



# Hello CS109

WELCOME

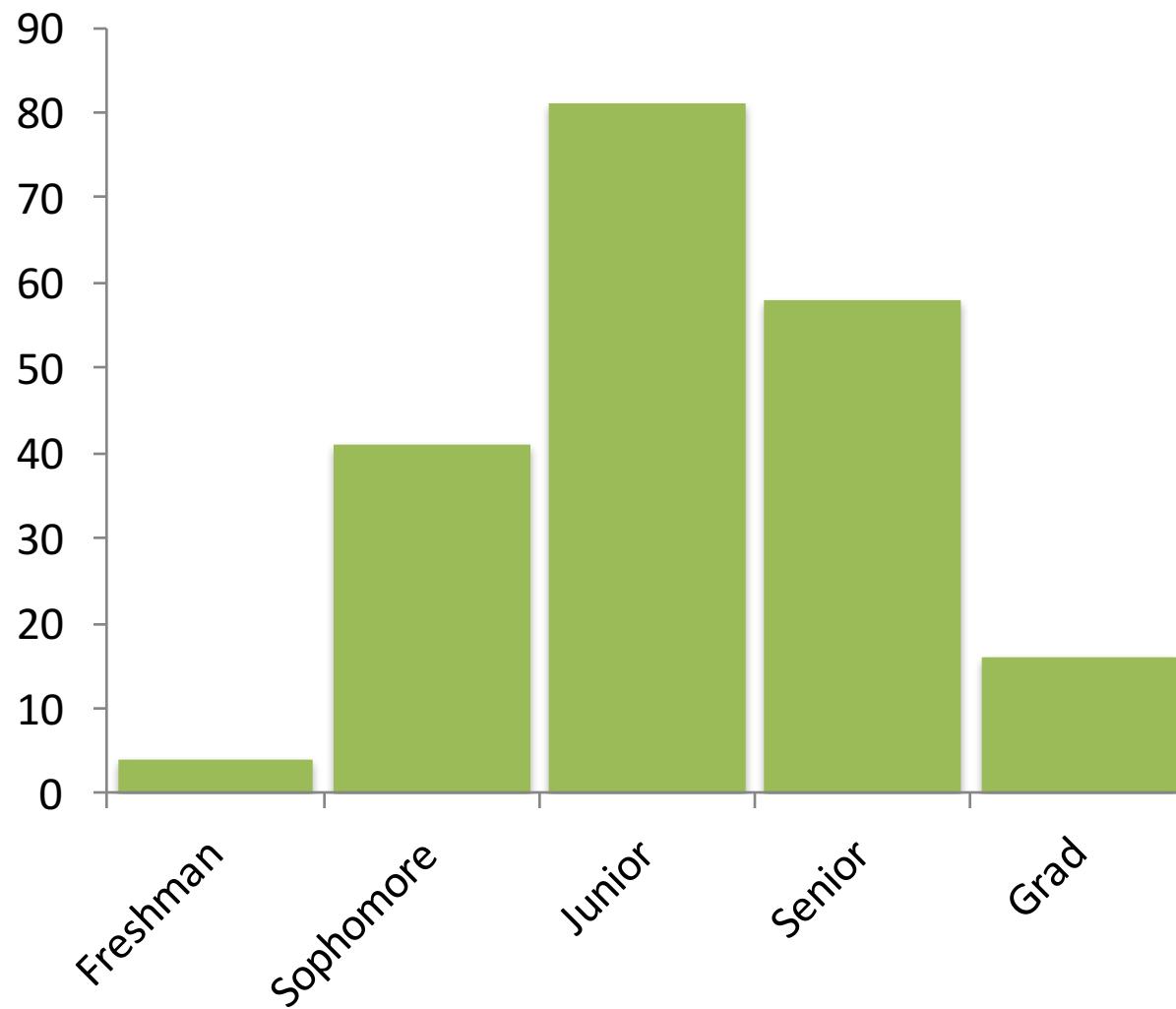
CS 106B  
Lecture 0  
March 28th, 2016

# Hi, I'm Chris

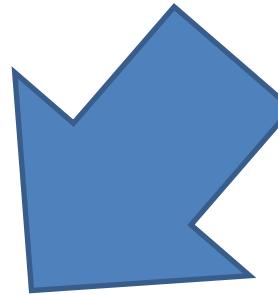
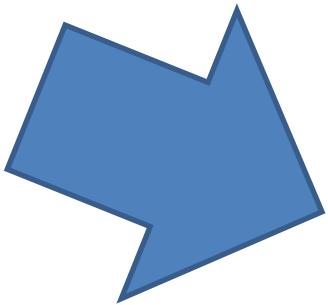
Chris Piech (piech@cs.stanford.edu)



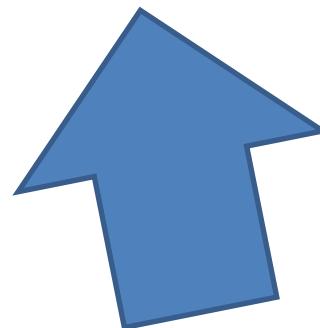
# Who Are You?



# Essential Information



[cs109.stanford.edu](http://cs109.stanford.edu)



# Prereqs

What you really need:

**CS106B/X:**

- Recursion
- Hash Tables
- Binary Trees
- Basic Programming

**CS103:**

- Proof techniques (induction)
- Set theory

**Math 51 or CME 100**

- Multivariate differentiation
- Multivariate integration
- Basic facility with linear algebra (vectors)

# Staff Contact

- Post to Piazza
- Go to Working Office Hours
- Email [cs109@cs.stanford.edu](mailto:cs109@cs.stanford.edu)

# How Many Units?

```
int numUnits(bool isGrad, bool wantsFewerUnits) {  
    if (!isGrad) return 5;  
    if (!wantsFewerUnits) return 5;  
  
    if (reallyWantFewerUnits()) {  
        return 3;  
    } else {  
        return 4;  
    }  
}
```

# Class Breakdown

- |     |   |
|-----|---|
| 45% | <b>6 Assignments</b>                                  |
| 20% | <b>Midterm</b><br>Tuesday May 3 <sup>rd</sup> , 7-9pm |
| 35% | <b>Final</b><br>Monday June 6th                       |
| 5%  | <b>Lecture Participation</b>                          |

# Late Days

2

# Honor Code

You can talk to your friends

Cite your group

Don't look up solutions

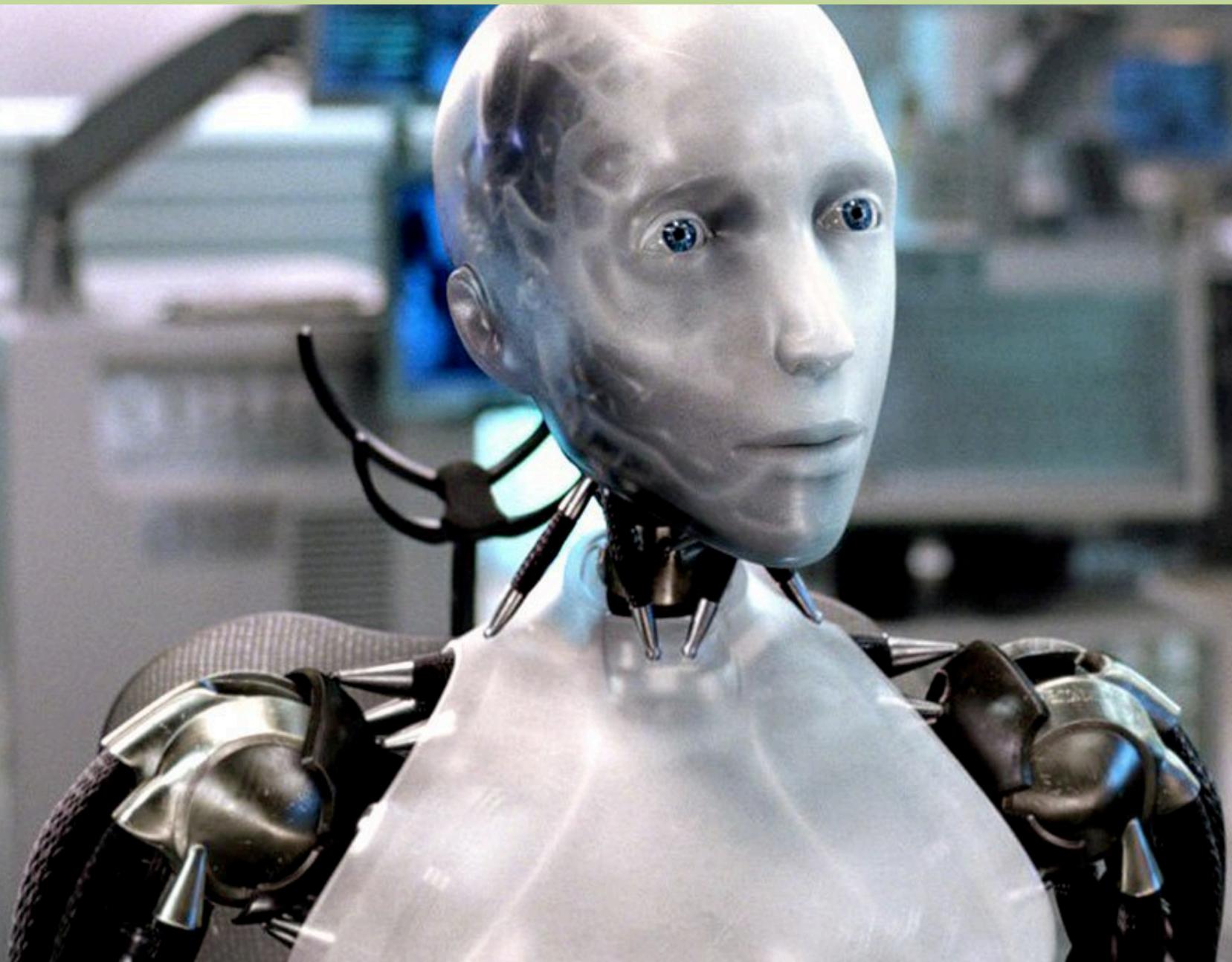
# Video Taped



# Story of Modern AI

What does it take to make a robot?

