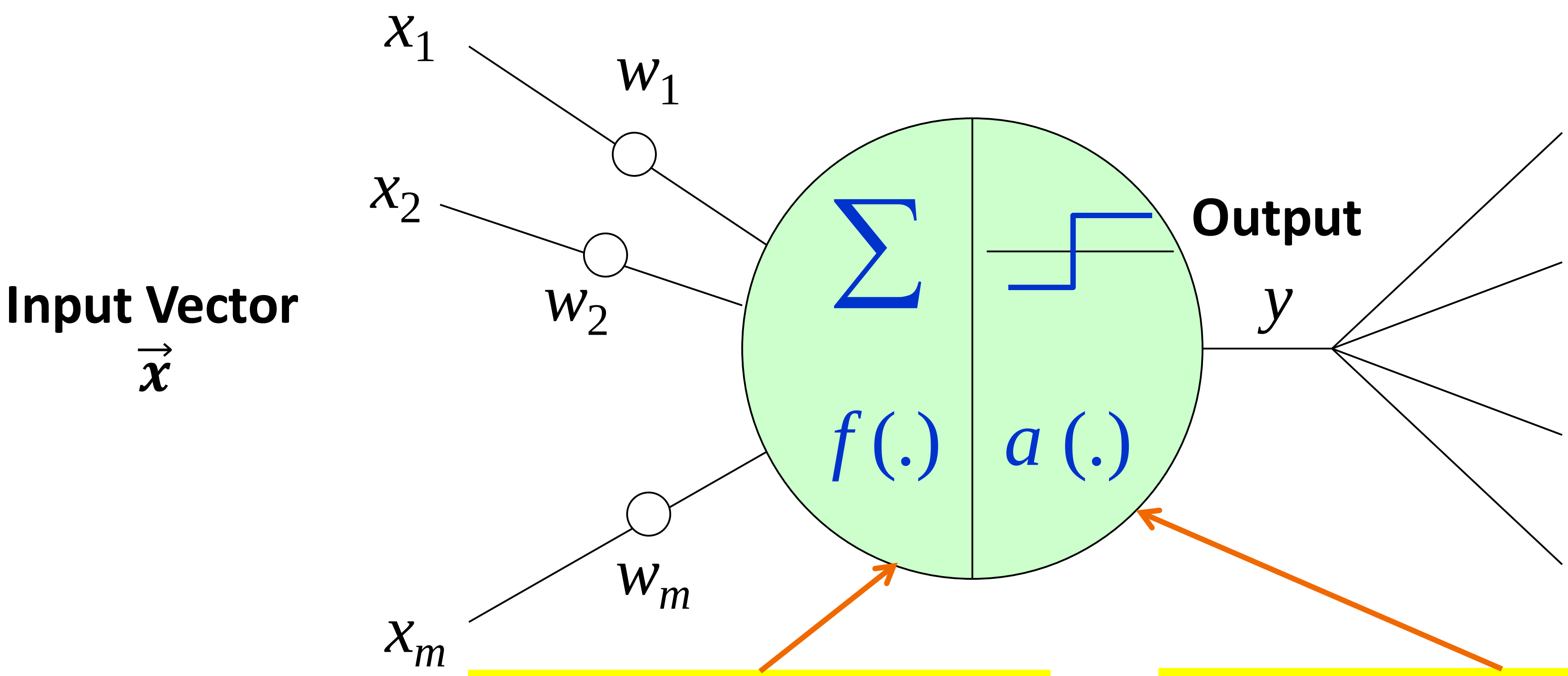
# Backpropagation

(Introduction)

# The Artificial Neuron

Proposed by McCulloch and Pitts [1943]
M-P neurons



**f**
**Integration Function**
***Aggregating input signals***

***a***
**Activation Function**
***Thresholding Logic***

# How to train a Perceptron?

Proposed by Rosenblatt [1962]

