



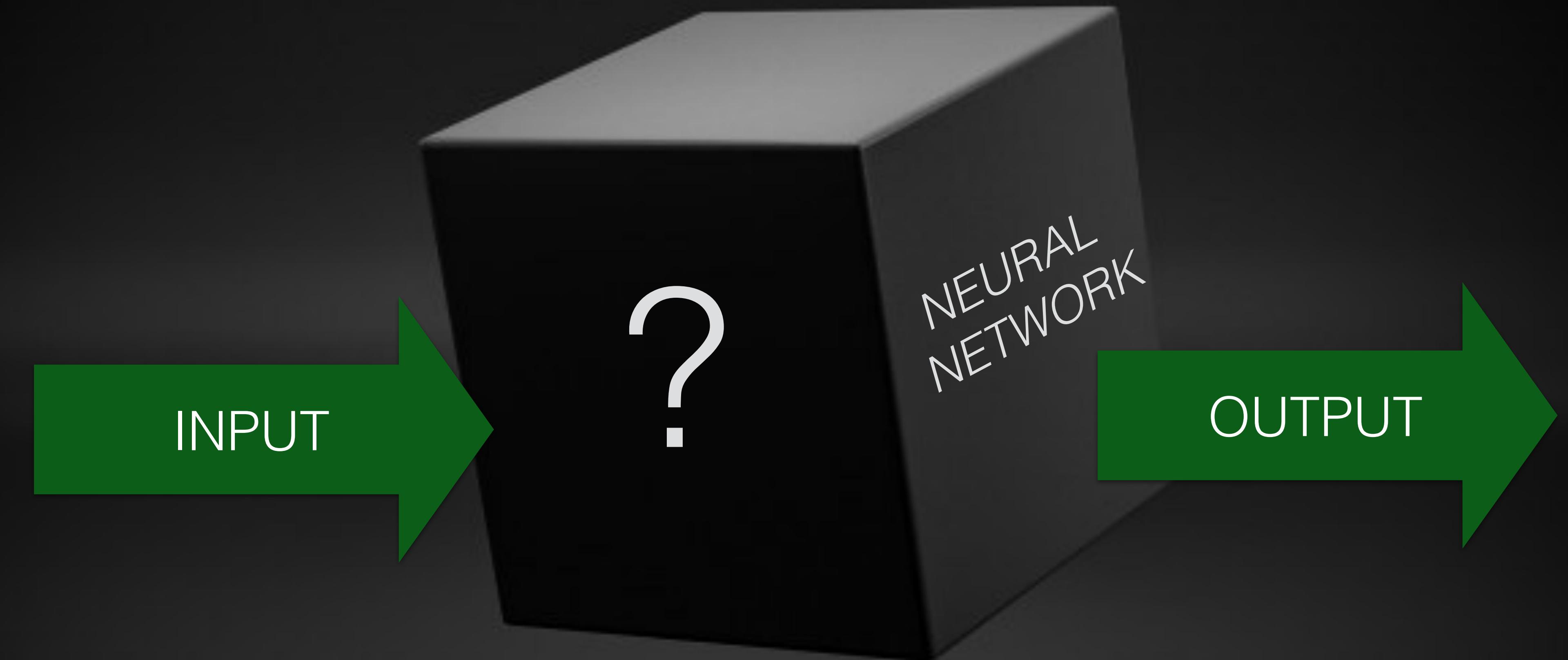
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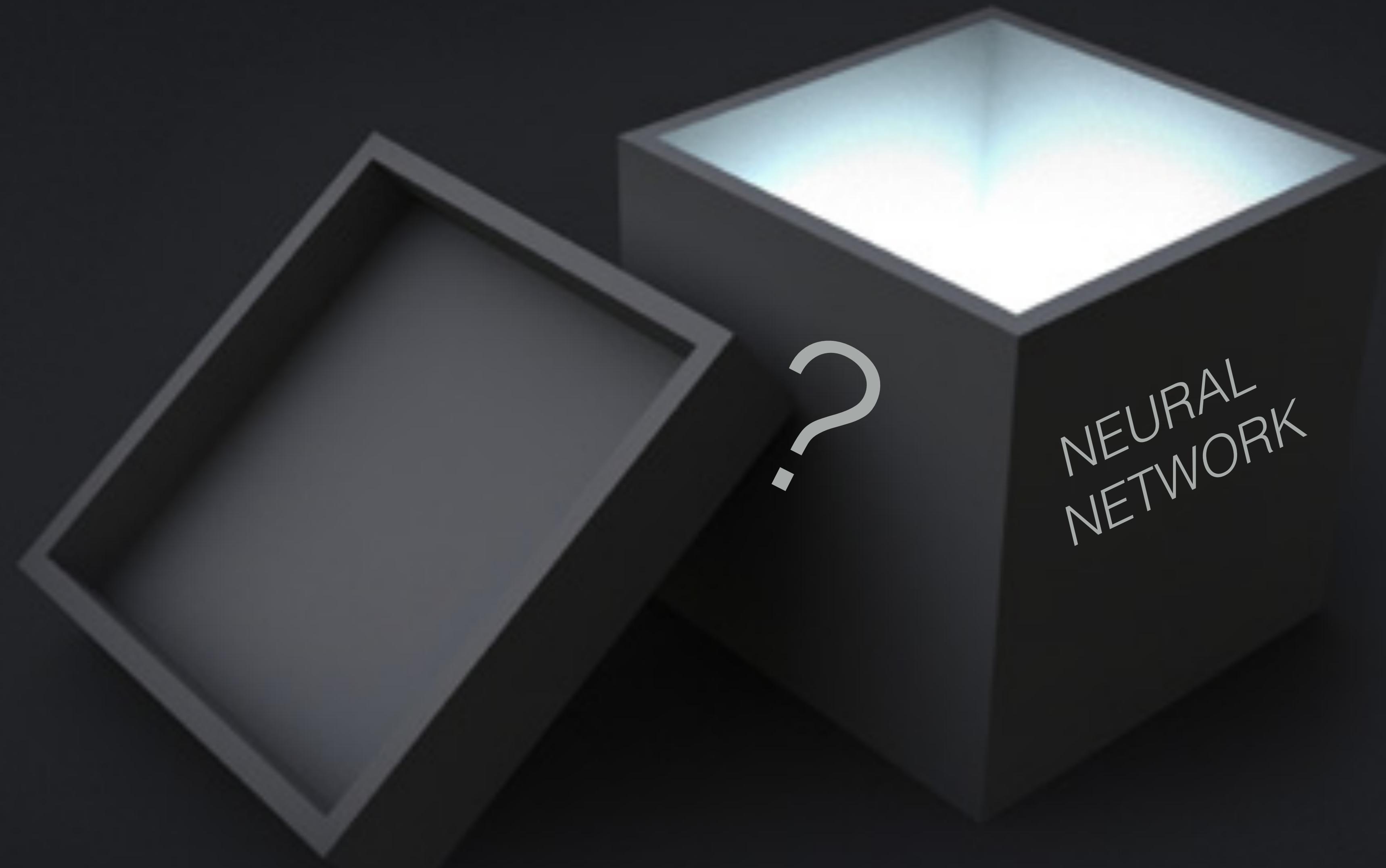
# PEEKING UNDER THE HOOD OF AN ARTIFICIAL NEURAL NETWORK