# Sci-Fi Has Promised Me Robots



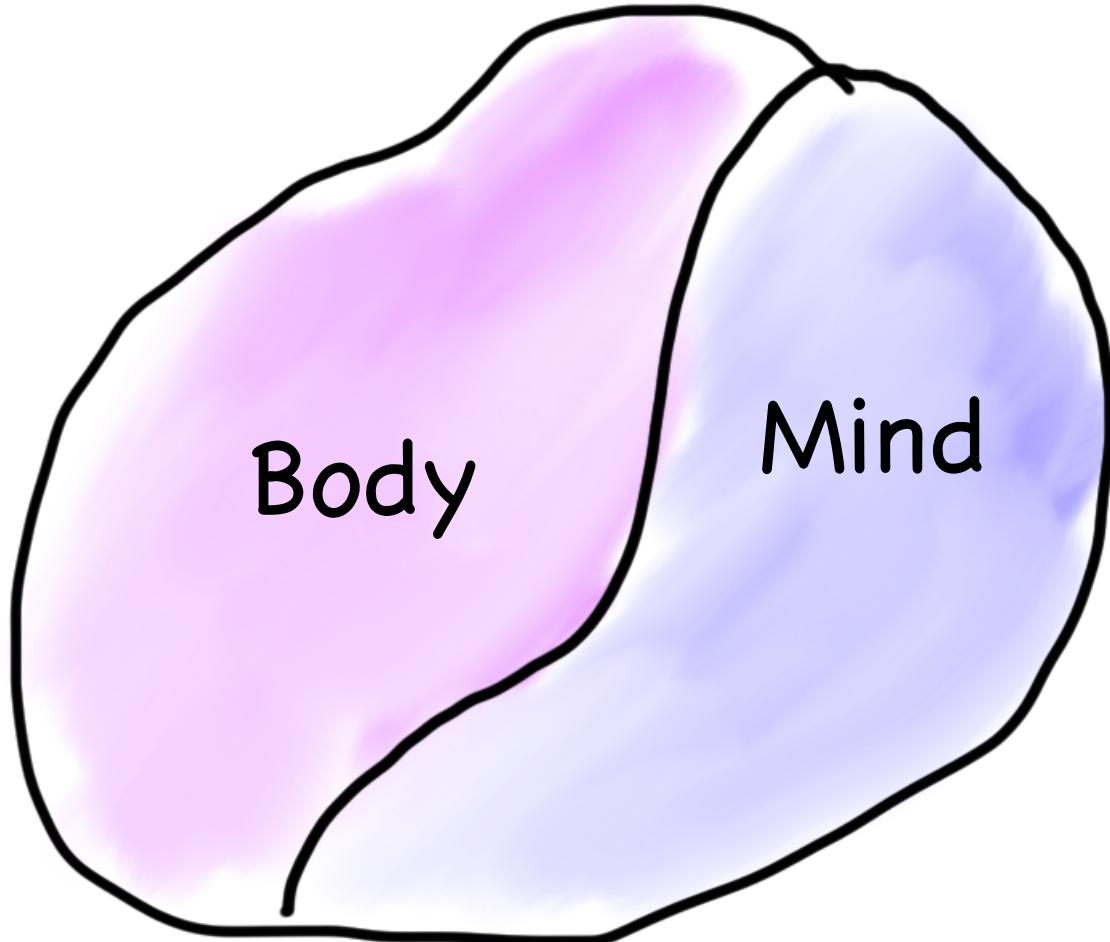
# House Cleaning Robot



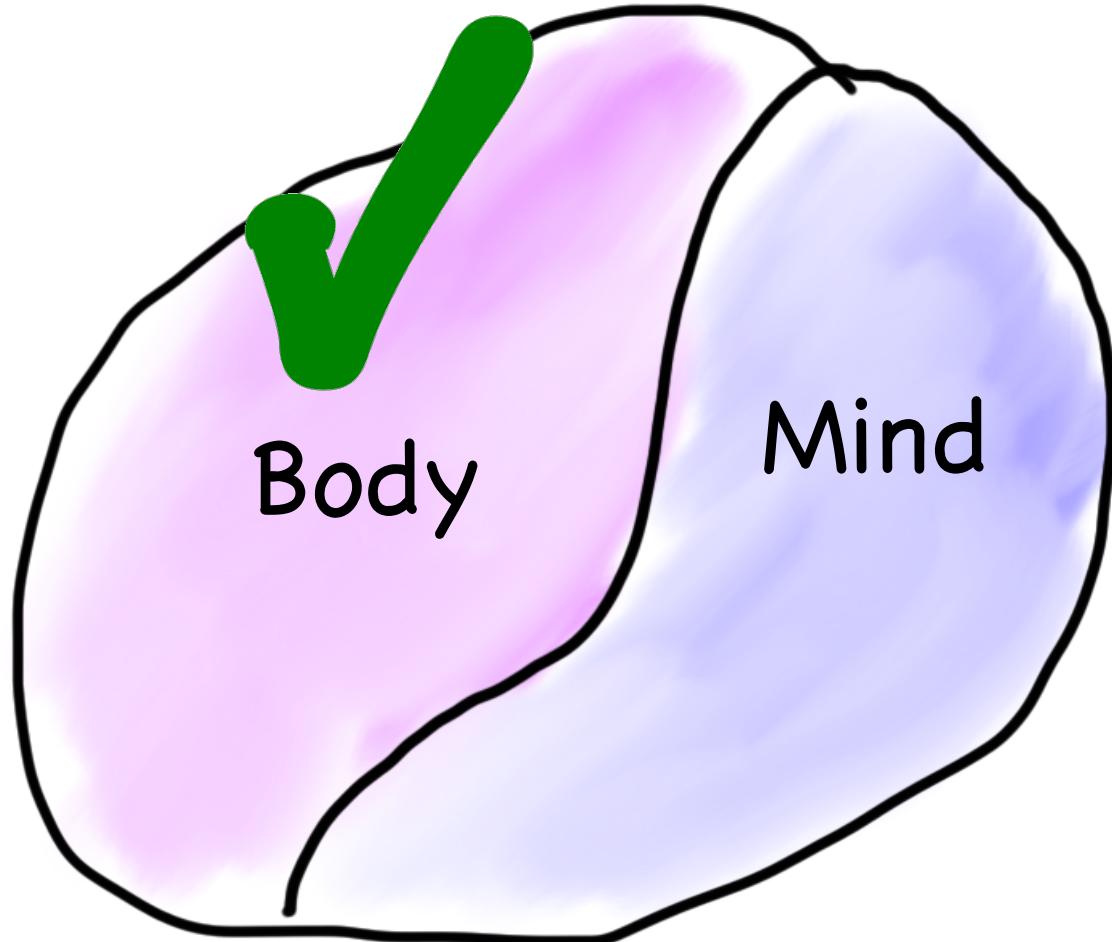
# House Cleaning Robot



# Robots?



# Robots?



# Brief History



# Narrow Intelligence

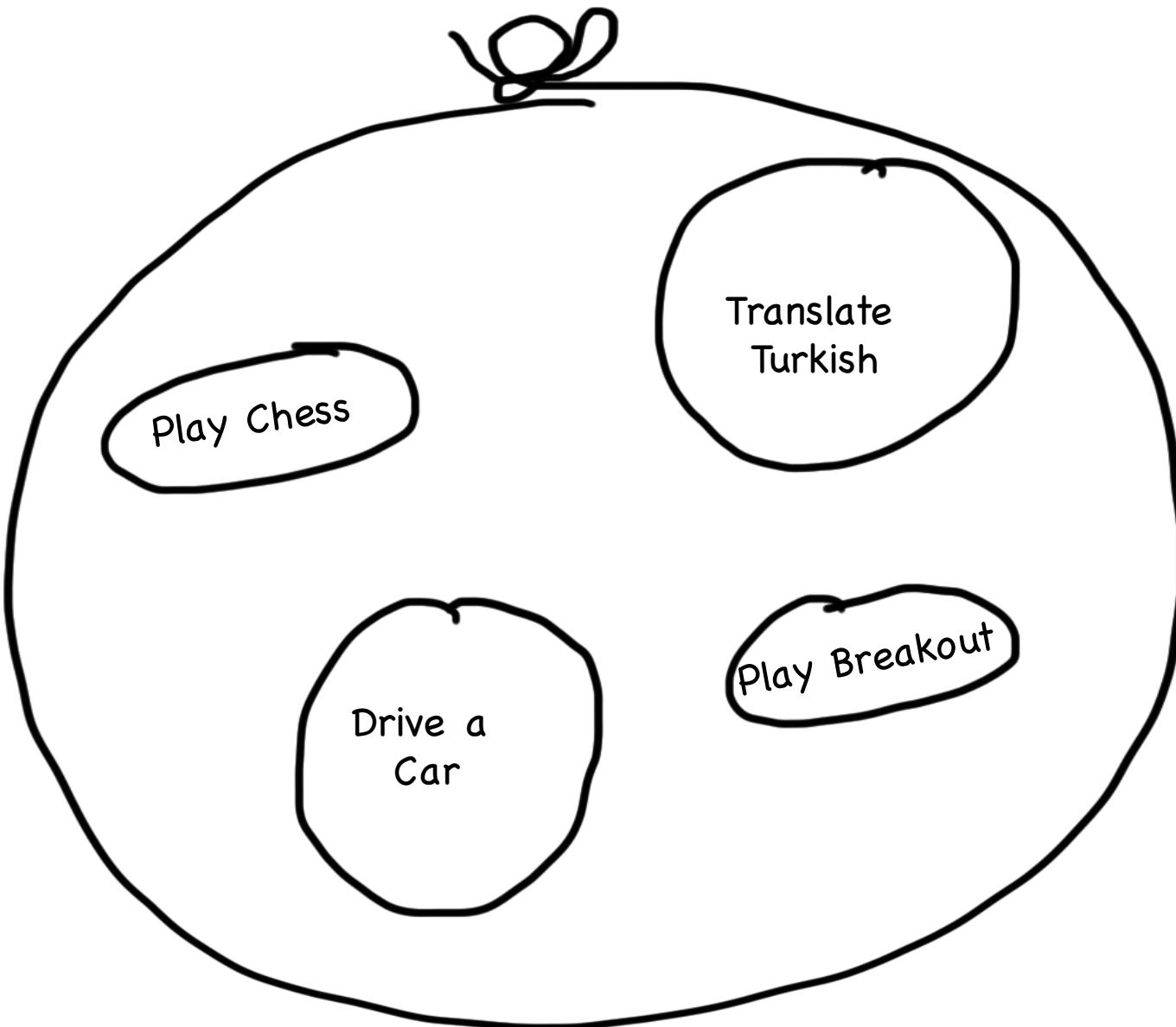
Play Chess

Translate  
Turkish

Drive a  
Car

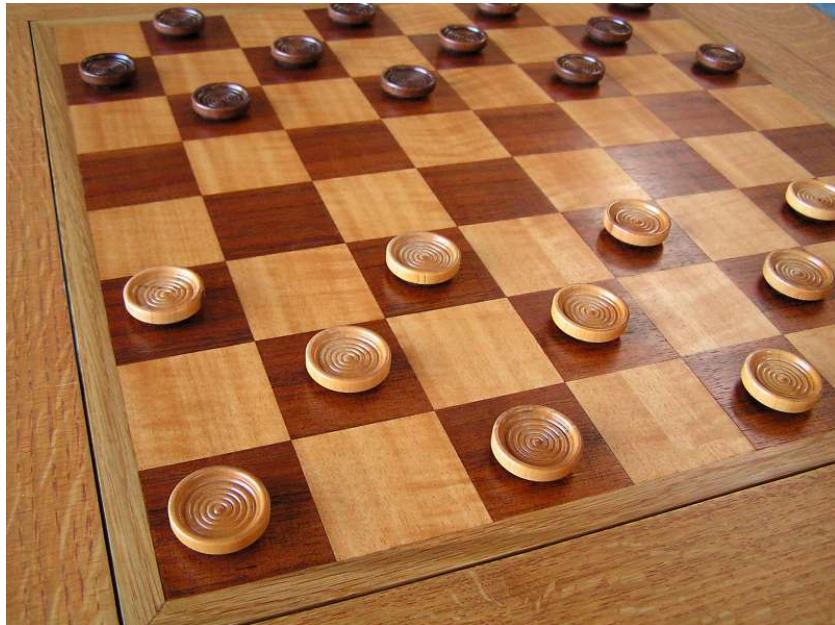
Play Breakout

# General Intelligence

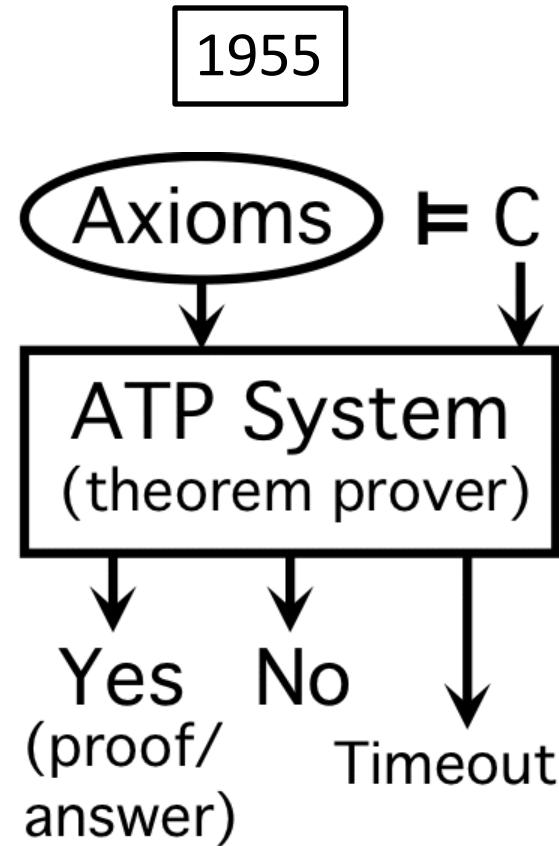


# Early Optimism 1950

1952



1955



# Early Optimism 1950

“Machines will be capable,  
within twenty years, of doing  
any work a man can do.”  
–Herbert Simon, 1952

# Underwhelming Results 1950s to 1980s

*The spirit is willing but the flesh is weak.*



(Russian)



*The vodka is good but the meat is rotten.*

The world is too complex

# **BRACE YOURSELVES**



# **WINTER IS COMING**

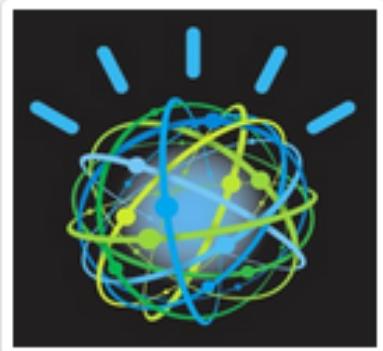
# Big Milestones Pt 1



1997 Deep Blue

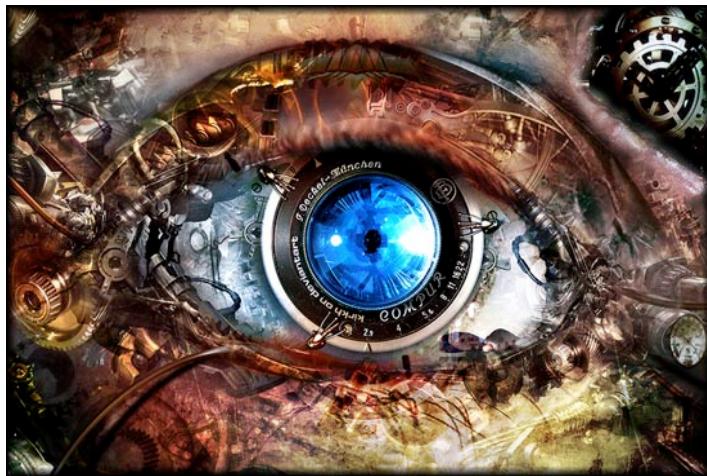
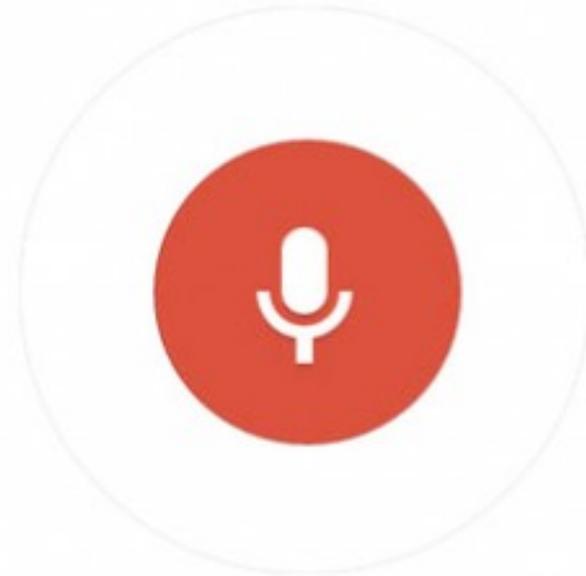


2005 Stanley



2011 Watson

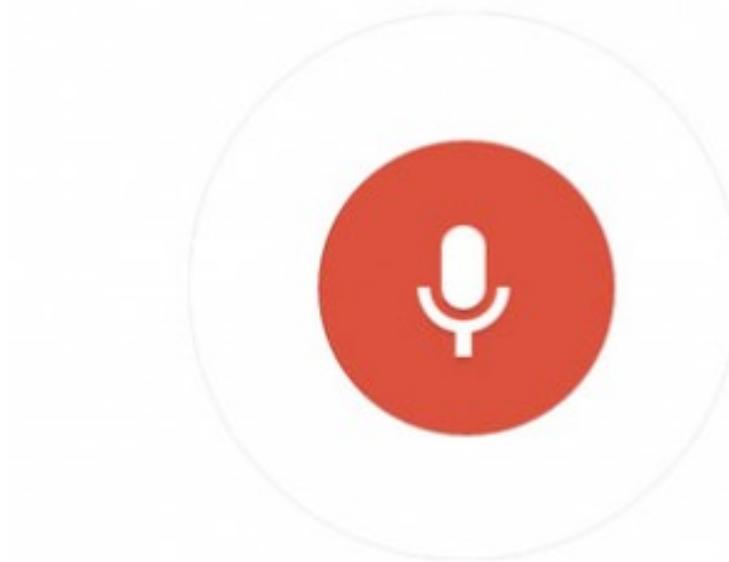
# Big Milestones Pt 2



# Told Vision Was 30 Years Out



# Told Speech Was 30 Years Out



Almost perfect...

# Huge Progress



# Passed the Turing Test?



**EUGENE GOOSTMAN**  
**THE WEIRDEST CREATURE IN THE WORLD**

33% of judges thought Eugene was a human

When only given 5 minutes...