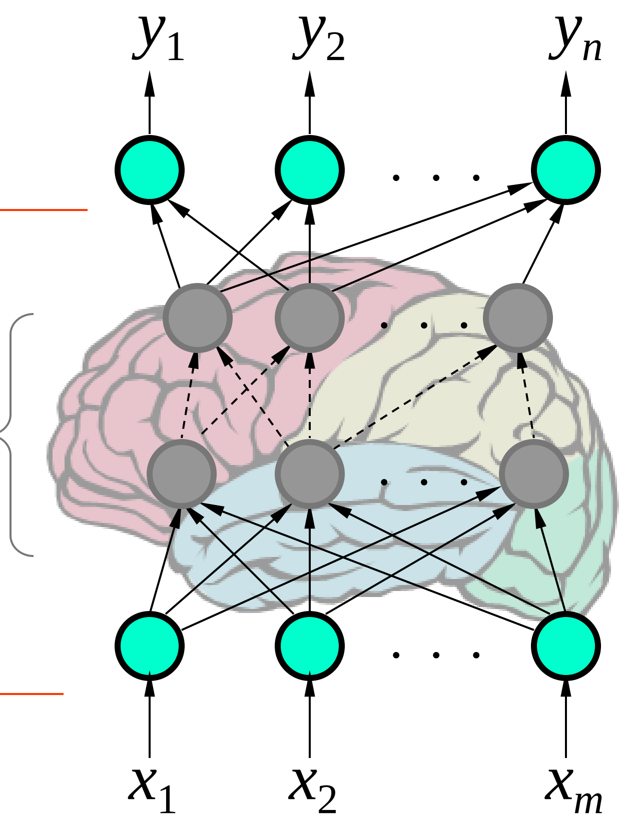
- Perceptron Algorithm - Iterative algorithm to learn the weight vector
- Basic Idea
  - Update weights in proportion to the error contributed by inputs

```
Randomly initialize weight vector $\vec{w}_0$

Repeat until error is less than a threshold $\gamma$ or max_iterations $M$:

For each training example $(\vec{x}_i, t_i)$:

        Predict output $y_i$ using current network weights $\vec{w}_n$
        Update weight vector as follows:

    $\vec{w}_{n+1} = \vec{w}_n + \eta * (t_i - y_i) * \vec{x}_i$
```