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# The “black box” objection



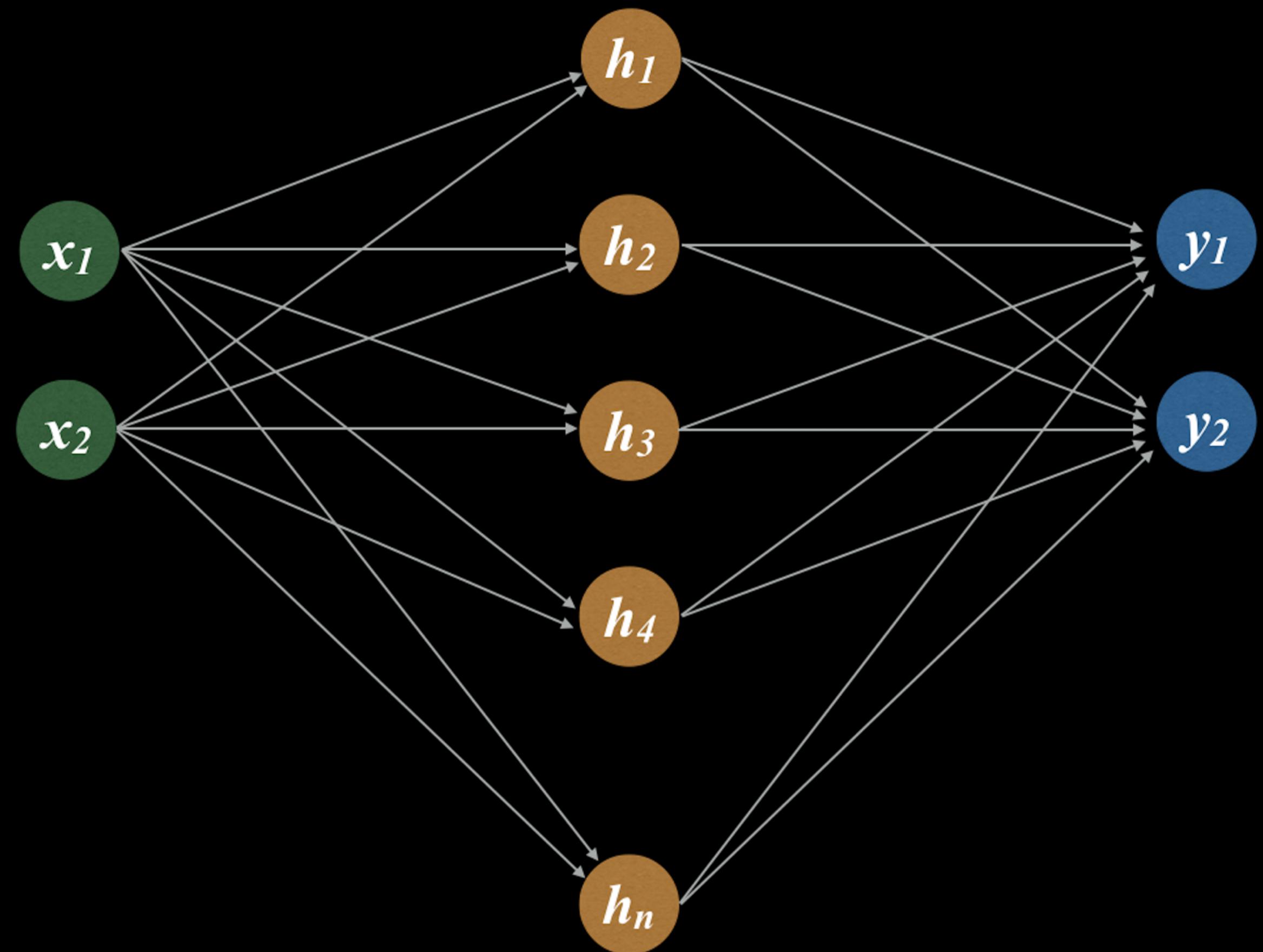
# What's inside?



# What's inside?



# What's inside a neural network?



*A multilayer perceptron.*

Think *brain*...



...with a vast network of *interconnected neurons*.



# How do we learn?

# How do we teach?





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# The conventional teaching process (for better or for worse!)

1. Known information is communicated to the learner



2. Student communicates the information back



3. Responses are assessed, errors are corrected

11/10/06  
Generic Problems with Lab Report!

OCN3211 MARINE & ENVIRONMENTAL CHEMISTRY LABORATORY REPORT I FORMAT FALL, 2006

This report is to only focus on your field work from September 20, and October 4, 2006. The report should be written as though you were an environmental professional and not a student in a Florida Tech class. Below is the format we all agreed that should be in the report. Please follow it closely. Due by 12 PM on October 20, 2006.

1 A WELL THOUGHT OUT TITLE (ALL IN CAPS!!) ? WHAT ? WHEN ? WHERE ?  
Department of Marine & Environmental Systems  
Florida Institute of Technology  
Melbourne, Florida 32901

2 ABSTRACT (10 points)  
In about 150-200 words give the key design and important result of your work. You must include some data in part of the results in your abstract. What are the conclusions of your report? A sentence or two about your major conclusions is necessary. You don't need any more than that is more appropriate for an introduction section. Spend some extra time to organize and edit the main picture you wish to leave with the reader. Write the abstract last, but not too quickly.

3 INTRODUCTION (10 points): 3-4 paragraphs  
Give more introductory material on salinity, temperature and dissolved oxygen in natural waters, including what typical values are found in natural waters? Consider the significance of these measurements? YOU MUST INCLUDE AT LEAST TWO RECENT PEER REVIEWED PUBLICATIONS WHICH HELP YOUR STUDY. ANYONE WHO WANTS TO MEASURE DISSOLVED OXYGEN IN AN ESTUARINE SYSTEM MUST WANT TO MEASURE DISSOLVED OXYGEN IN AN ESTUARINE SYSTEM. PEER REVIEWED ARTICLES MUST BE PUBLISHED IN 2005 OR 2006 AND MUST BE RELATED TO ESTUARINE STUDIES. BE SURE TO GIVE SOME RELEVANT DATA FROM EACH OF THE ARTICLES. At the end of the introduction section state the goals of your study and briefly describe the study area and environmental setting. A MAP is required!

4 METHODS (10 points)  
Describe field collection of data. Include all instruments used (makes and models). Two well written paragraphs should be sufficient. Make no references to students or TAs or classes.

5 RESULTS AND DISCUSSION  
Tables (15 points)  
Prepare a table showing all the final field data. You may attach this as an appendix if you wish. Do not use the spreadsheet given to you on the course website. Generate a good, useful table on your own that is well organized. The table should have salinity, temperature, depth and DO (both in mg/l and % saturation) for all field work to date.

6 Figures (15 points)  
Prepare a minimum of three figures that show the most important results of your investigation.

7 Refer to figures in your discussion  
Now that we understand what your data shows, in the remainder of the discussion describe the significance of your observations. How do your results compare to other investigations? How do they compare to the references you included in the introduction? You must include some salinity, temperature and DO data from other studies for Crane Creek and Indian River Lagoon.

8 REFERENCES (10 points): References must be cited in the text. References format is shown on course website. A minimum of 5, relevant or web sites may be used. A prior lab report is OK!