What is going on?

# Story of Modern AI

# Two Great Ideas

1. Probability from Examples

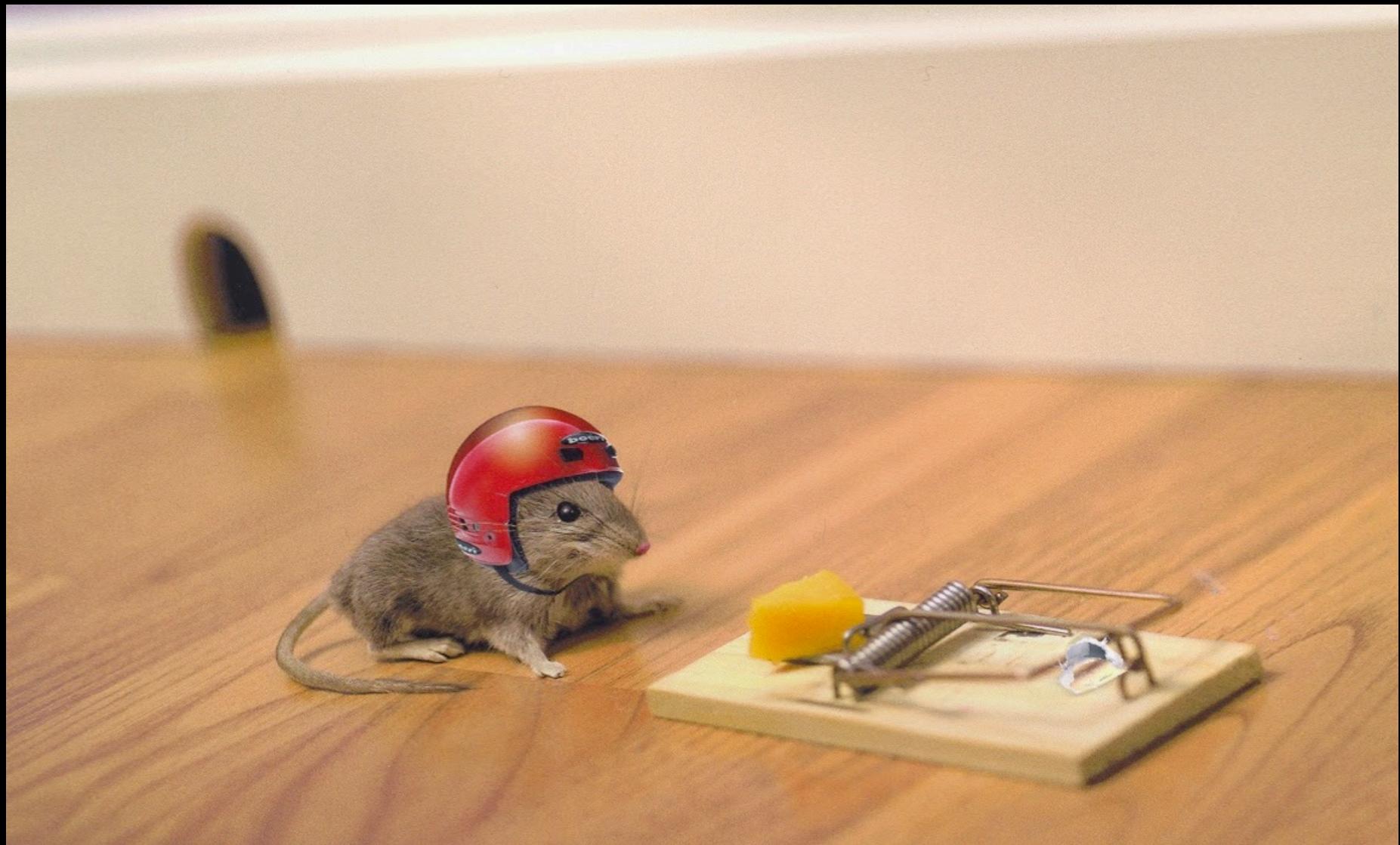
2. Artificial Neurons

# Two Great Ideas

1. Probability from Examples

2. Artificial Neurons

# 1. Probability From Examples



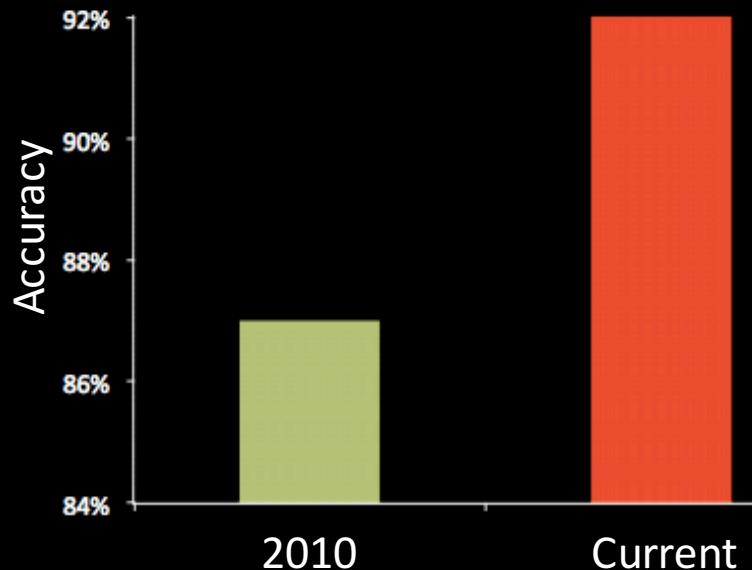
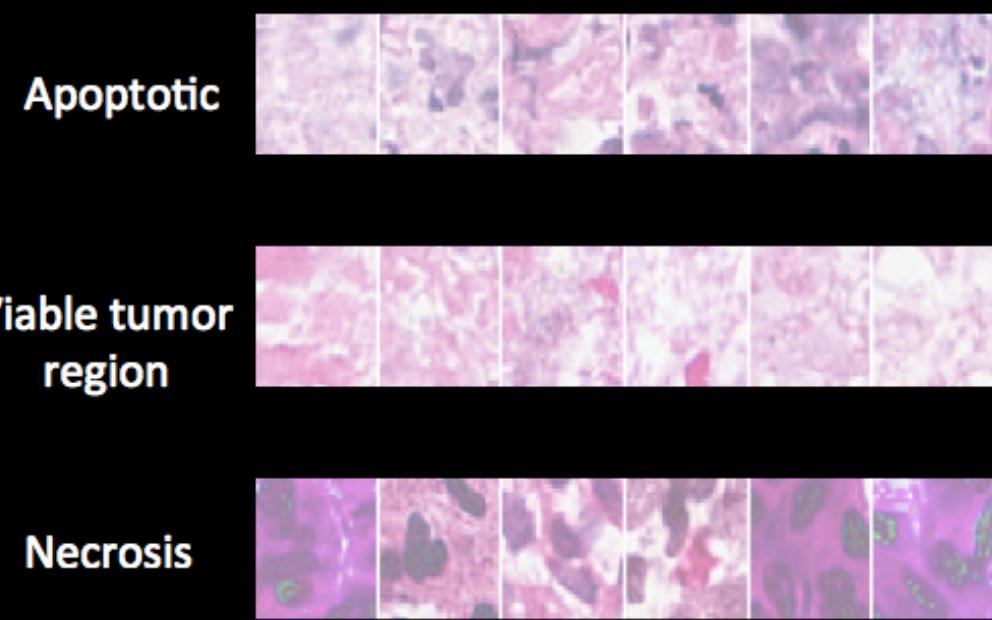
# When Does the Magic Happen?

Lots of  
Data + Sound  
Probability

# Machine Learning

Basically just a rebranding of statistics  
and probability.

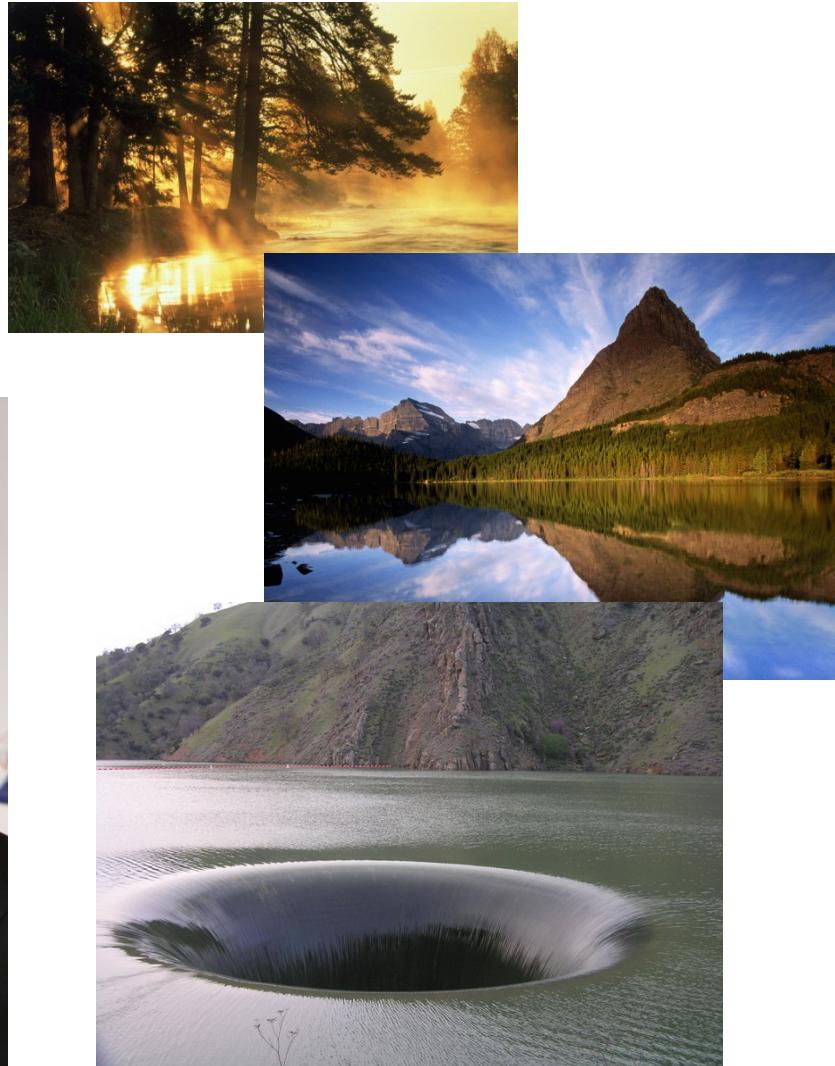
# Vision: Detect Cancer



# Vision: Detect Digits

0 0 0 0 0 0 0 0 0 0 0 0 0  
1 1 1 1 1 1 1 1 1 1 1 1 1  
2 2 2 2 2 2 2 2 2 2 2 2 3  
3 3 3 3 3 3 3 3 3 3 3 3 3  
4 4 4 4 4 4 4 4 4 4 4 4 4  
5 5 5 5 5 5 5 5 5 5 5 5 5  
6 6 6 6 6 6 6 6 6 6 6 6 6  
7 7 7 7 7 7 7 7 7 7 7 7 7  
8 8 8 8 8 8 8 8 8 8 8 8 8  
9 9 9 9 9 9 9 9 8 9 9 9 9

# Vision: Detect Faces



# Vision is Hard

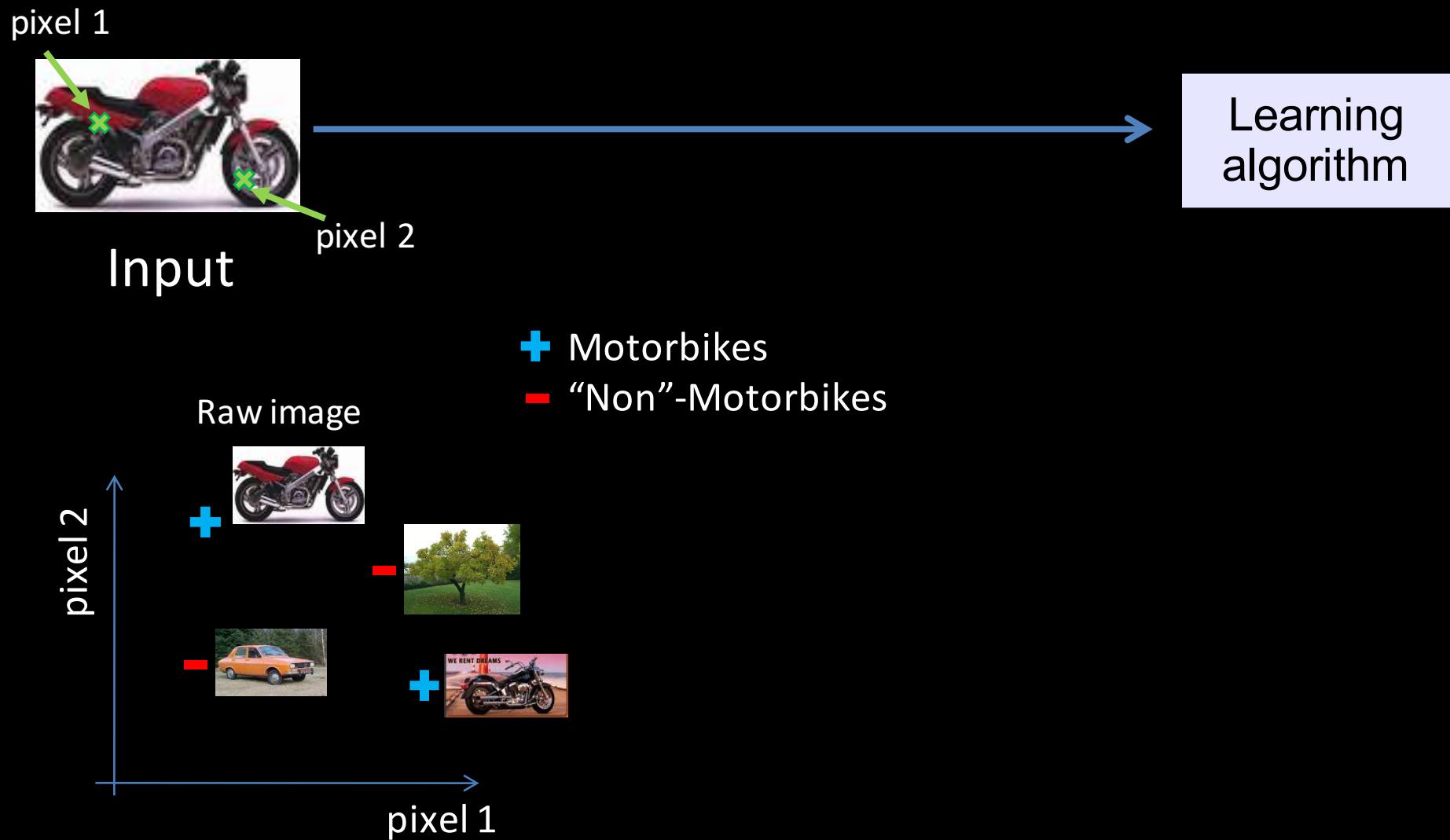
You see this:



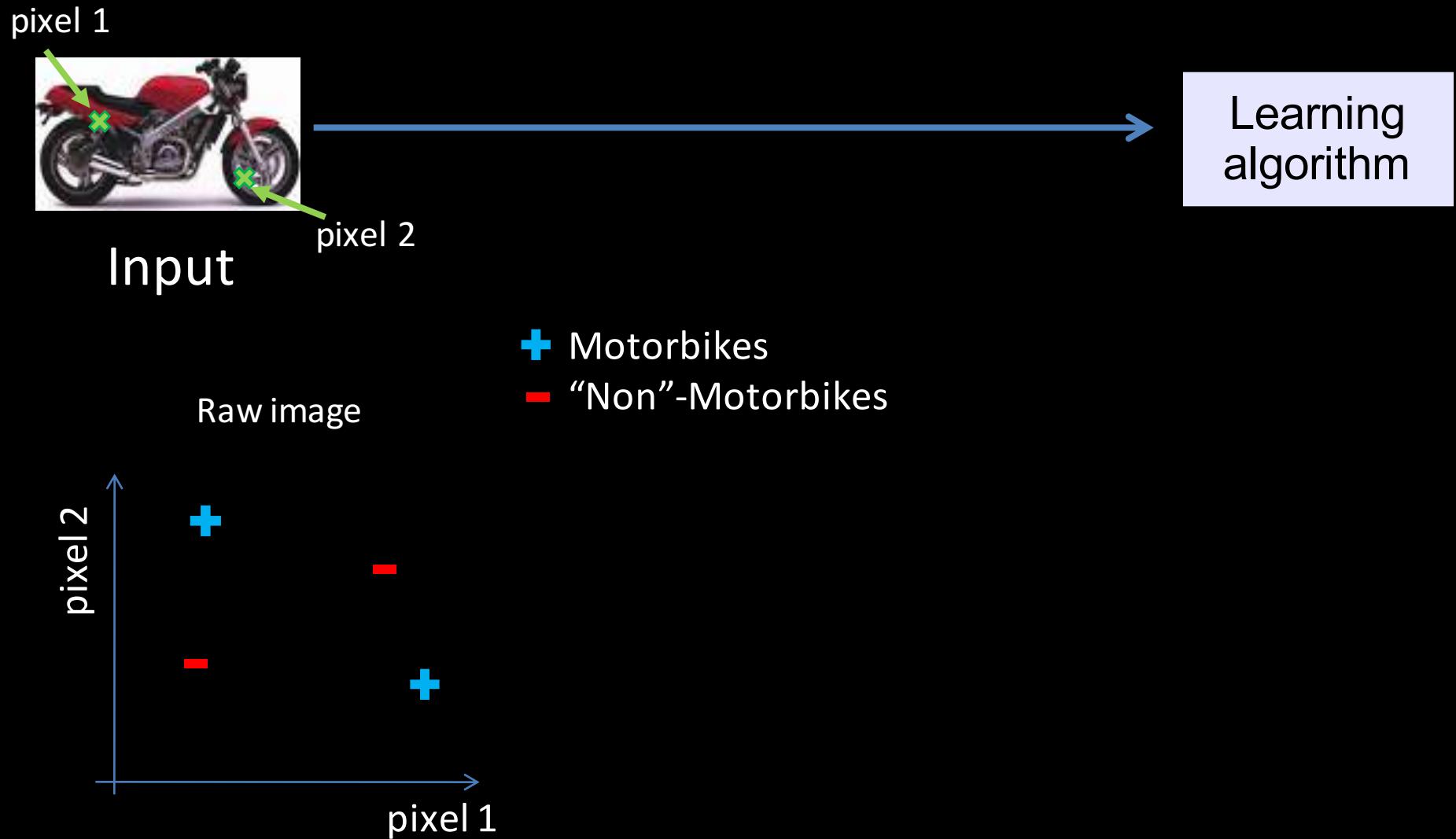
But the camera sees this:

194	210	201	212	199	213	215	195	178	158	182	209
180	189	190	221	209	205	191	167	147	115	129	163
114	126	140	188	176	165	152	140	170	106	78	88
87	103	115	154	143	142	149	153	173	101	57	57
102	112	106	131	122	138	152	147	128	84	58	66
94	95	79	104	105	124	129	113	107	87	69	67
68	71	69	98	89	92	98	95	89	88	76	67
41	56	68	99	63	45	60	82	58	76	75	65
20	43	69	75	56	41	51	73	55	70	63	44
50	50	57	69	75	75	73	74	53	68	59	37
72	59	53	66	84	92	84	74	57	72	63	42
67	61	58	65	75	78	76	73	59	75	69	50