Learning Rate

Error

# Multi-Layered Perceptrons (MLPs)

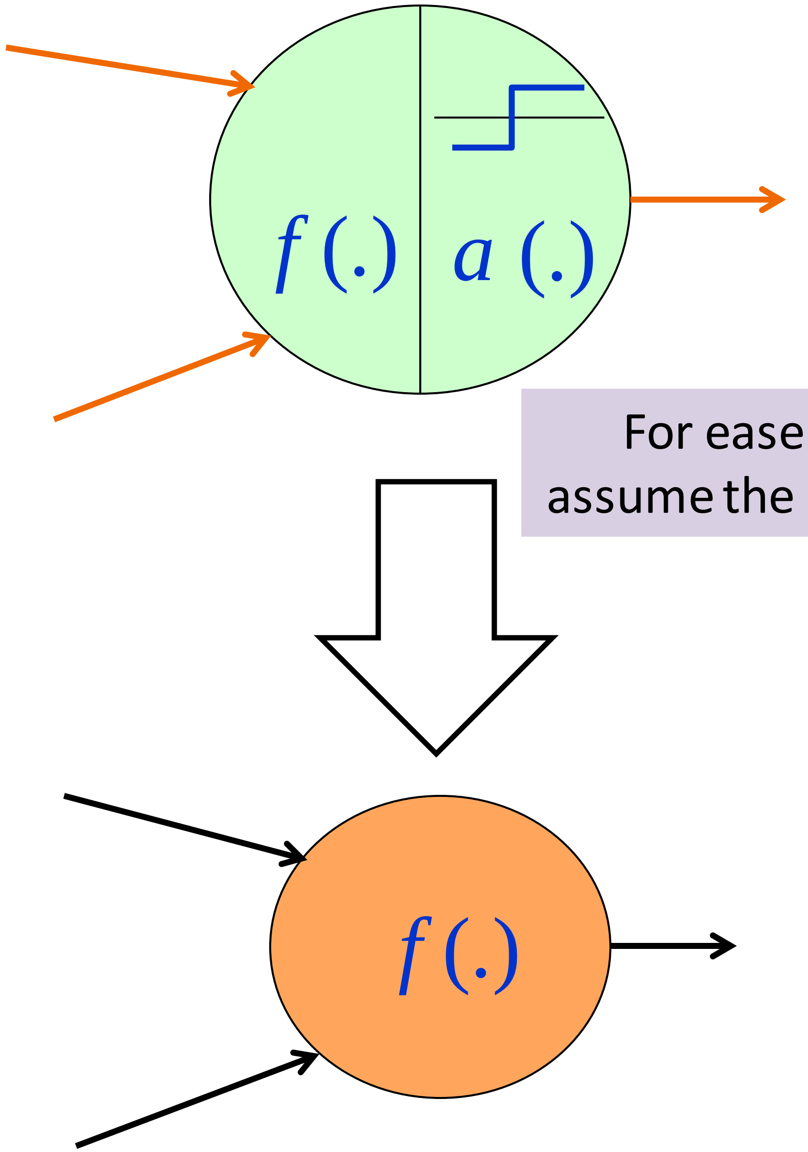


Output Layer

Hidden Layer

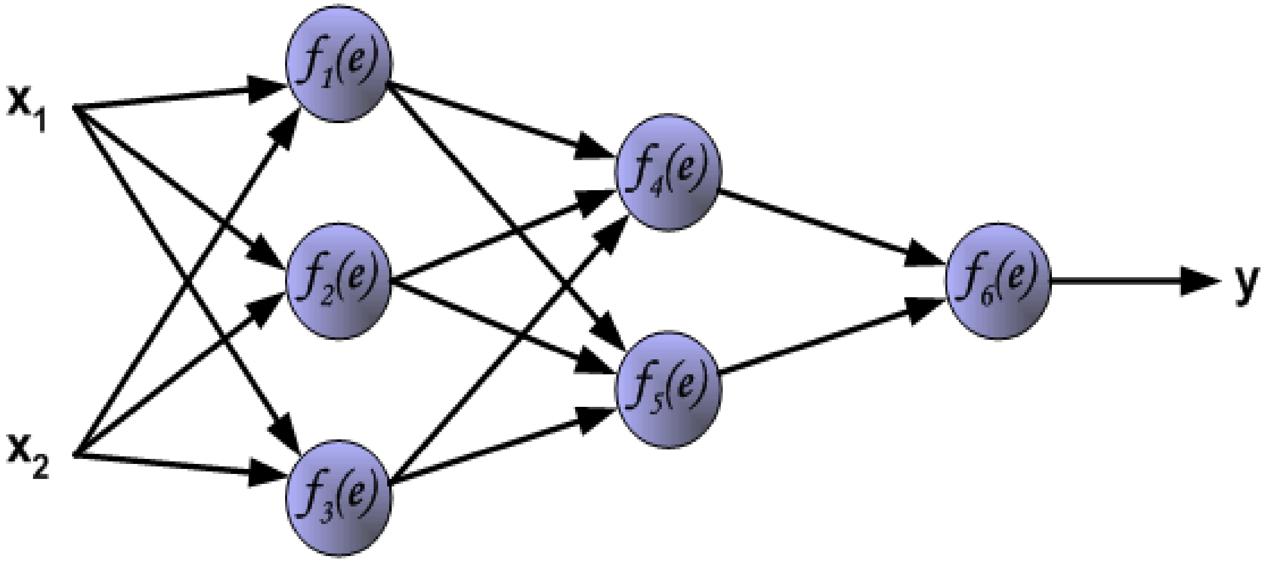
Input Layer

# The Back Propagation Algorithm



For ease of explanation, assume the change of notation