9 Textbooks are lame!

10 Professional Appearance (10 pts) - spelling, typos, grammar, format.

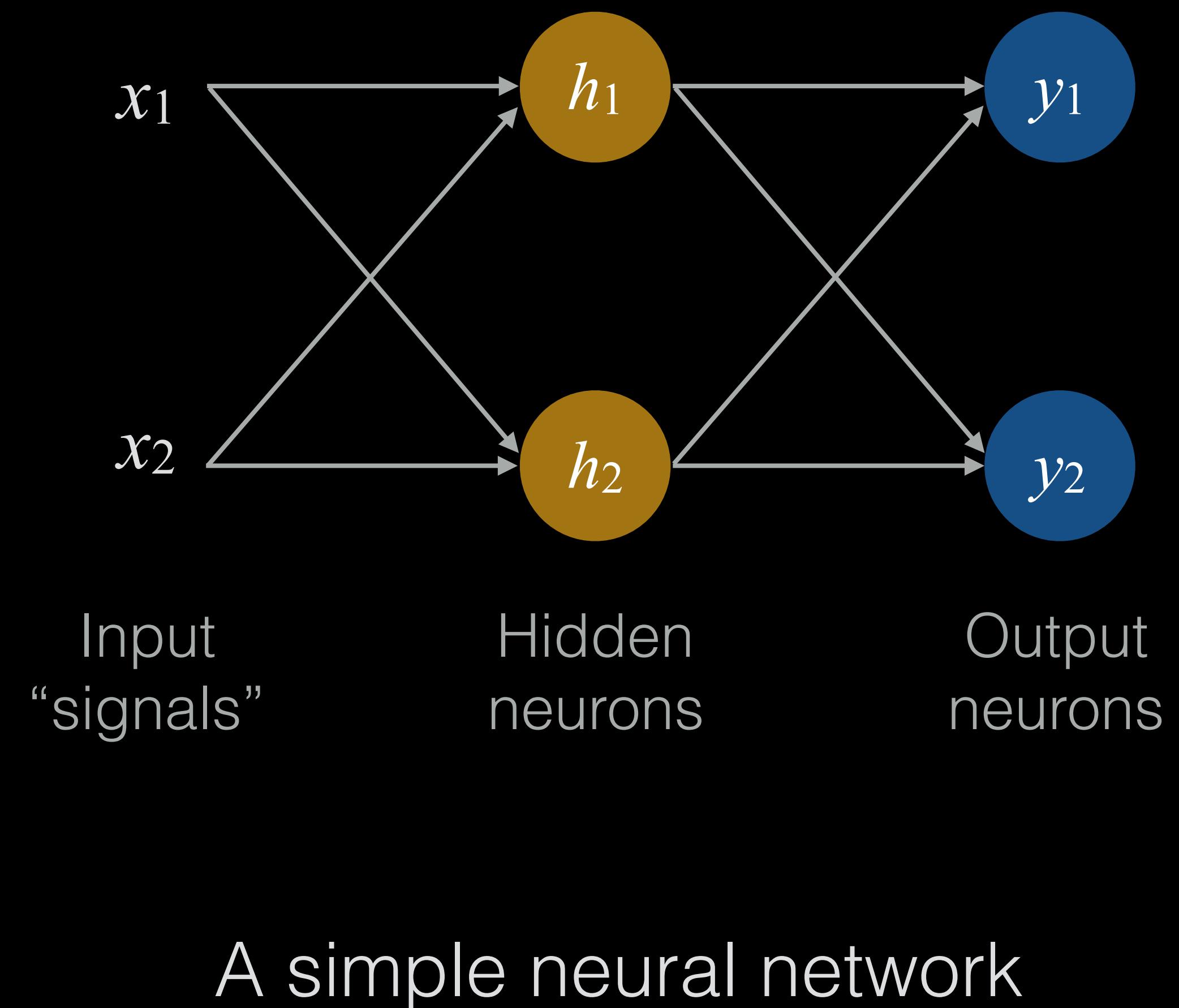
11 Double Space. Main text - Single space  
ABSTRACT

12 TABLES MUST HAVE TITLES (ONE PER TABLE OR ON EACH PAGE IF THE TABLE GOES BEYOND ONE PAGE)

13 "DATA" IS PLURAL.

4. Repeat until the task is mastered perfectly (hopefully!)

# What goes on inside?

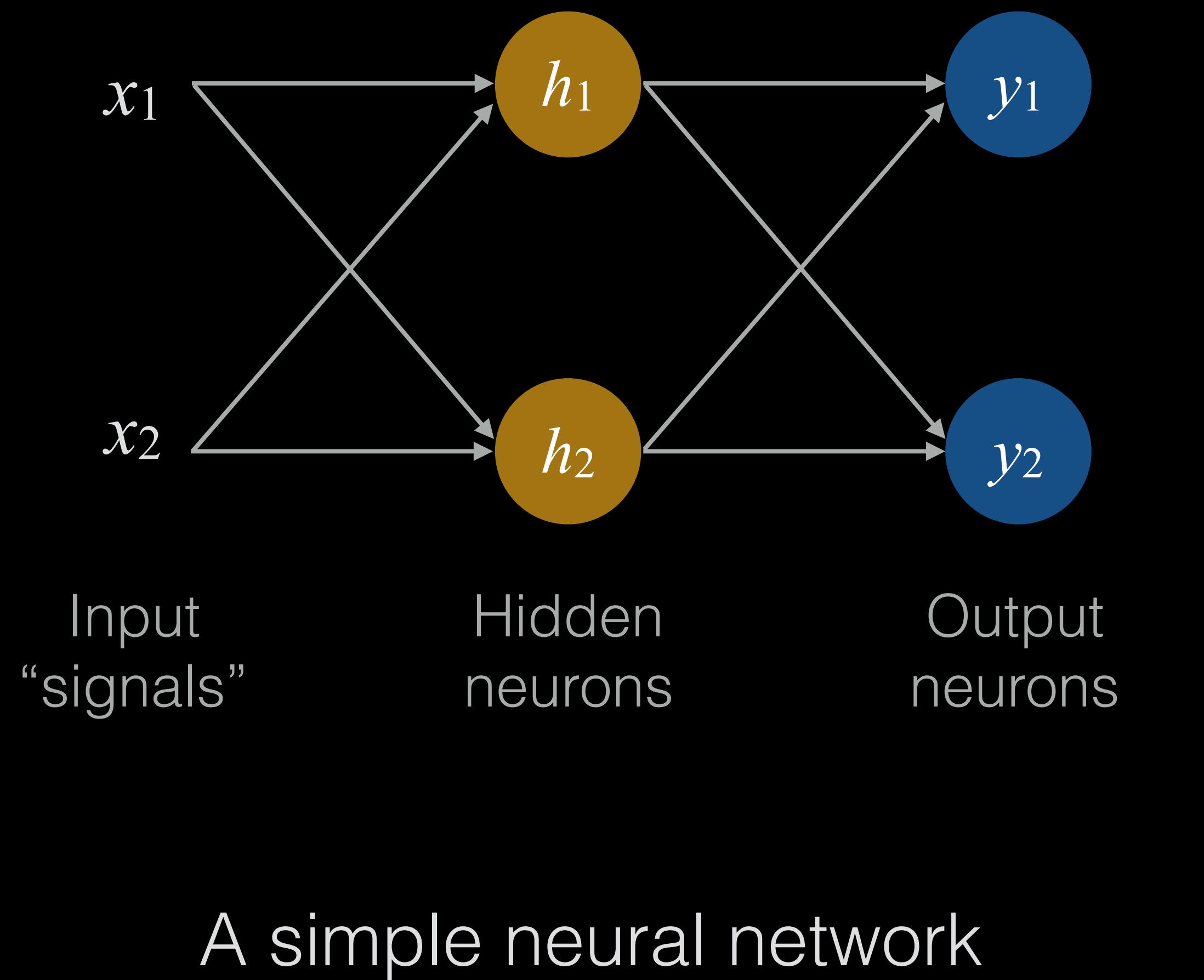


The network is passed a signal of information.

A decision is made about the information (e.g., to what class does it belong?) — ***output***

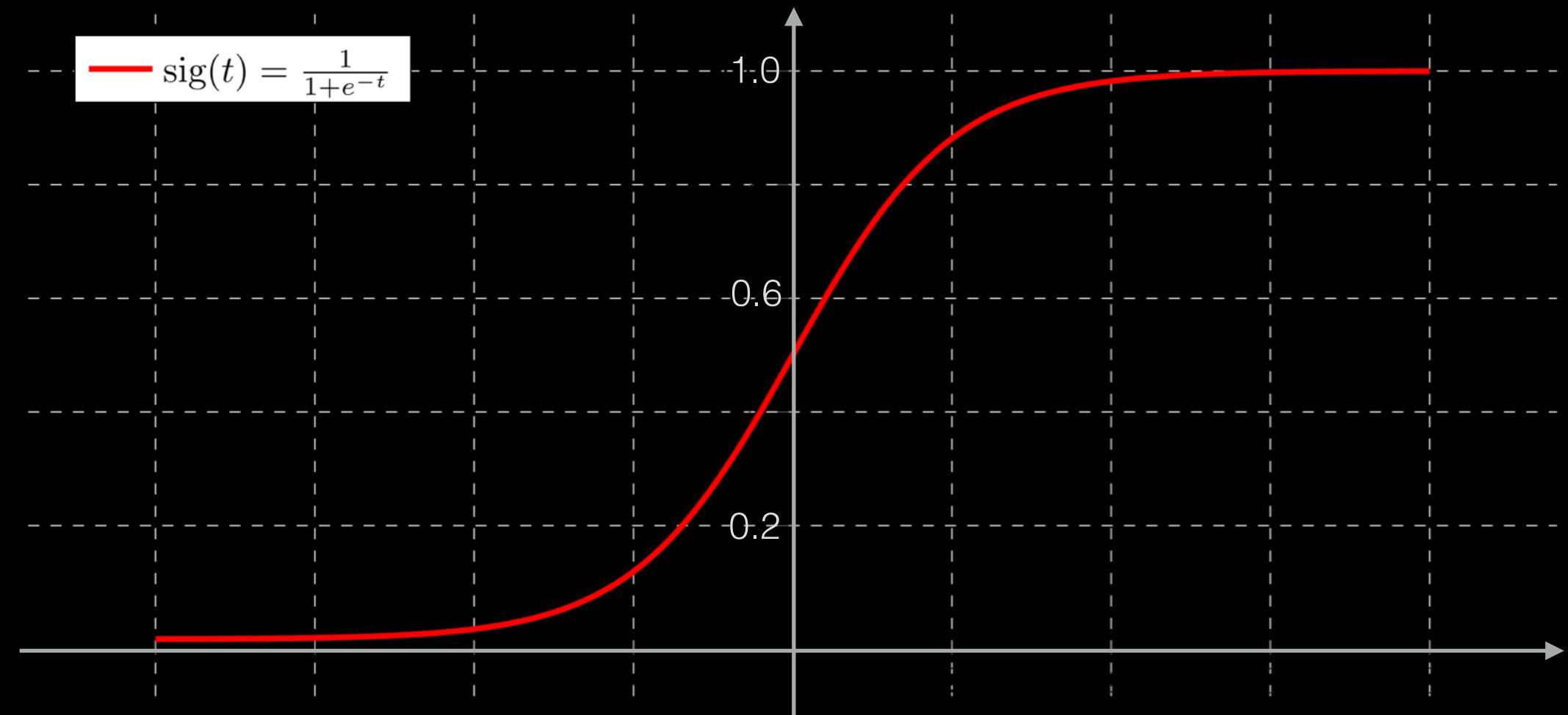
The decision is compared to the known information. If the network erred, small adjustments are made to its “thinking process.”