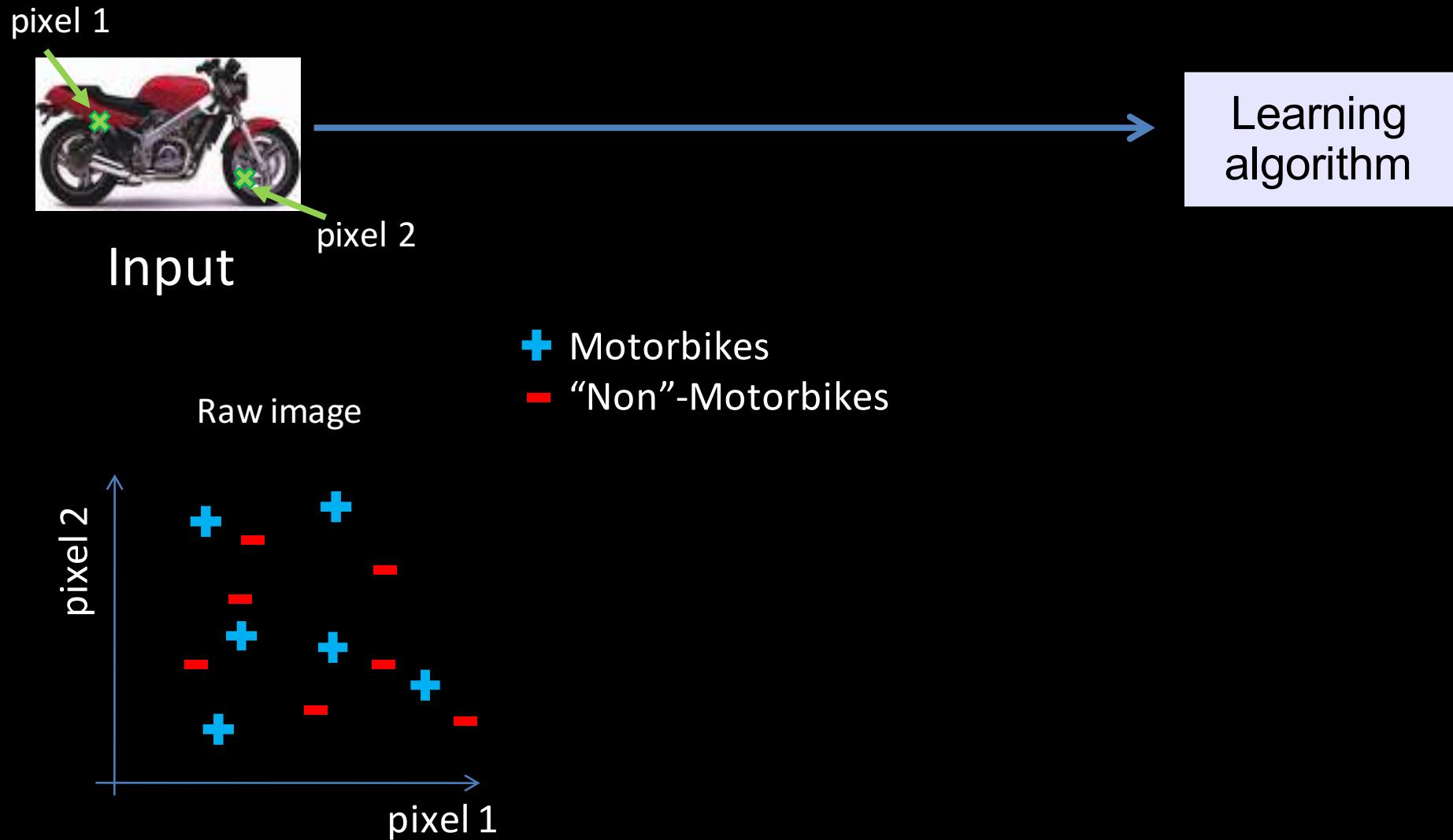
# Machine Learning



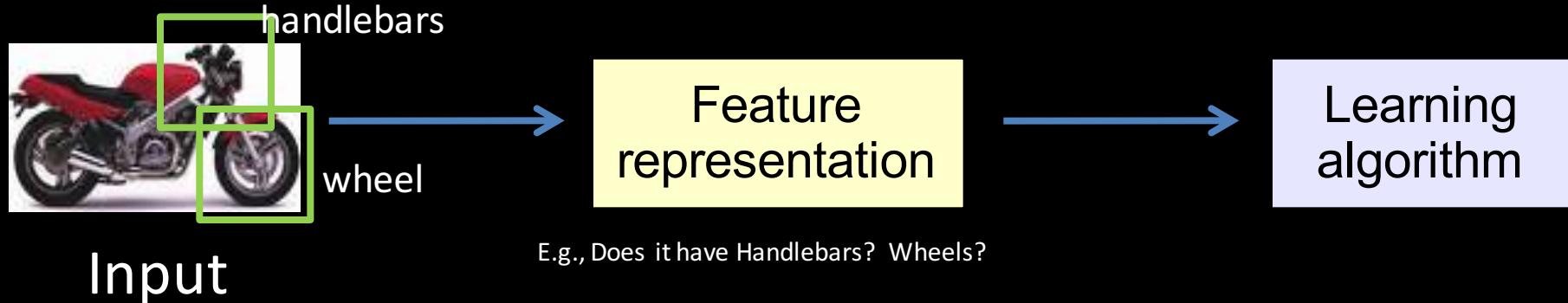
# Machine Learning



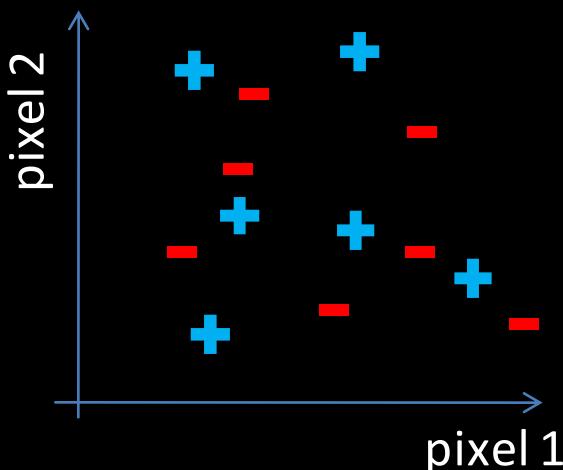
# Machine Learning



# Machine Learning

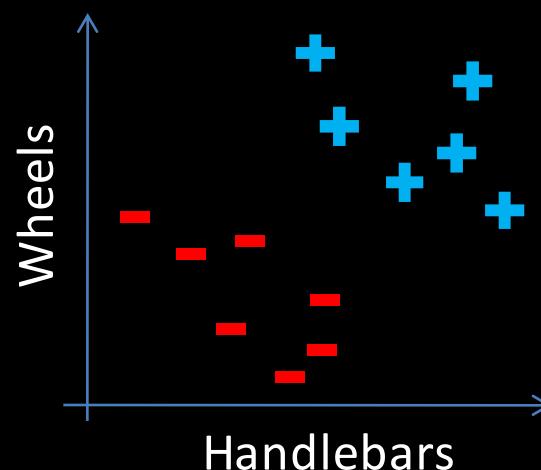


Raw image

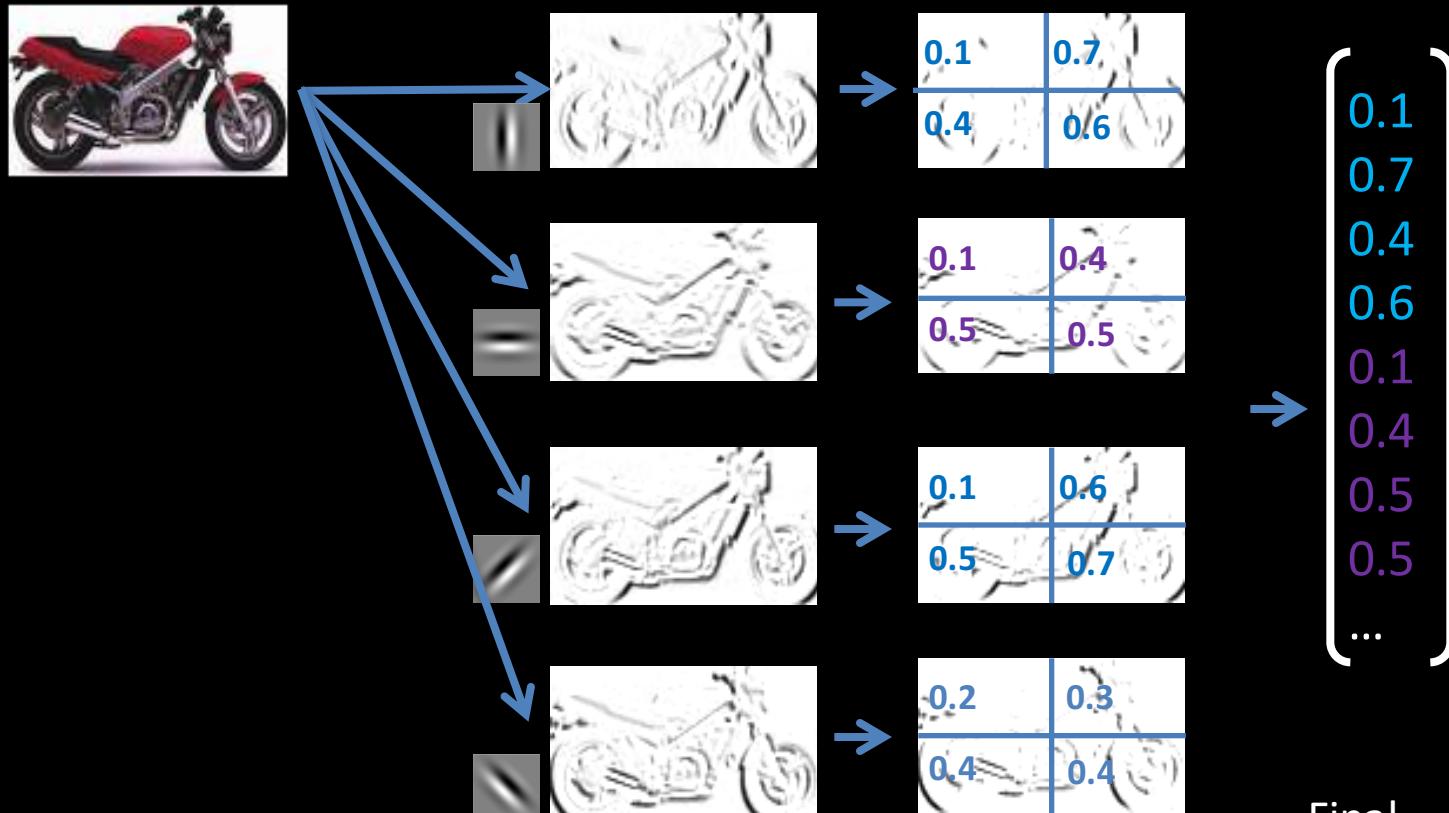


- + Motorbikes
- “Non”-Motorbikes

Features



# Human Created Features



Find edges  
at four  
orientations

Sum up edge  
strength in  
each quadrant

Final  
feature  
vector

# Human Created Features

Images/video



Image

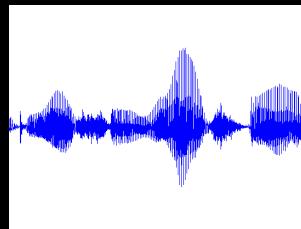


Vision features

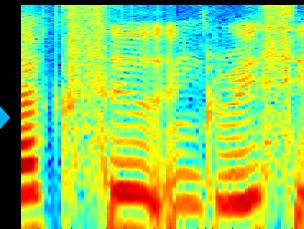


Detection

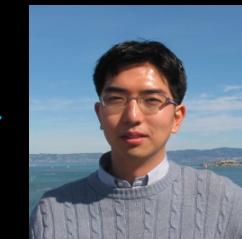
Audio



Audio



Audio features



Speaker ID

# Not Perfect...



# Some Great Thinkers



Daphne Koller



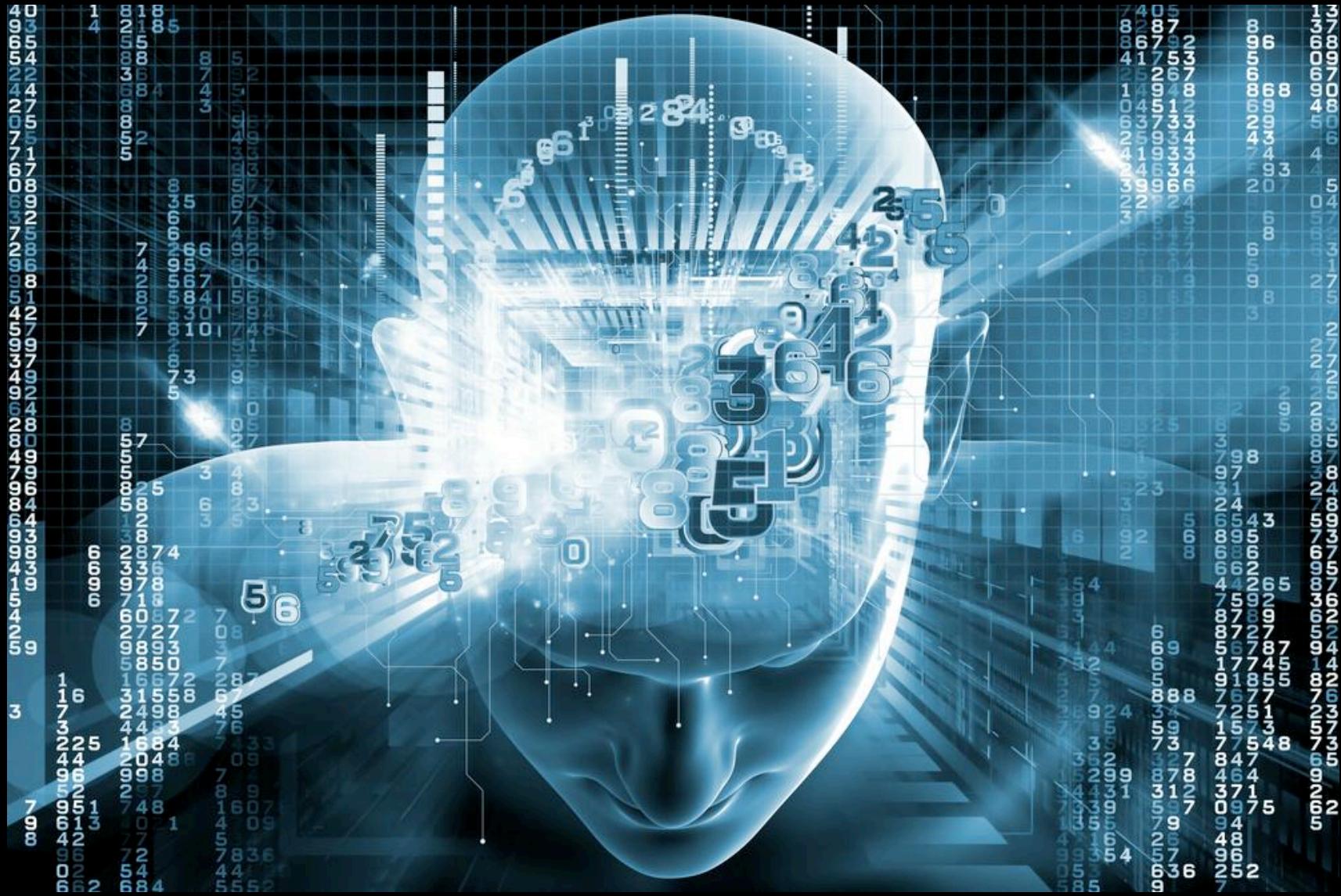
Mehran Sahami

# Two Great Ideas

1. Probability from Examples

2. Artificial Neurons

# 2. Artificial Neurons



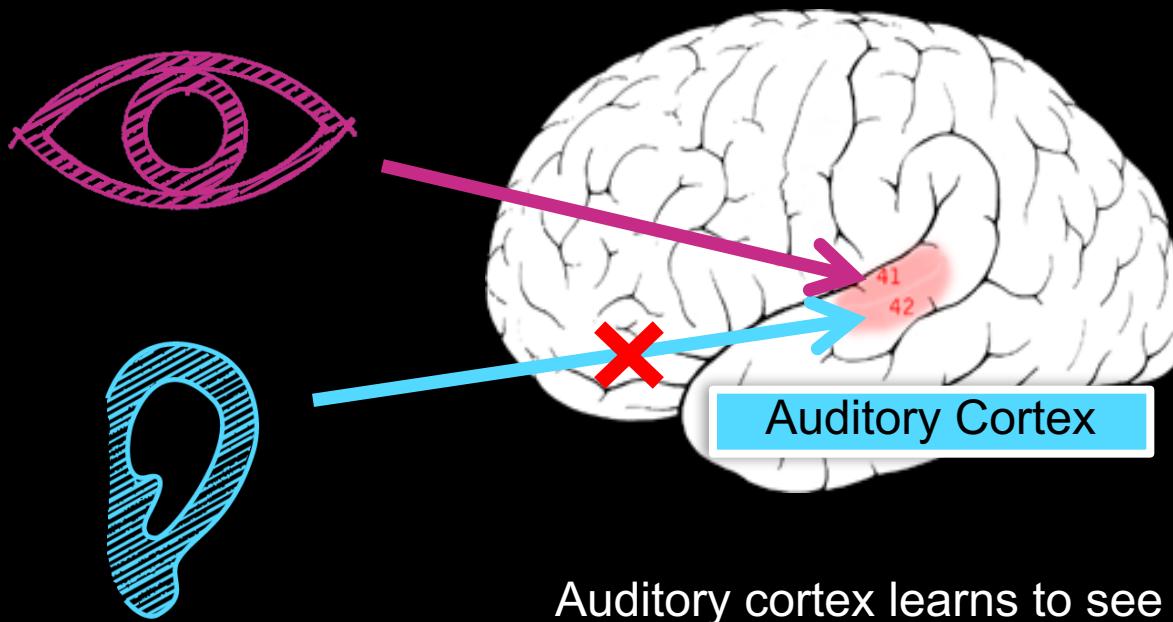
# One Algorithm Hypothesis

Much of perception in the brain can be explained with a single learning algorithm.



[Andrew Ng]

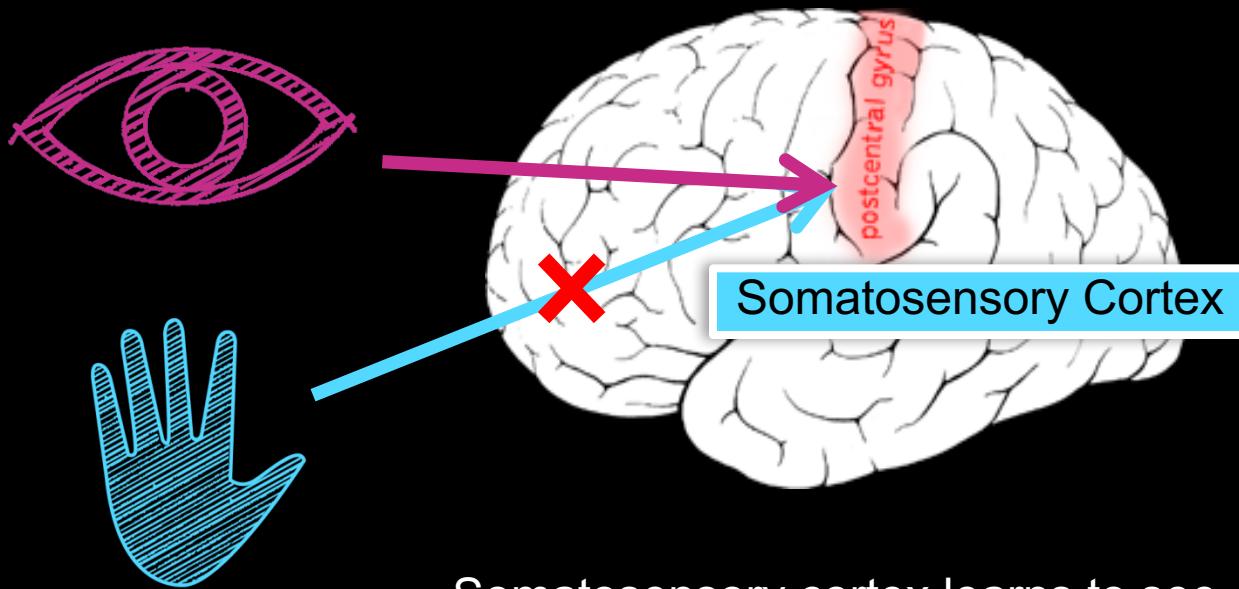
# One Algorithm Hypothesis



[Roe et al., 1992]

[Andrew Ng]

# One Algorithm Hypothesis

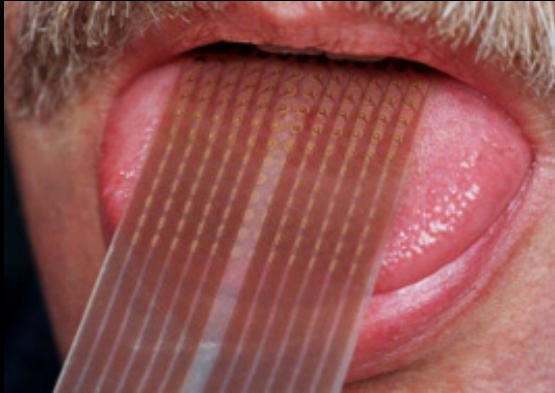


Somatosensory cortex learns to see

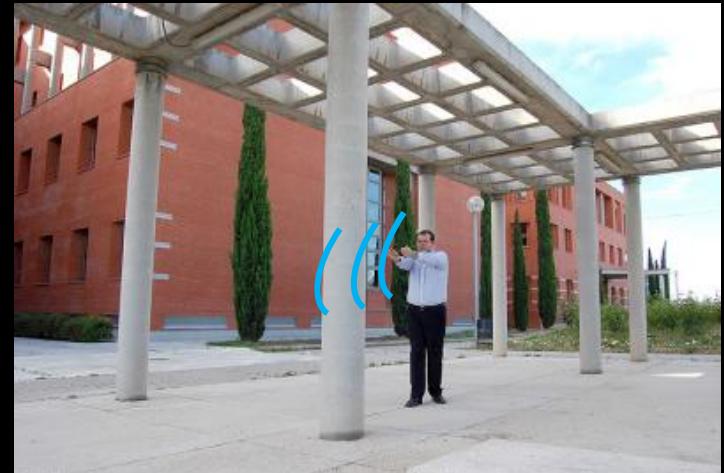
[Metin & Frost, 1989]

[Andrew Ng]

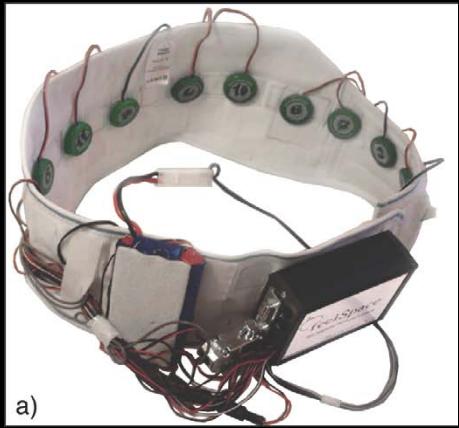
# Sensor Representations



Seeing with your tongue



Human echolocation (sonar)