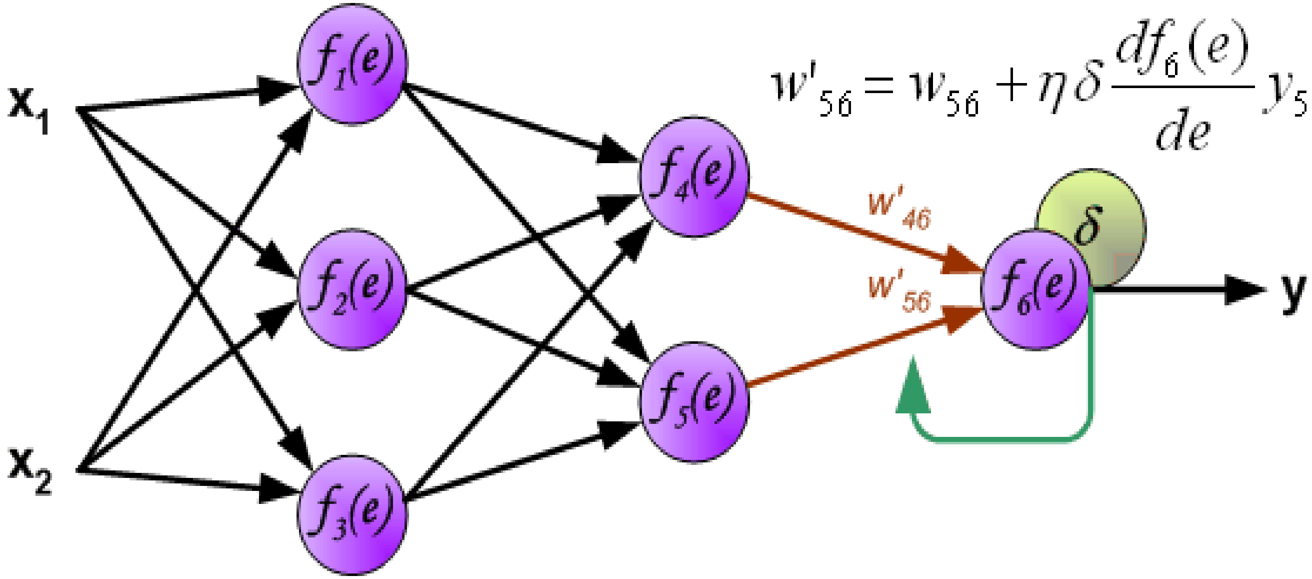
The resultant MLP



# Back Propagation Demo

$$w'_{46} = w_{46} + \eta\delta \frac{df_6(e)}{de} y_4$$

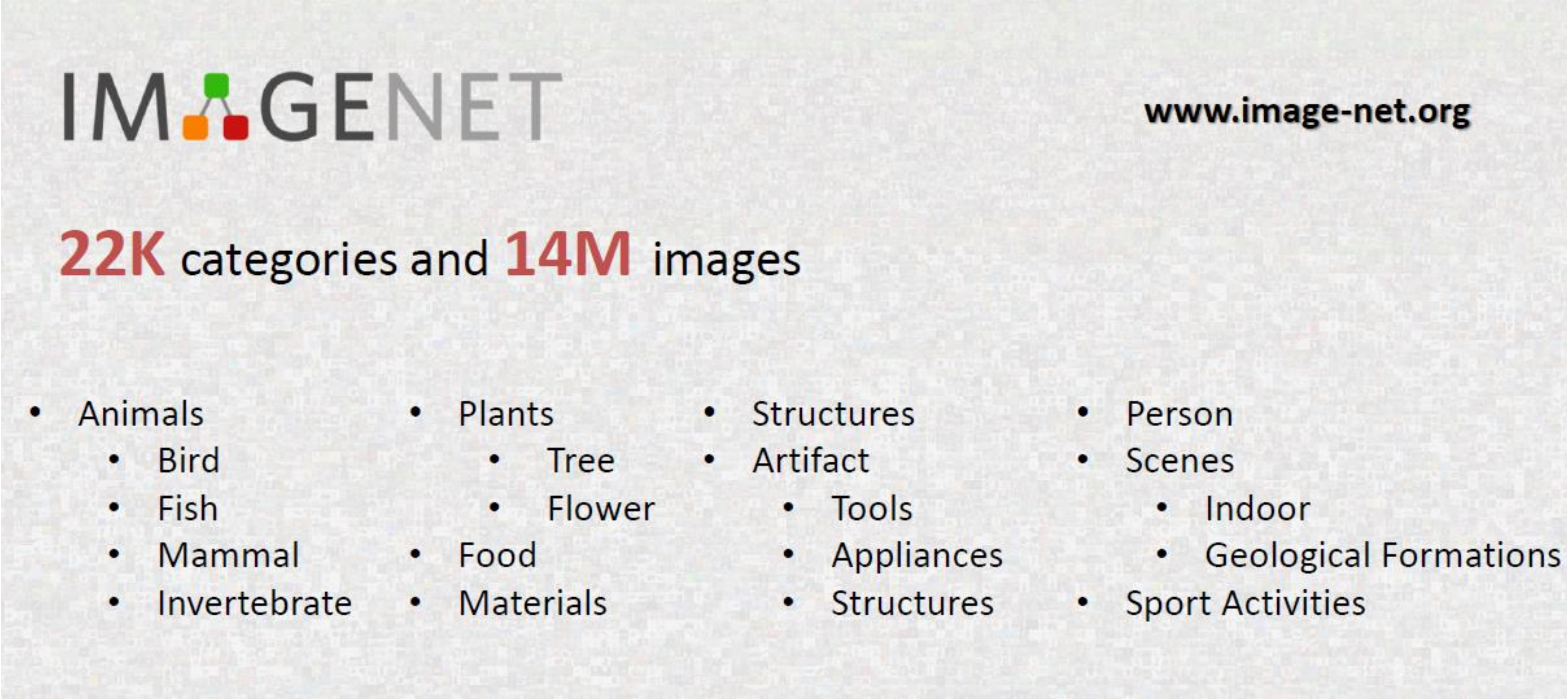
$$w'_{56} = w_{56} + \eta\delta \frac{df_6(e)}{de} y_5$$