# What goes on inside?

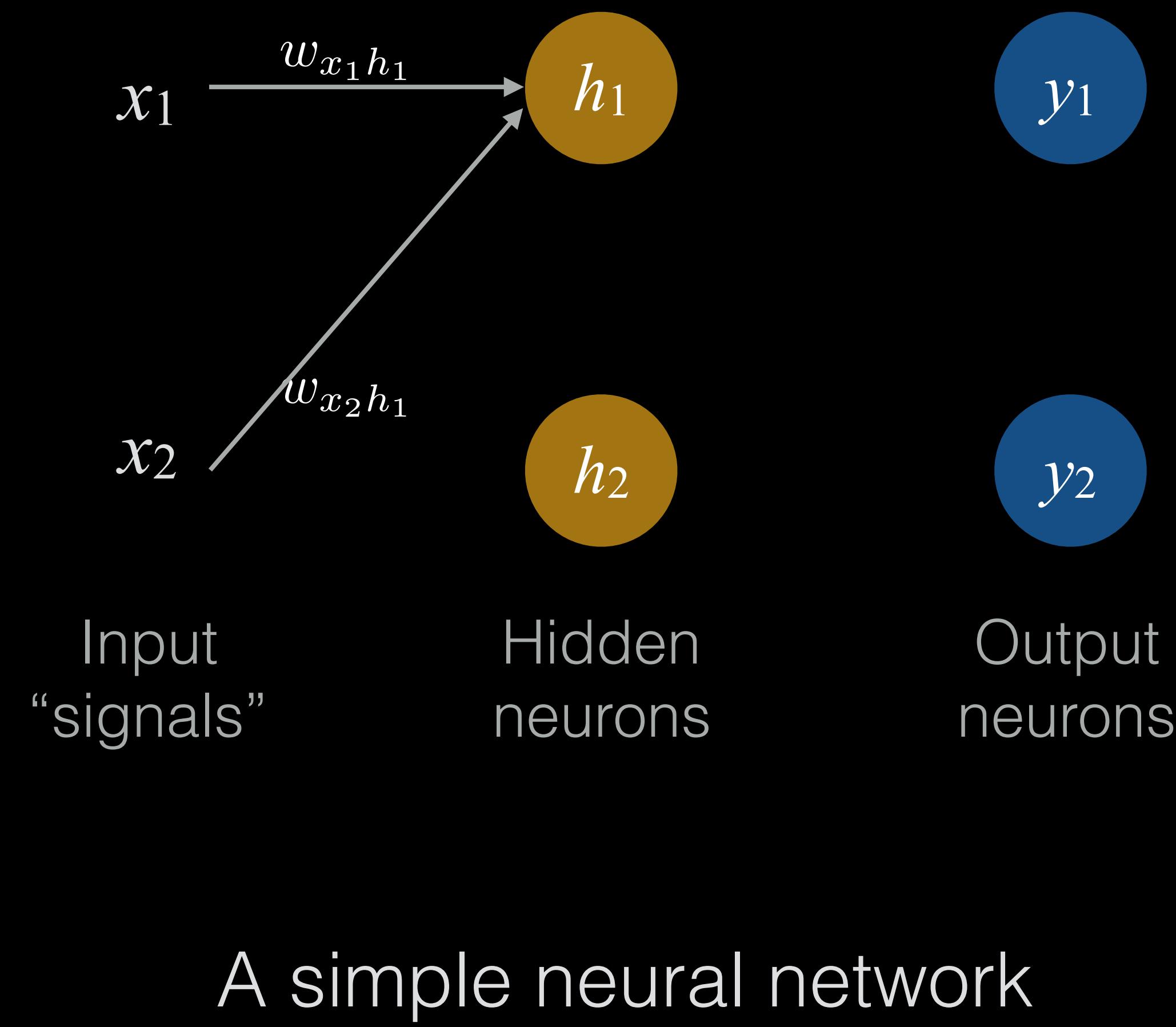


Each neuron receives as input a *weighted sum* ( $\Sigma$ ) from the previous layer and passes it to a ***transfer function***, for example:

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



# What goes on inside?



Consider the first hidden neuron,  
 $h_1$ :

1. Calculate the neuron's **input**:

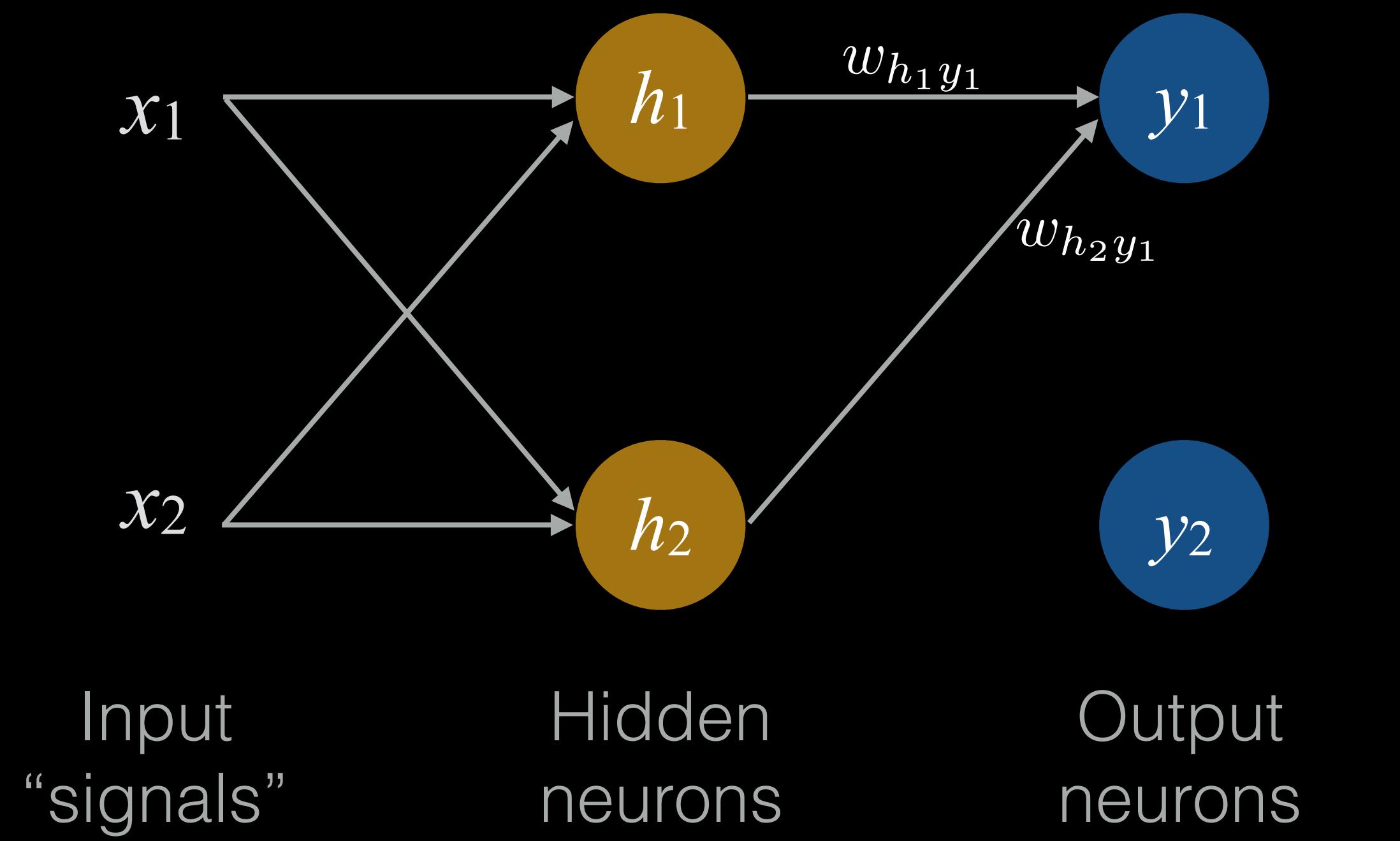
$$\Sigma_{h_1} = x_1 w_{x_1 h_1} + x_2 w_{x_2 h_1}$$