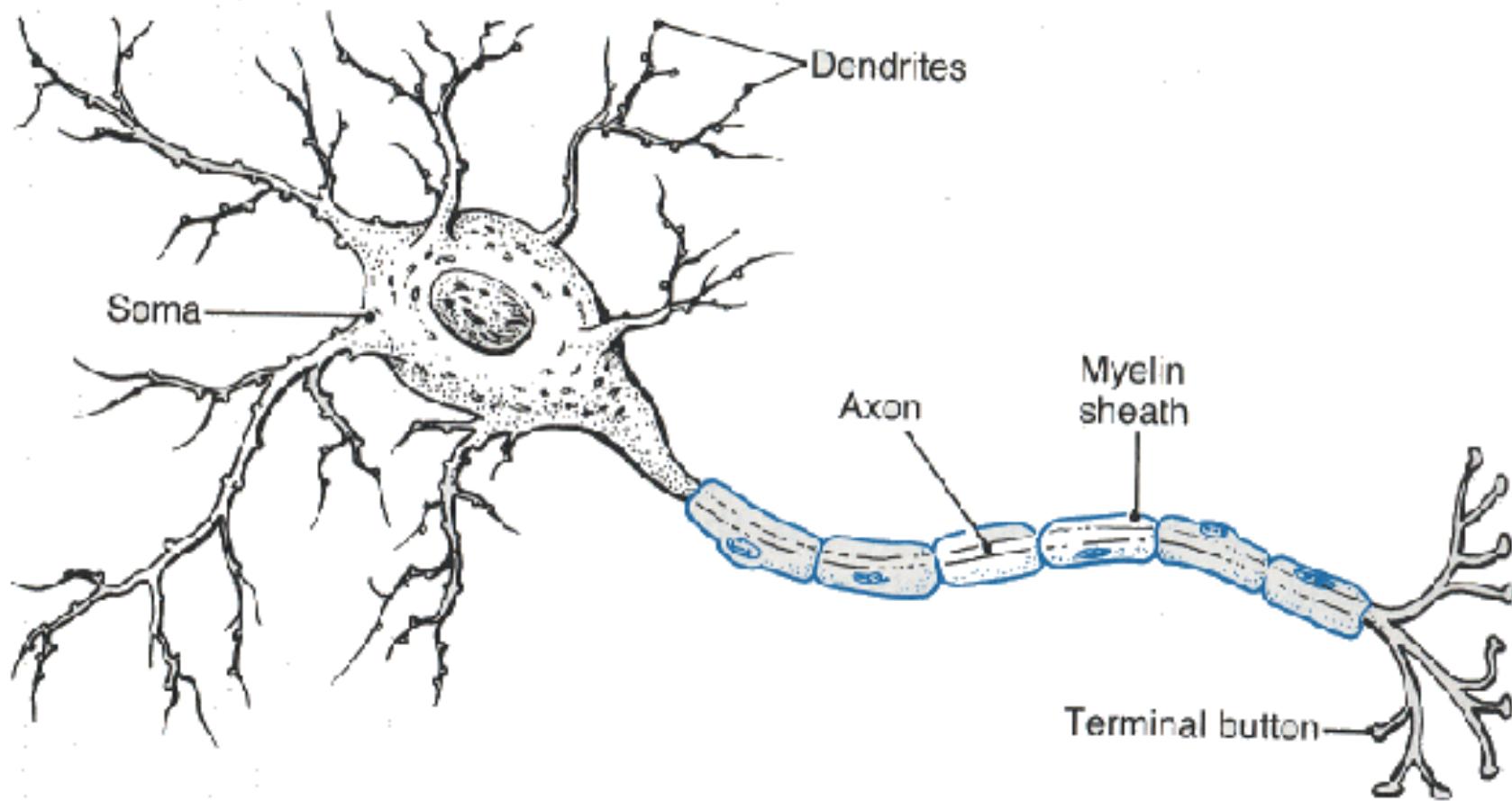


Haptic belt: Direction sense

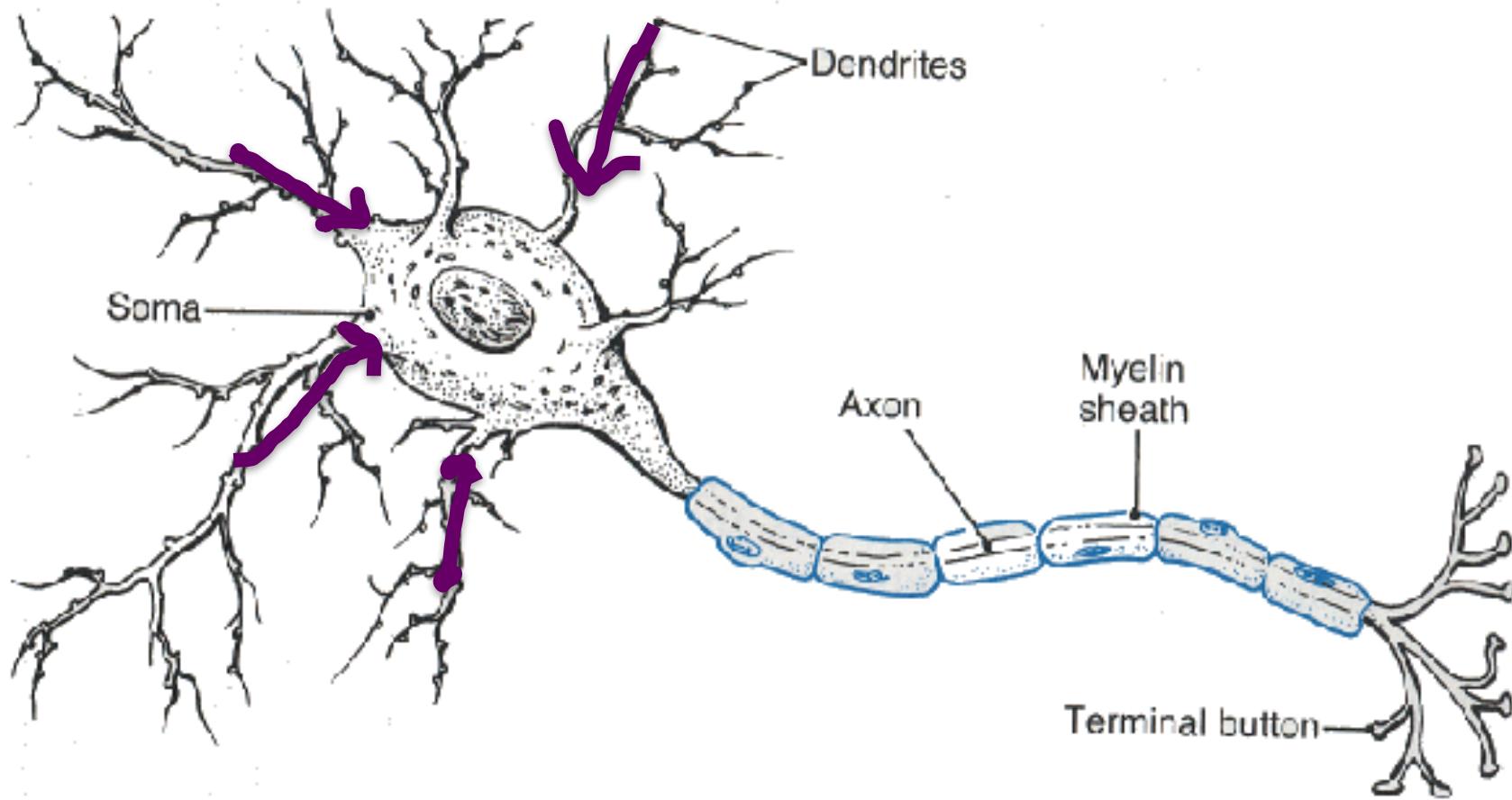


Implanting a 3<sup>rd</sup> eye

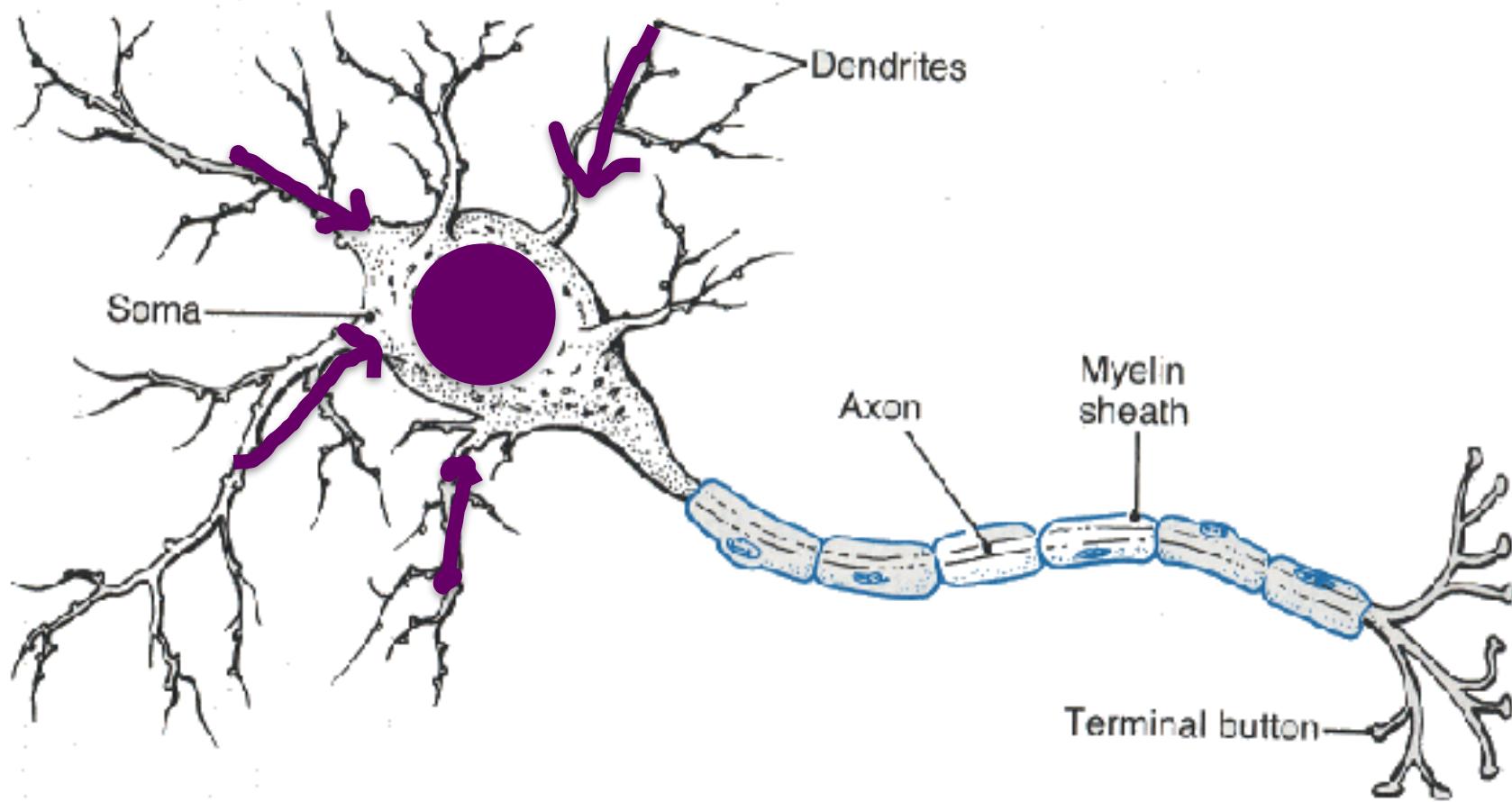
# Neuron



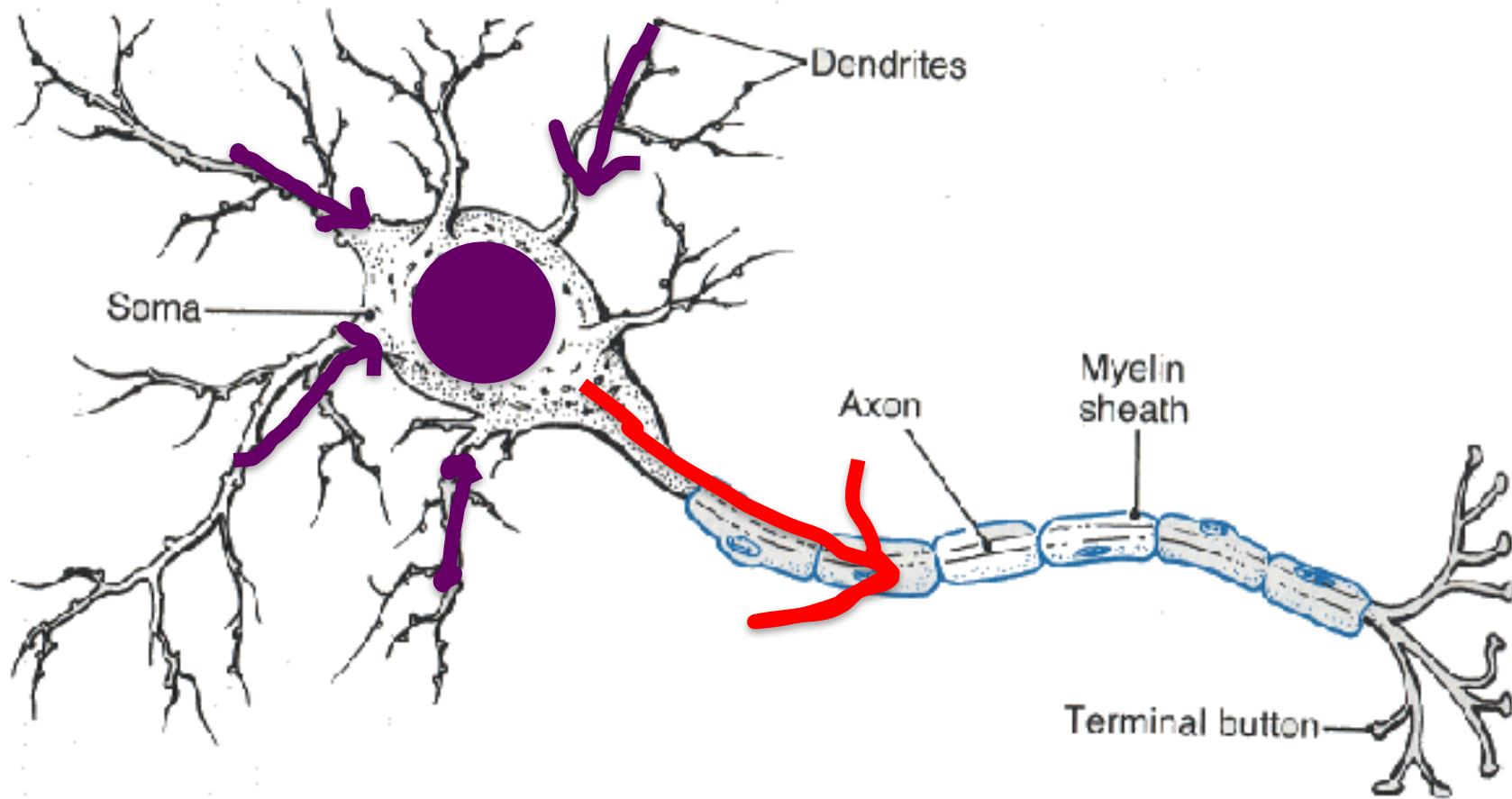
# Neuron



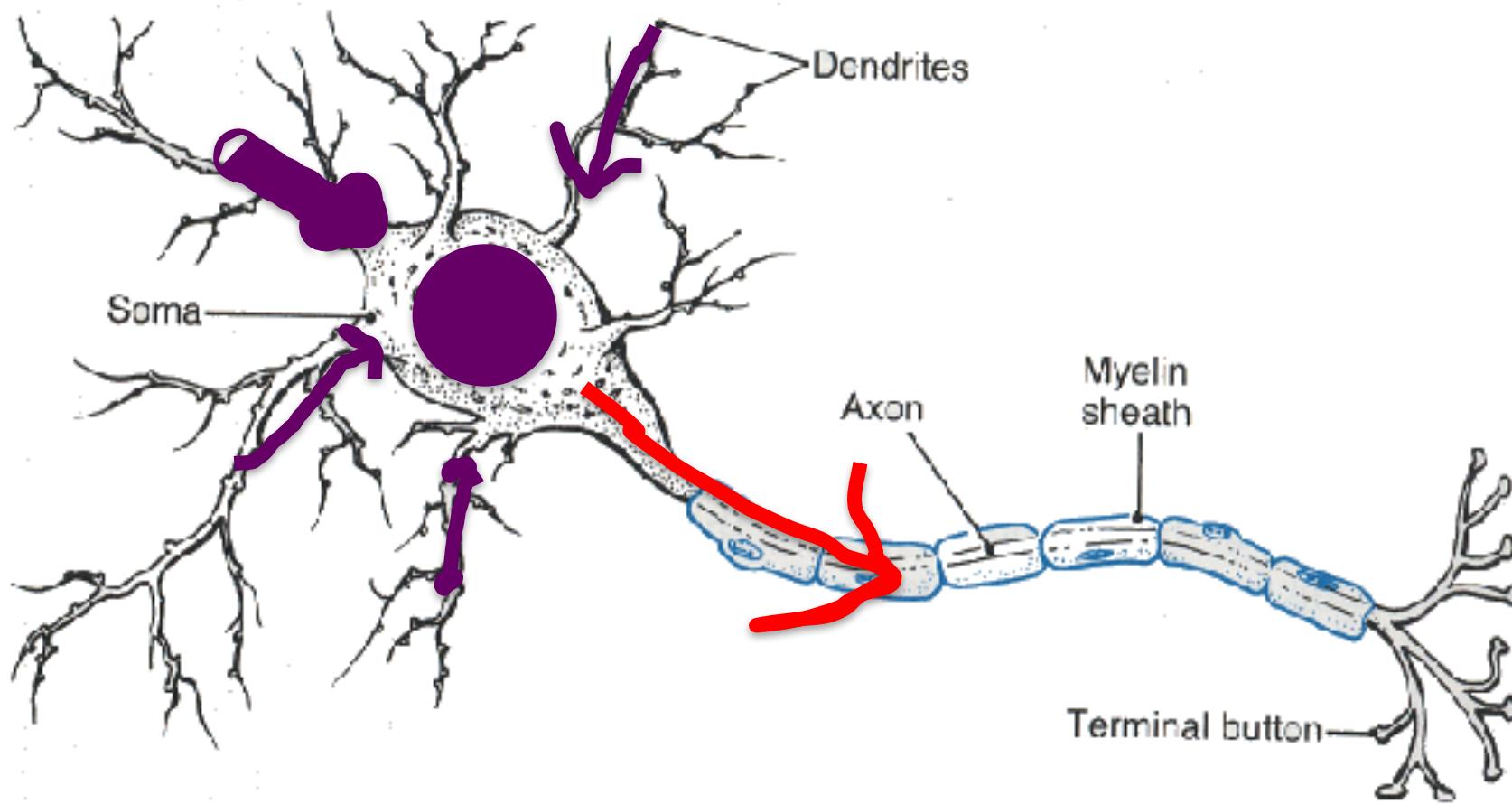