# Convolution Layer

(Introduction)

# ImageNet



IMAGENET

www.image-net.org

**22K** categories and **14M** images

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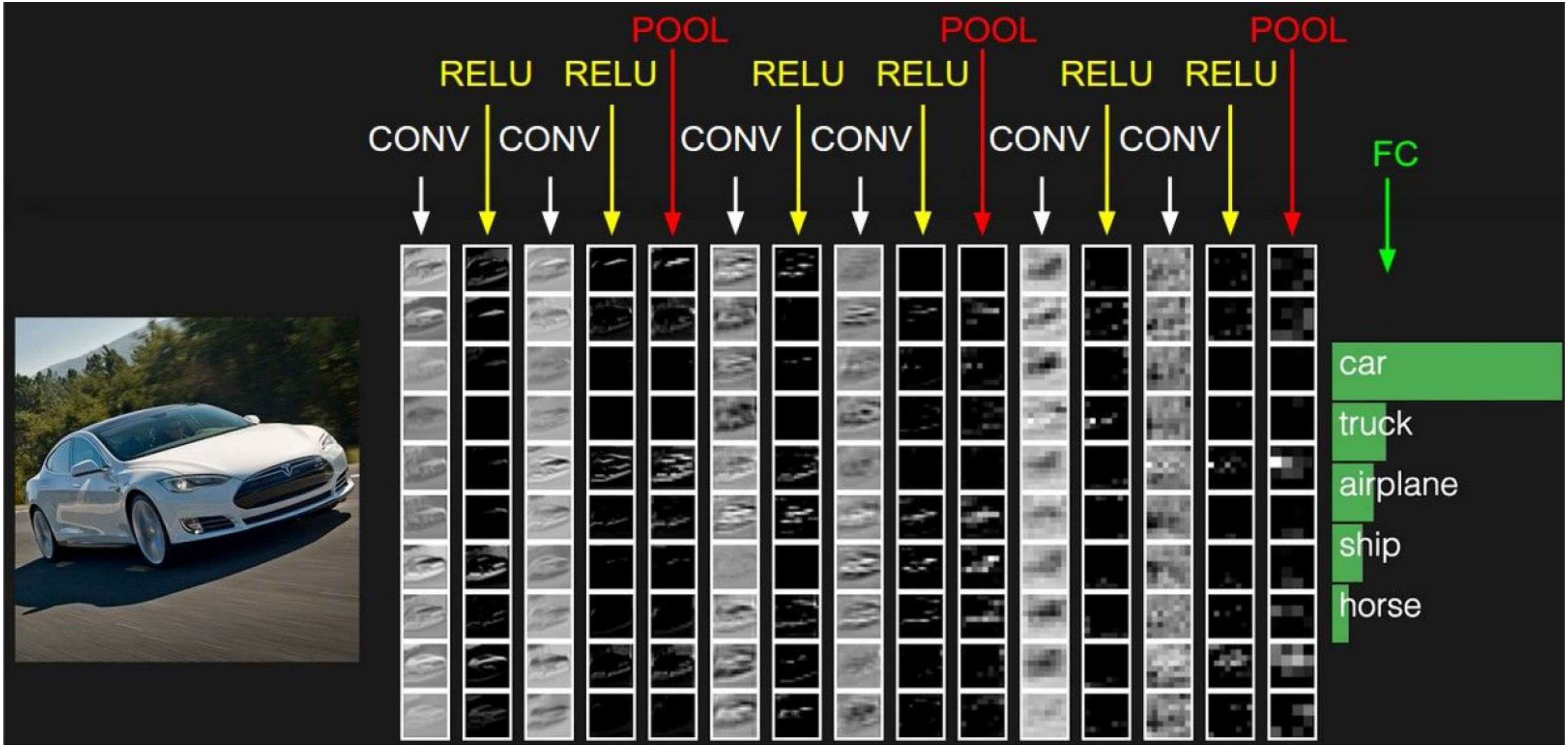
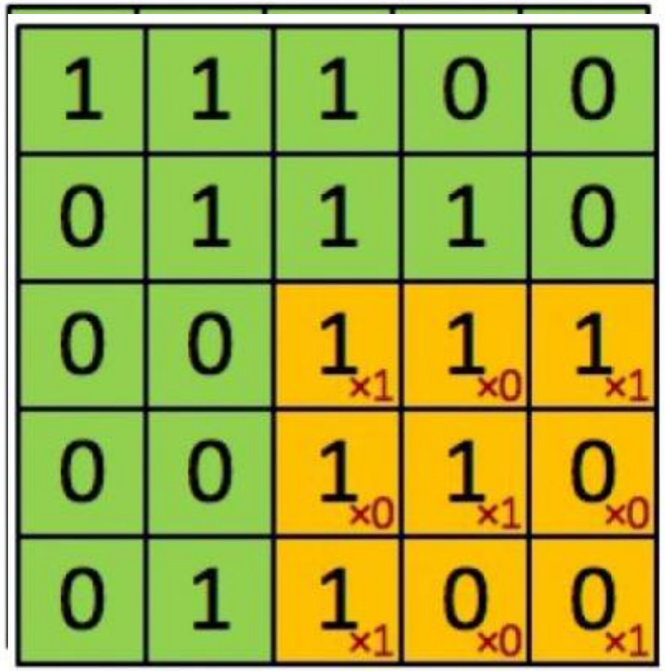
  - Bird
  - Fish
  - Mammal
  - Invertebrate
- Plants
  - Tree
  - Flower
- Food
- Materials
- Structures
- Artifact
  - Tools
  - Appliances
  - Structures
- Person
- Scenes
  - Indoor
  - Geological Formations
- Sport Activities