2. Calculate the neuron's **output**:

$$\frac{1}{1 + e^{-\Sigma_{h_1}}} = \frac{1}{1 + e^{-x_1 w_{x_1 h_1} - x_2 w_{x_2 h_1}}}$$

This gets passed to the output neurons,  $y_1$  and  $y_2$

# What goes on inside?



A simple neural network

Now the first output neuron,

$y_1$ :

3. Calculate the neuron's input:

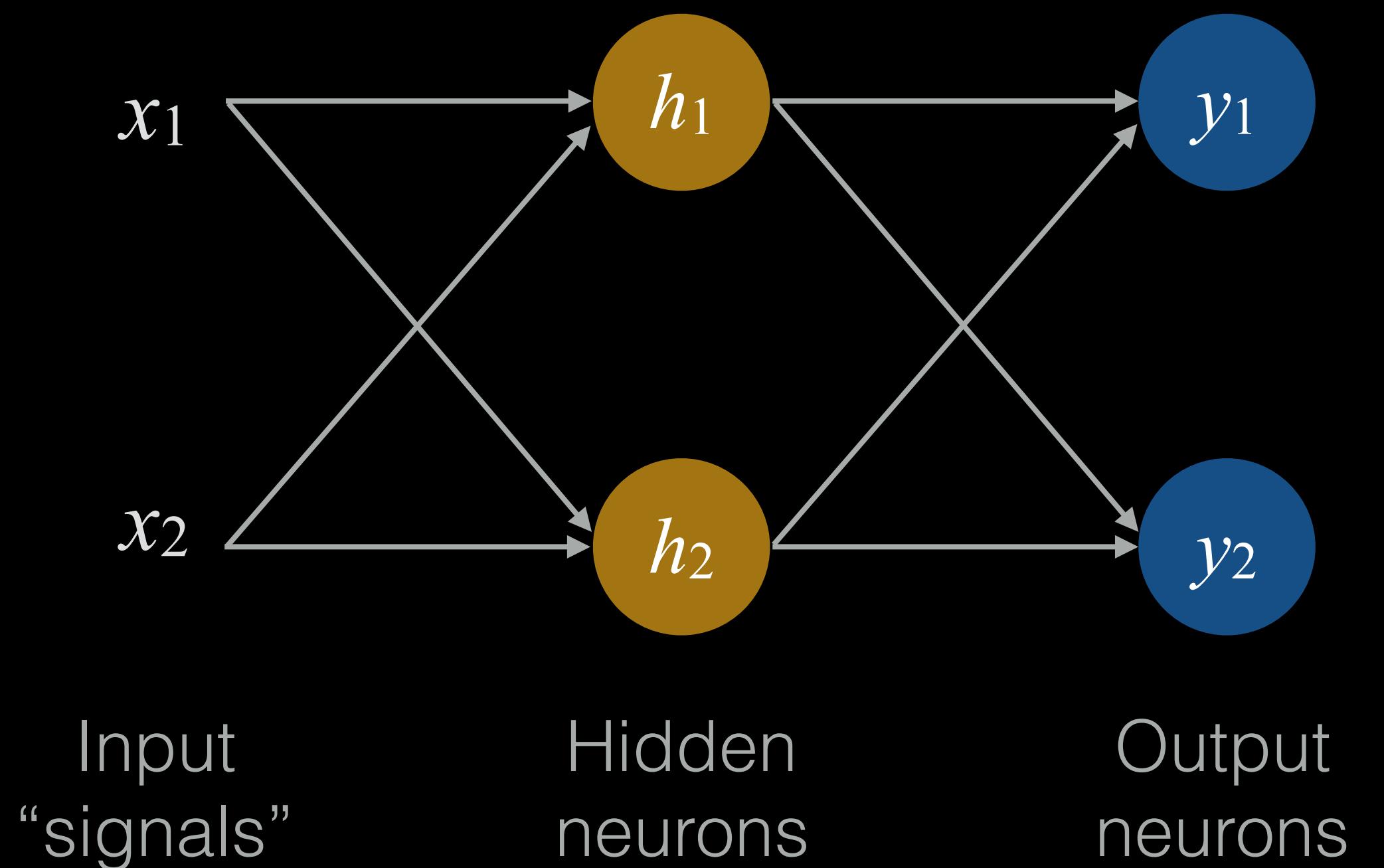
$$\sum_{y_1} = h_1 w_{h_1 y_1} + h_2 w_{h_2 y_1}$$

4. Calculate the neuron's output:

$$y_1 = \frac{1}{1 + e^{-h_1 w_{h_1 y_1} - h_2 w_{h_2 y_1}}}$$

This process is called ***forward propagation***.