# Neuron



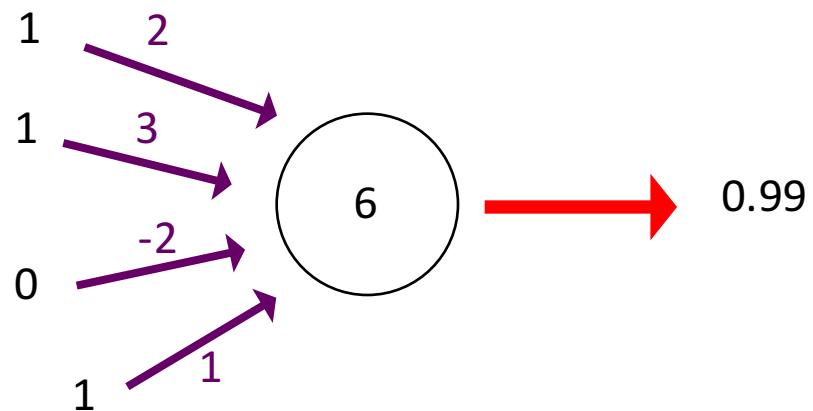
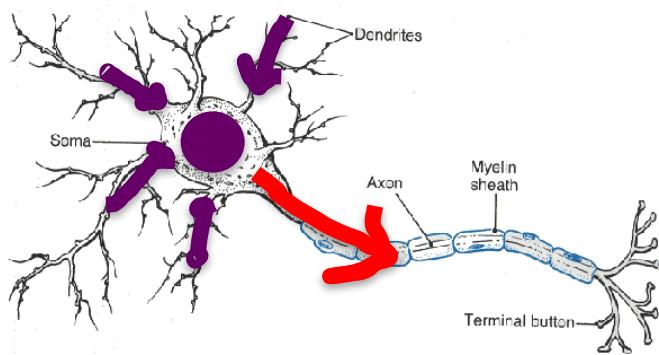
# Neuron



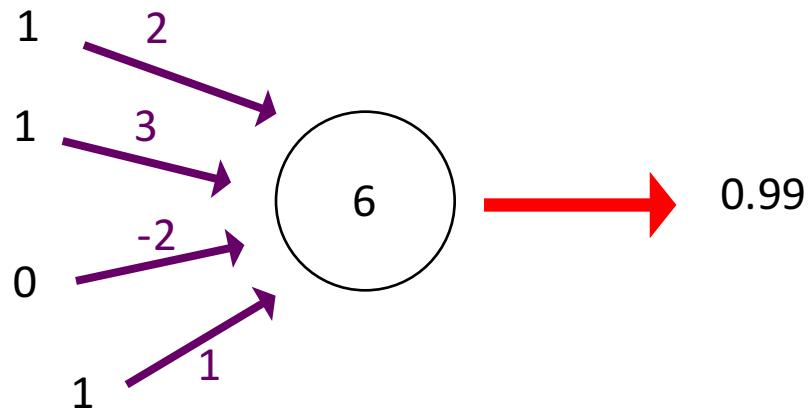
# Some Inputs are More Important



# Artificial Neuron

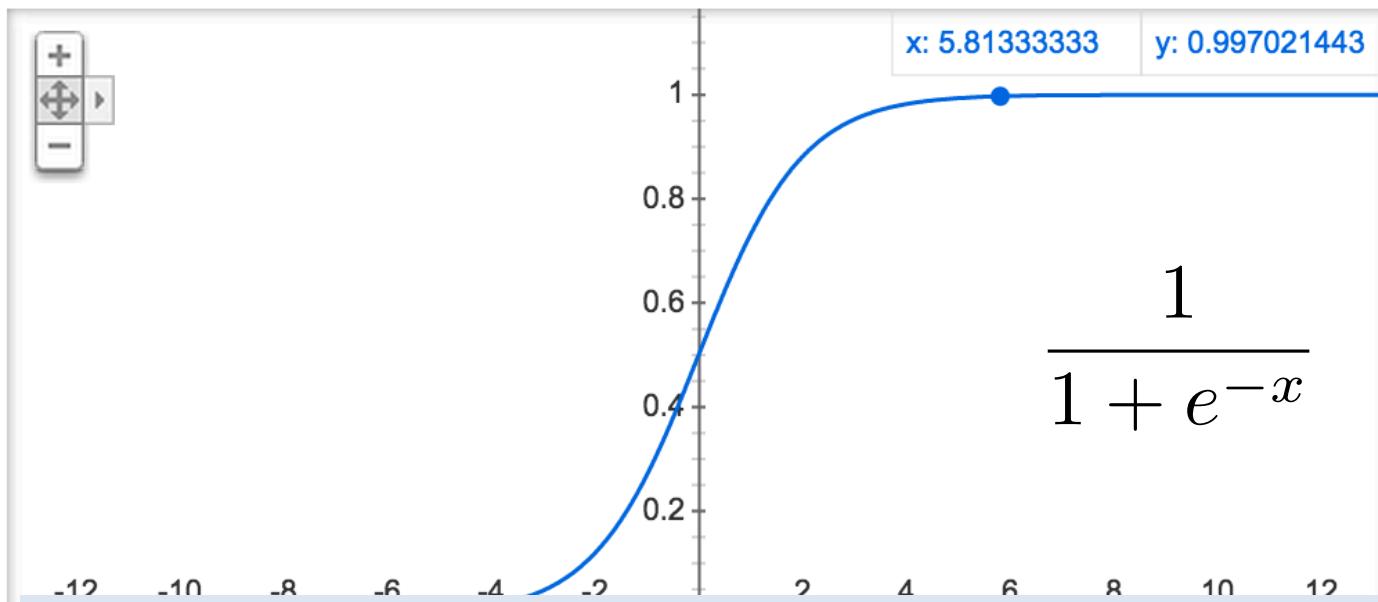
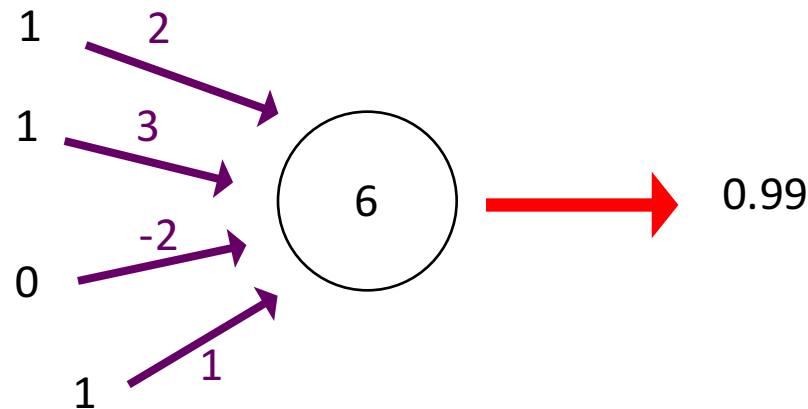


