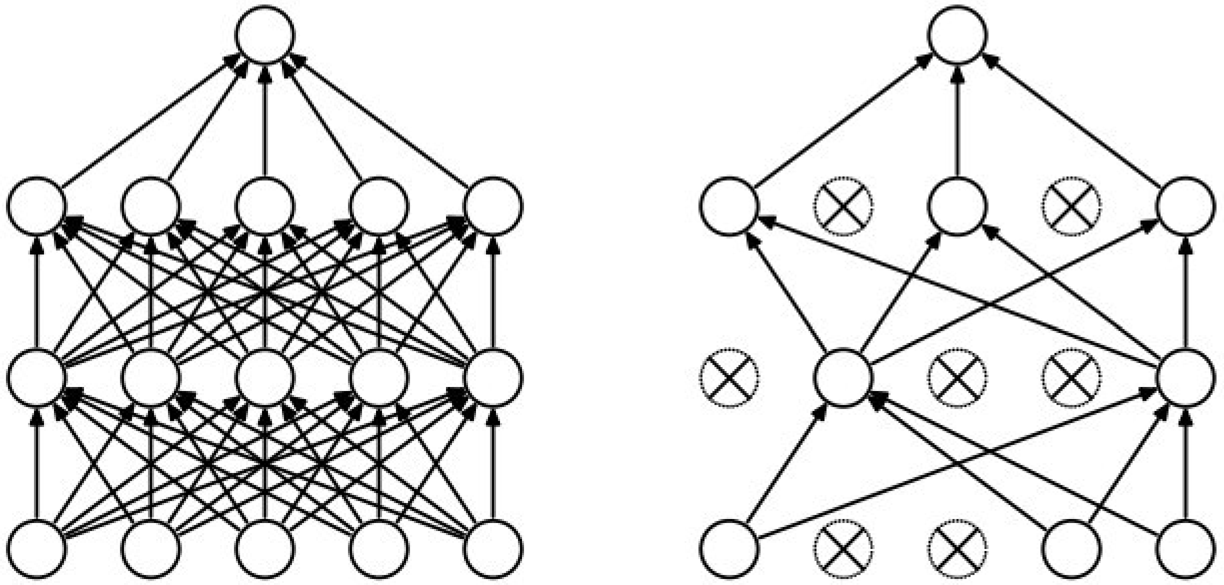
Original Data

Potential caveats?

- Hardcore overfitting
- No “golden standard” for architecture
- Computationally heavy