# What goes on inside?



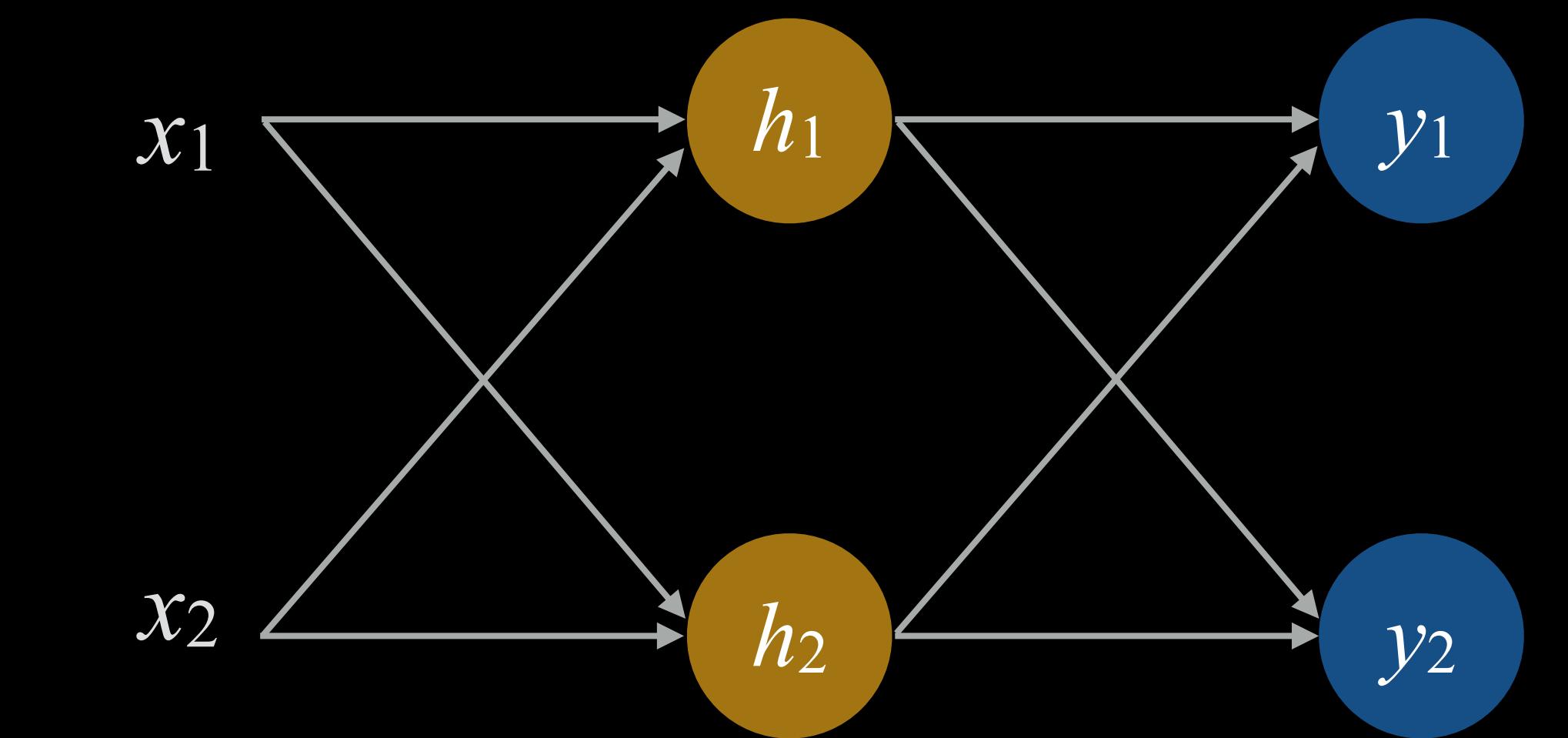
A simple neural network

The output is directly dependent on values of the *weights*.

**Goal:** *Find the best values of the weights to maximize the model's performance.*

Next, compare the output to the expected (target) values.

# What goes on inside?



Input  
“signals”

Hidden  
neurons

Output  
neurons

A simple neural network

## *Back propagation of error:*

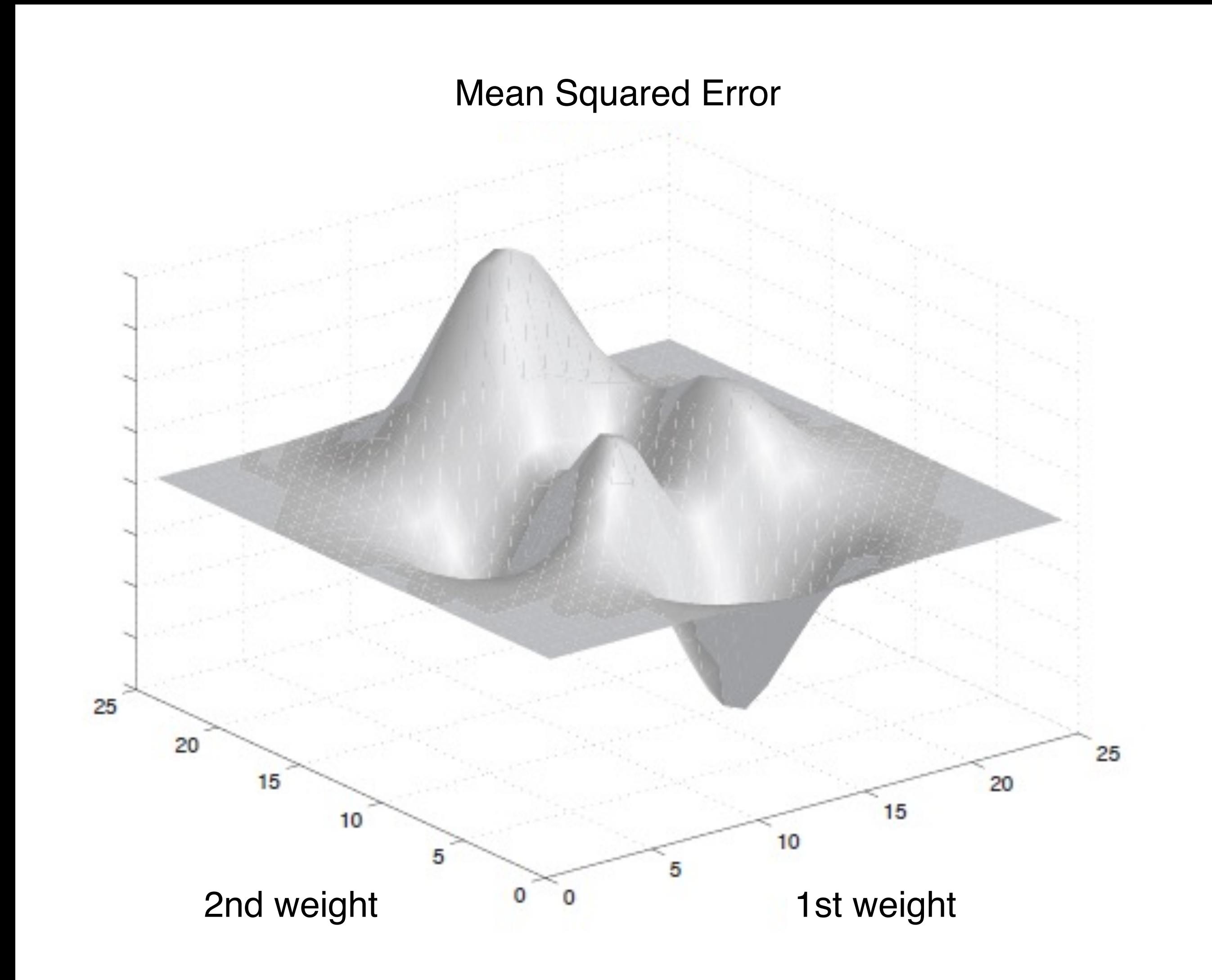
5. Determine each neuron's “responsibility” for the overall error. Call this  $\delta$ .
6. Adjust each weight accordingly:

Output layer:  $w = w + \eta \delta h$

Hidden layer:  $w = w + \eta \delta x$

with learning rate  $\eta < 0.1$

# What just happened?



# What about the black box objection?

*A neural network can theoretically approximate any function, but studying its structure won't provide any insights into the structure of the function being approximated.*

What *can* we learn?

1. Are data separable? In other words, is there any learnability?
2. Which attributes are relevant? Which are irrelevant?
3. How are the data being transformed?

# What can neural networks be used for?

Classification problems

Prediction of continuous variables

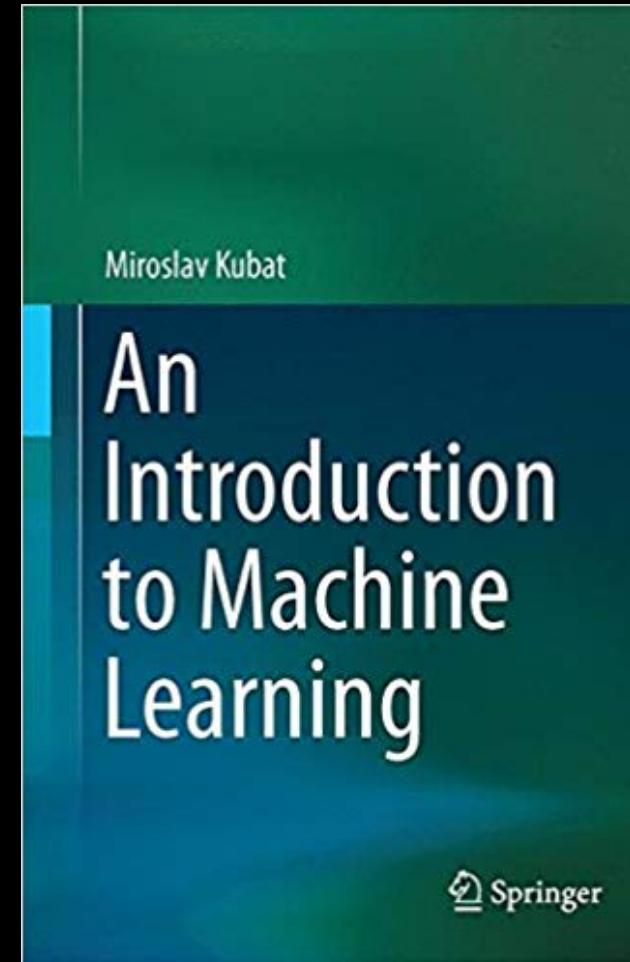
Forecasts

As long as:

1. The data are able to be transformed into linearly separable classes
2. You have enough data to train adequately
3. You don't care about the fine details of the function. In other words, performance is most important.