http://image-net.org/download-faq

# ConvNet with Pooling and FC Layers



# What is convolution of an image with a filter?

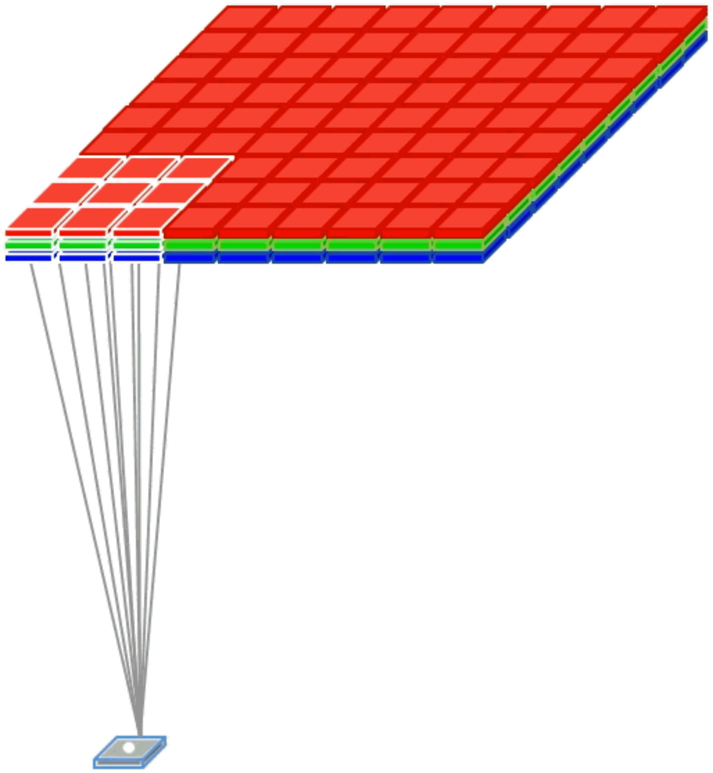


| | | | | |
|---|---|---|---|---|
| 1 | 1 | 1 | 0 | 0 |
| 0 | 1 | 1 | 1 | 0 |
| 0 | 0 | $1_{\times 1}$ | $1_{\times 0}$ | $1_{\times 1}$ |
| 0 | 0 | $1_{\times 0}$ | $1_{\times 1}$ | $0_{\times 0}$ |
| 0 | 1 | $1_{\times 1}$ | $0_{\times 0}$ | $0_{\times 1}$ |

Image

| | | |
|---|---|---|
| 4 | 3 | 4 |
| 2 | 4 | 3 |
| 2 | 3 | 4 |

Convolved Feature



# Thanks!!

**Questions?**