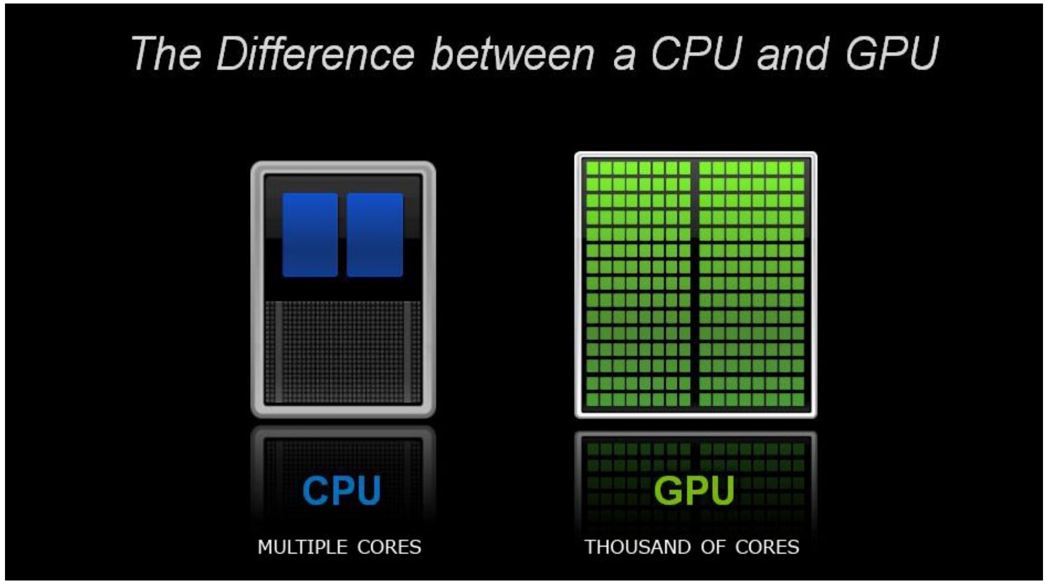
Regularization

- L1, L2, as usual
- Dropout

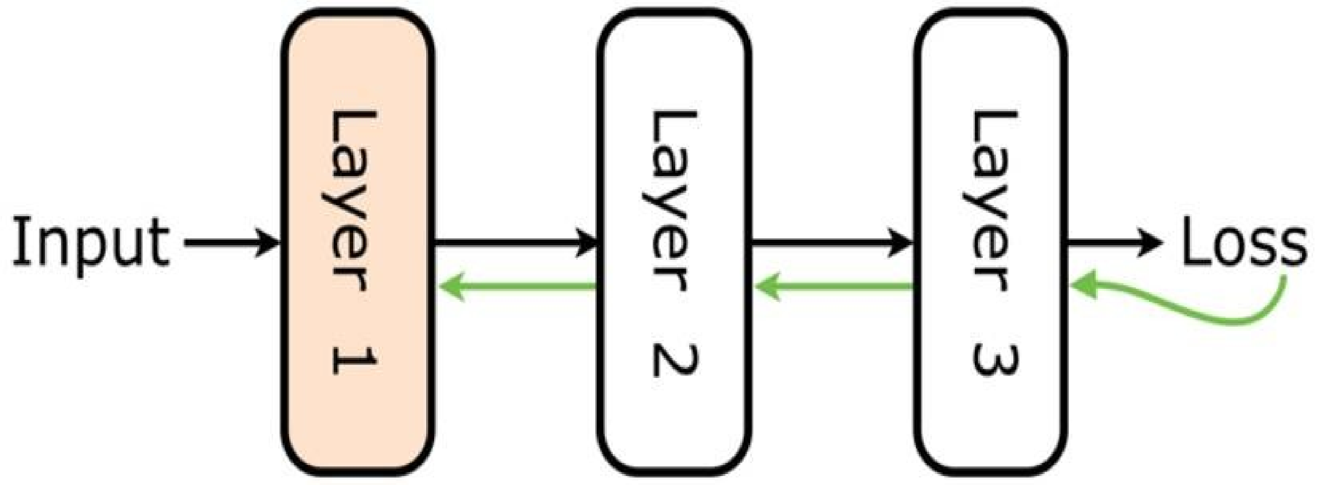


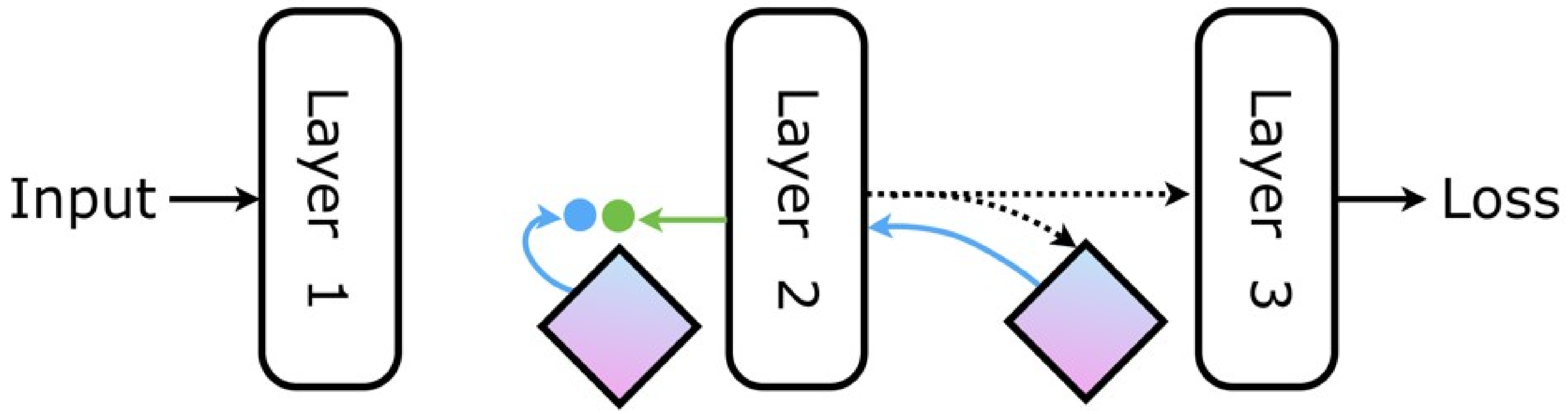
(a) Standard Neural Net (b) After applying dropout.

Computation



Is backprop the only choice?





Nuff

Let's code some neural networks!