If you want to *explore* your data set, a neural network may not be your best tool, or at least not at first!

# References



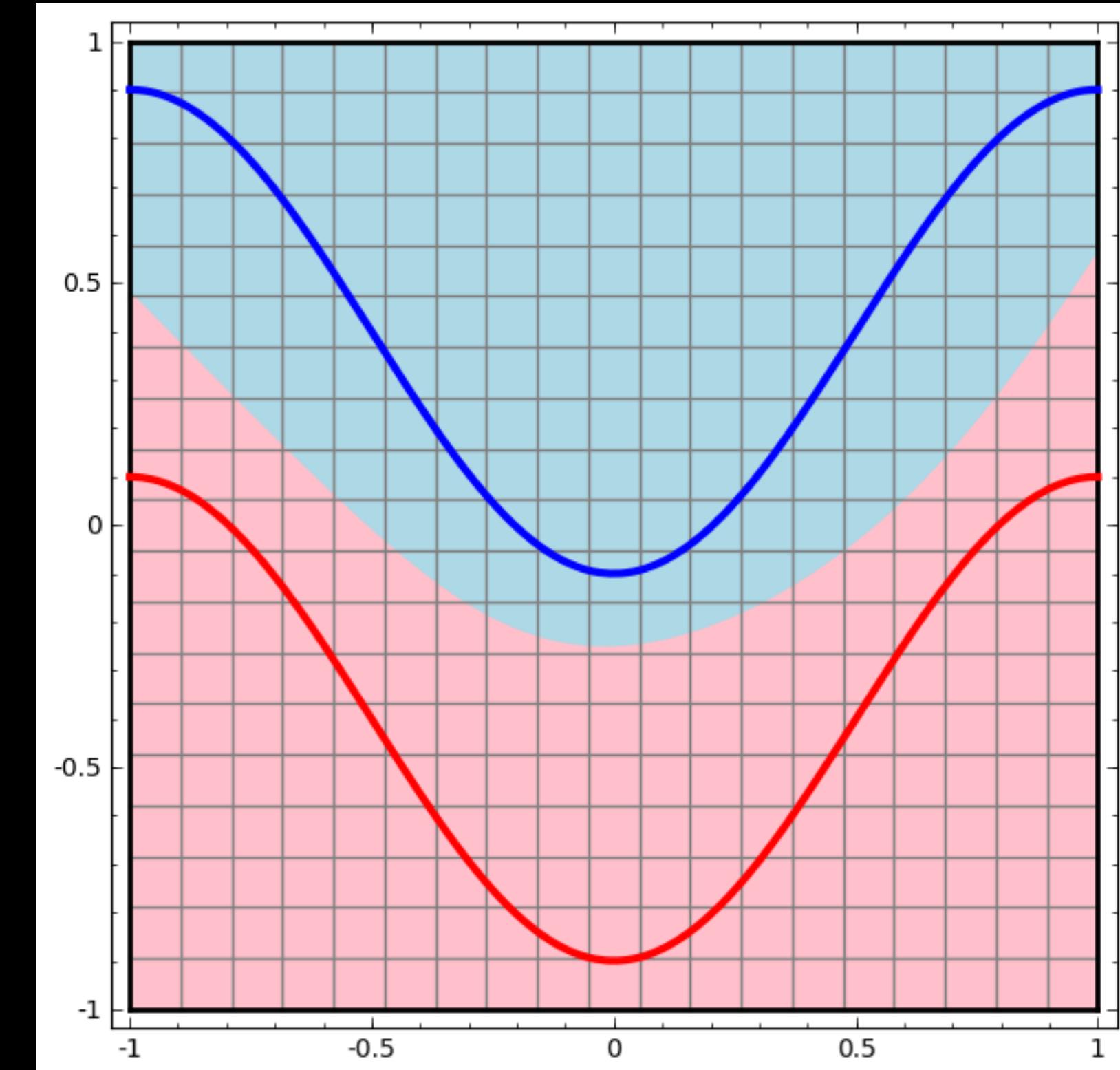
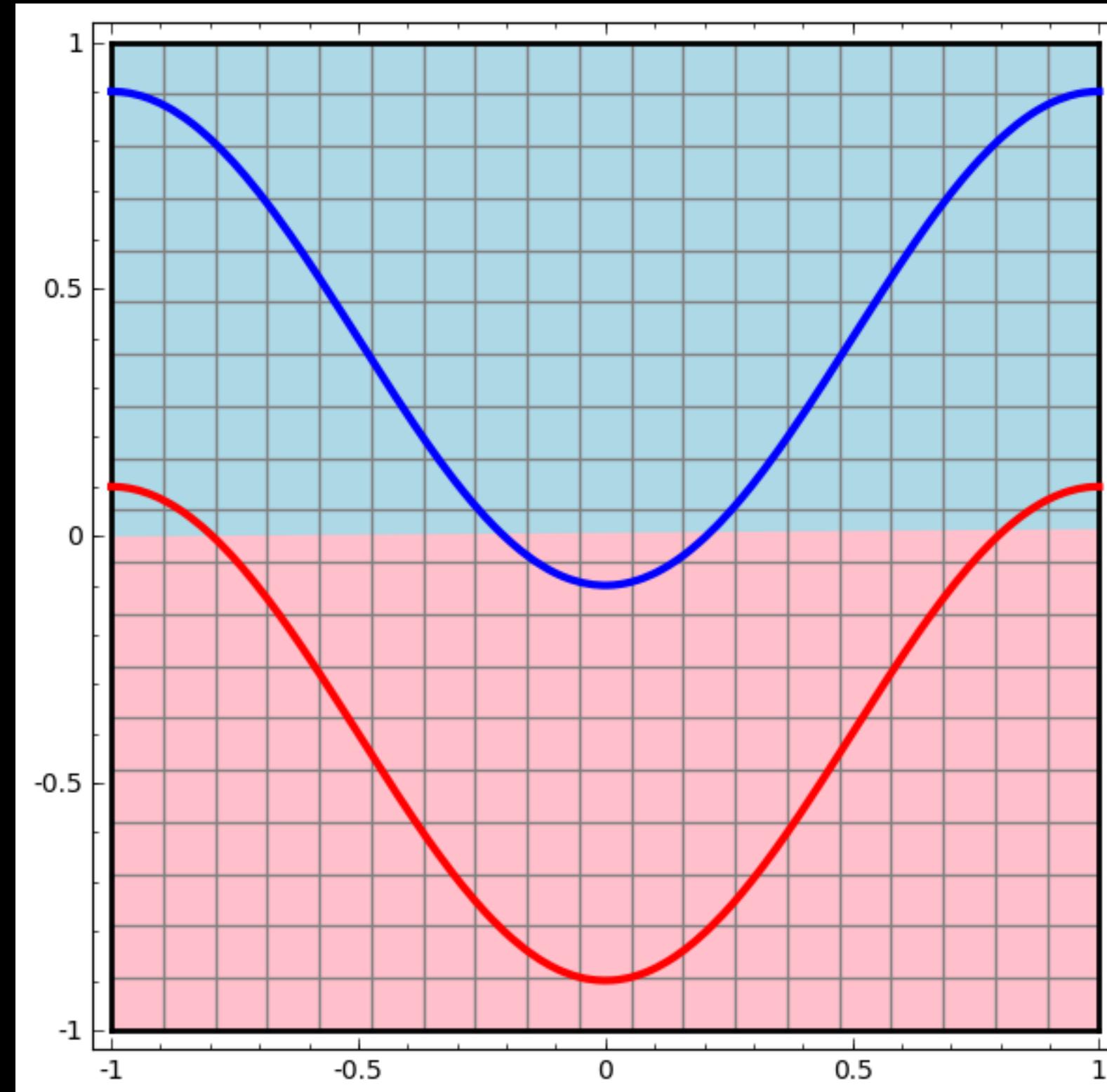
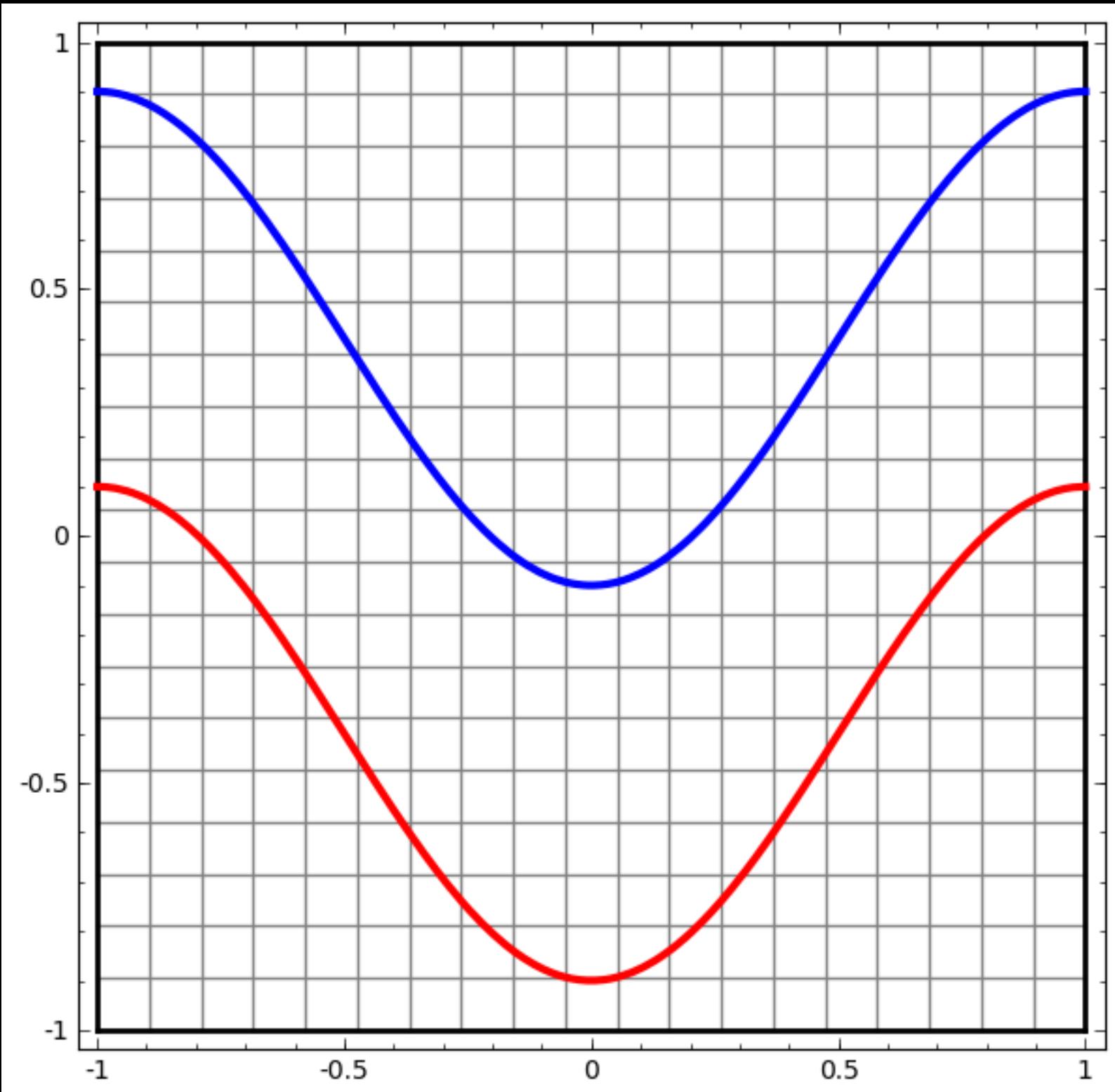
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Nielsen, M. A. (2015) *Neural Networks and Deep Learning*, Determination Press, available  
<http://neuralnetworksanddeeplearning.com/index.html>

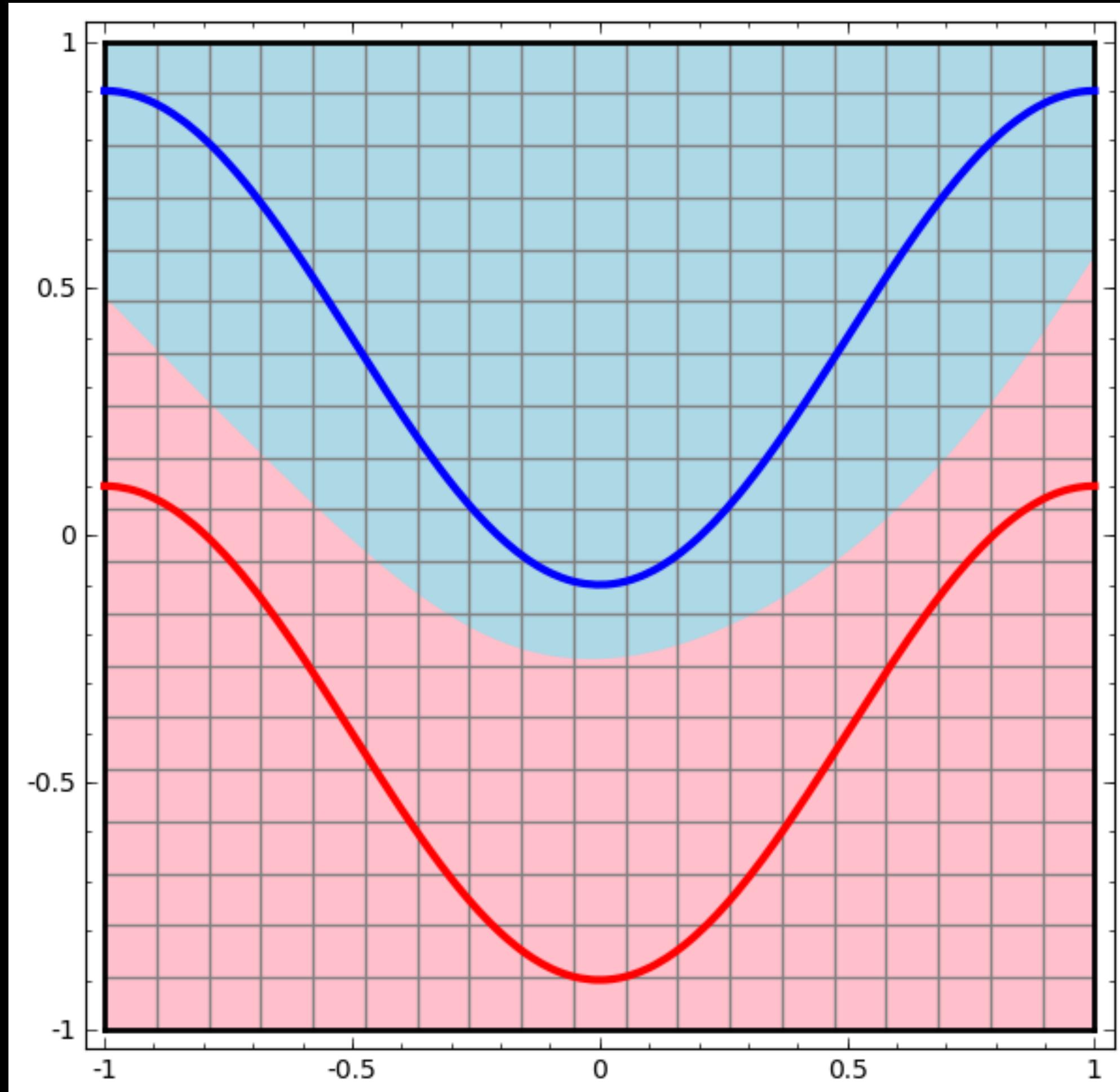
Olah, C. (2014) “Neural Networks, Manifolds, and Topology,” Colah’s blog, available <http://colah.github.io/posts/2014-03-NN-Manifolds-Topology/>.

# Extras...

# What just happened?



# What just happened?



Transfer  
function