# Artificial Neuron



```
input  sum = 1 * 2 +
             1 * 3 +
             0 * -2 +
             1 * 1
```

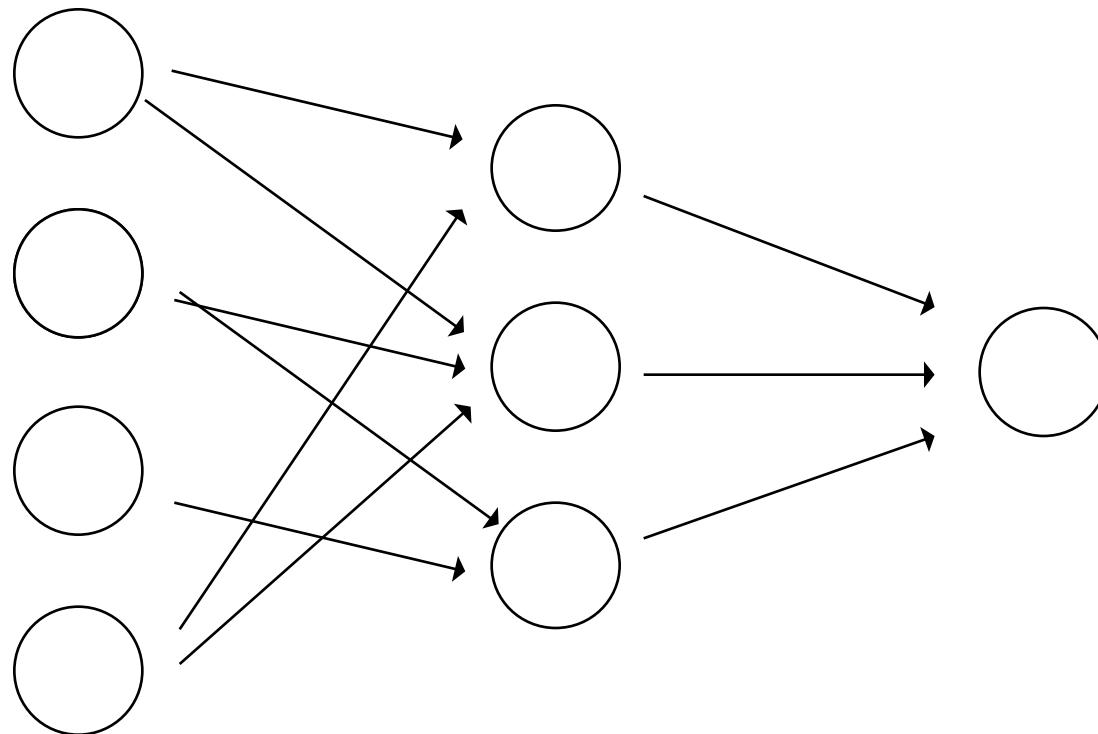
# Sigmoid Function



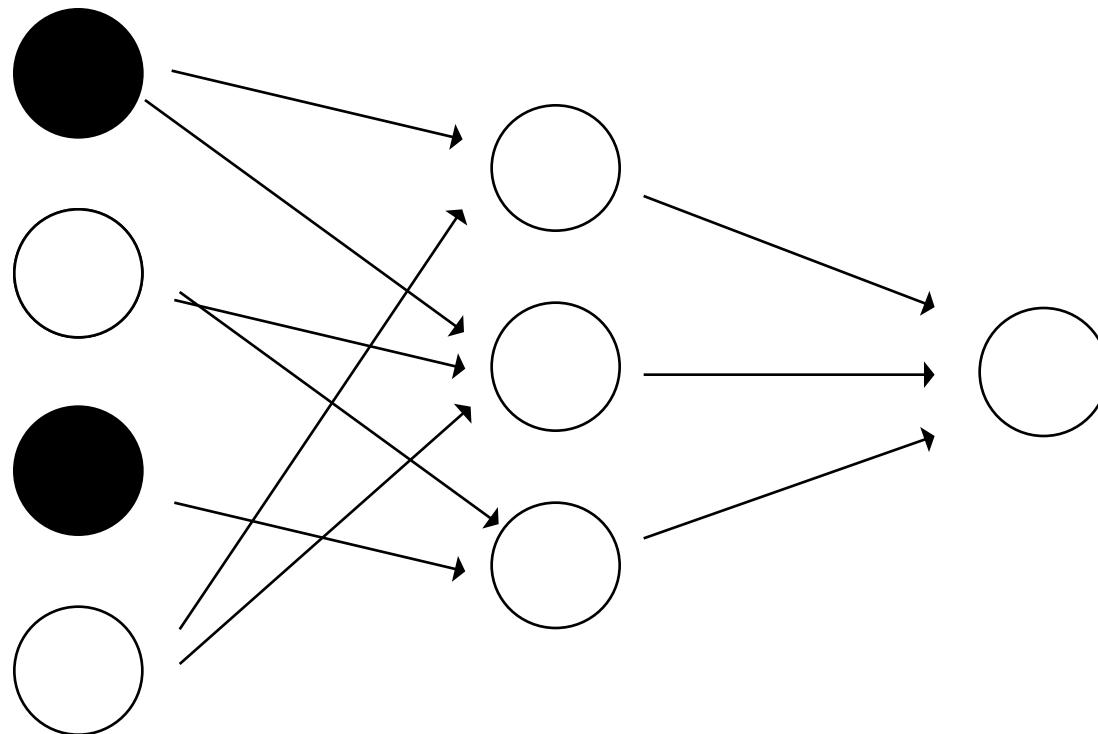
$$\frac{1}{1 + e^{-x}}$$

An artificial neuron is like a little probability calculator

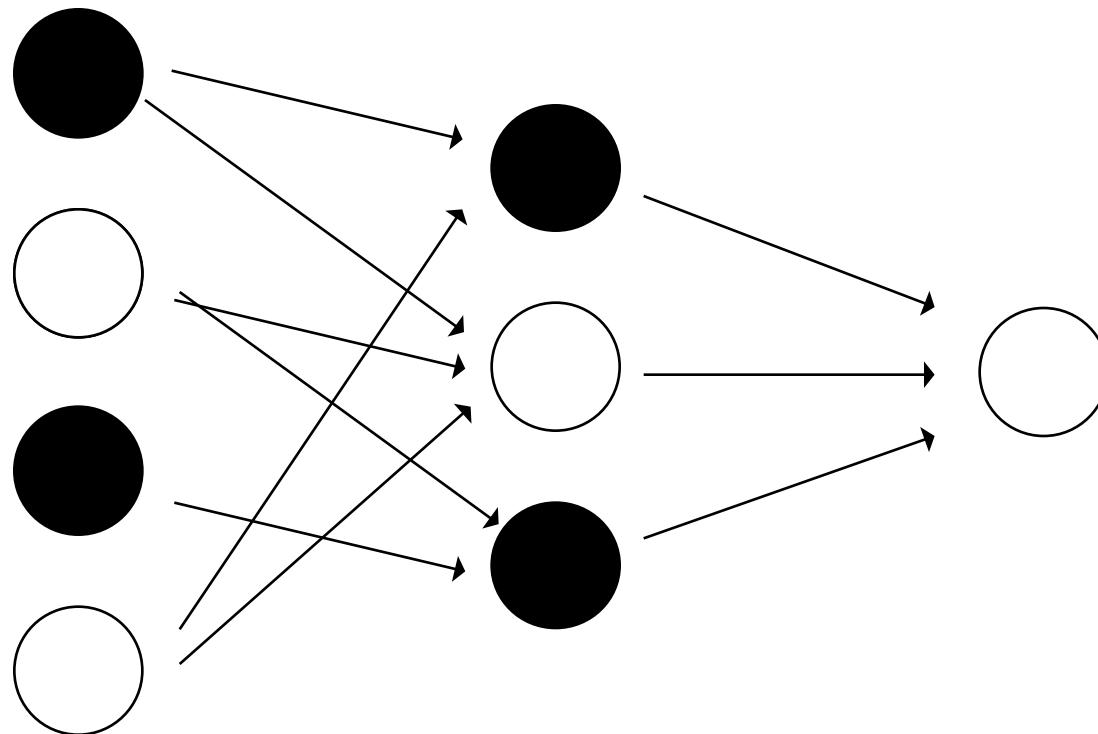
# Put Many Together



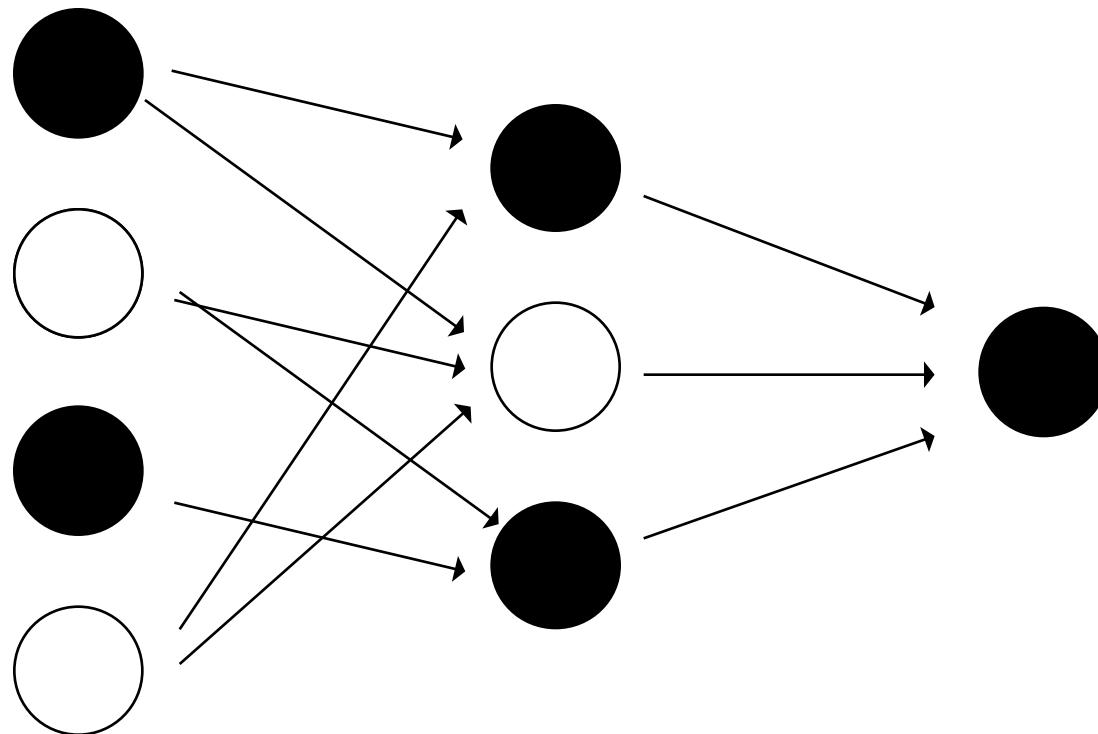
# Put Many Together



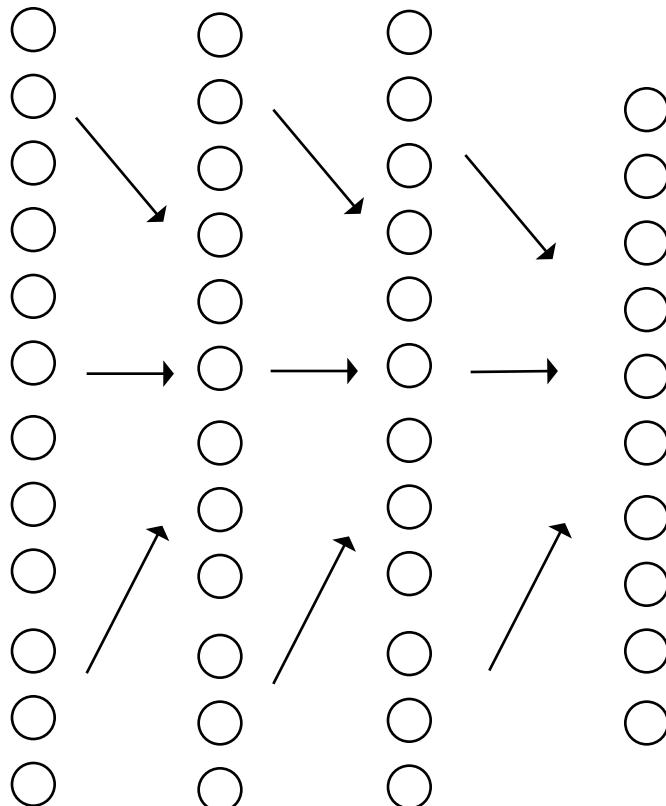
# Put Many Together



# Put Many Together

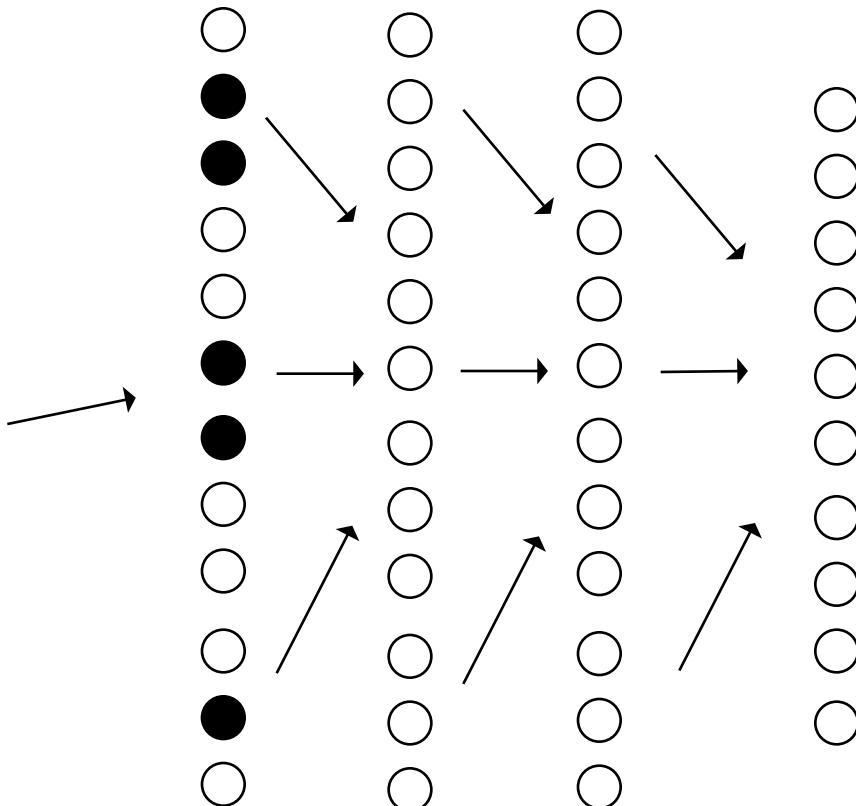


# Make It Useful



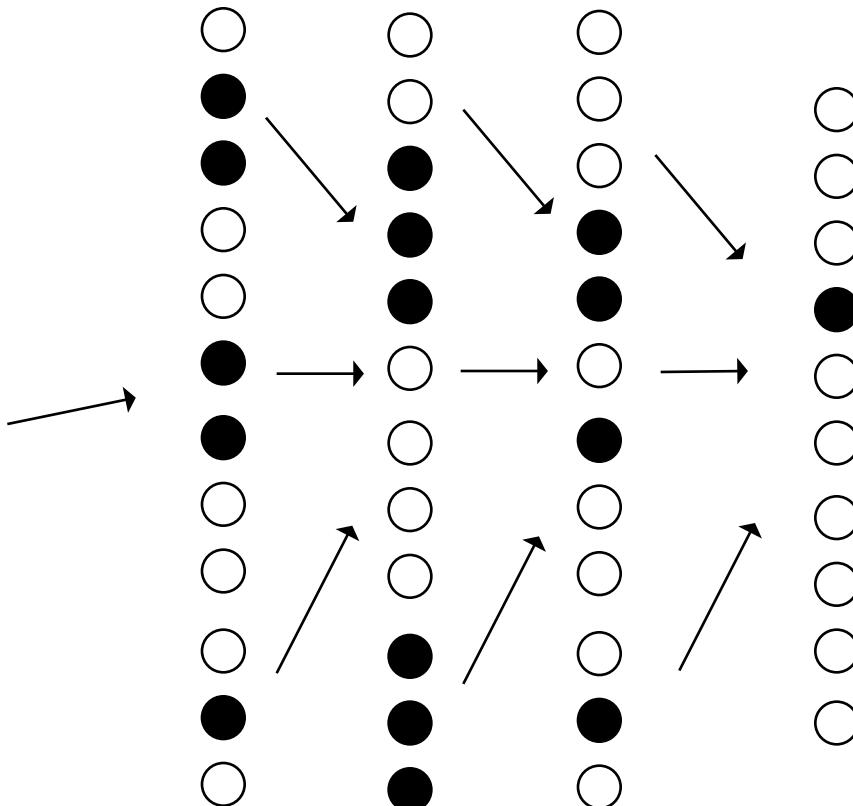
# Make It Useful

4



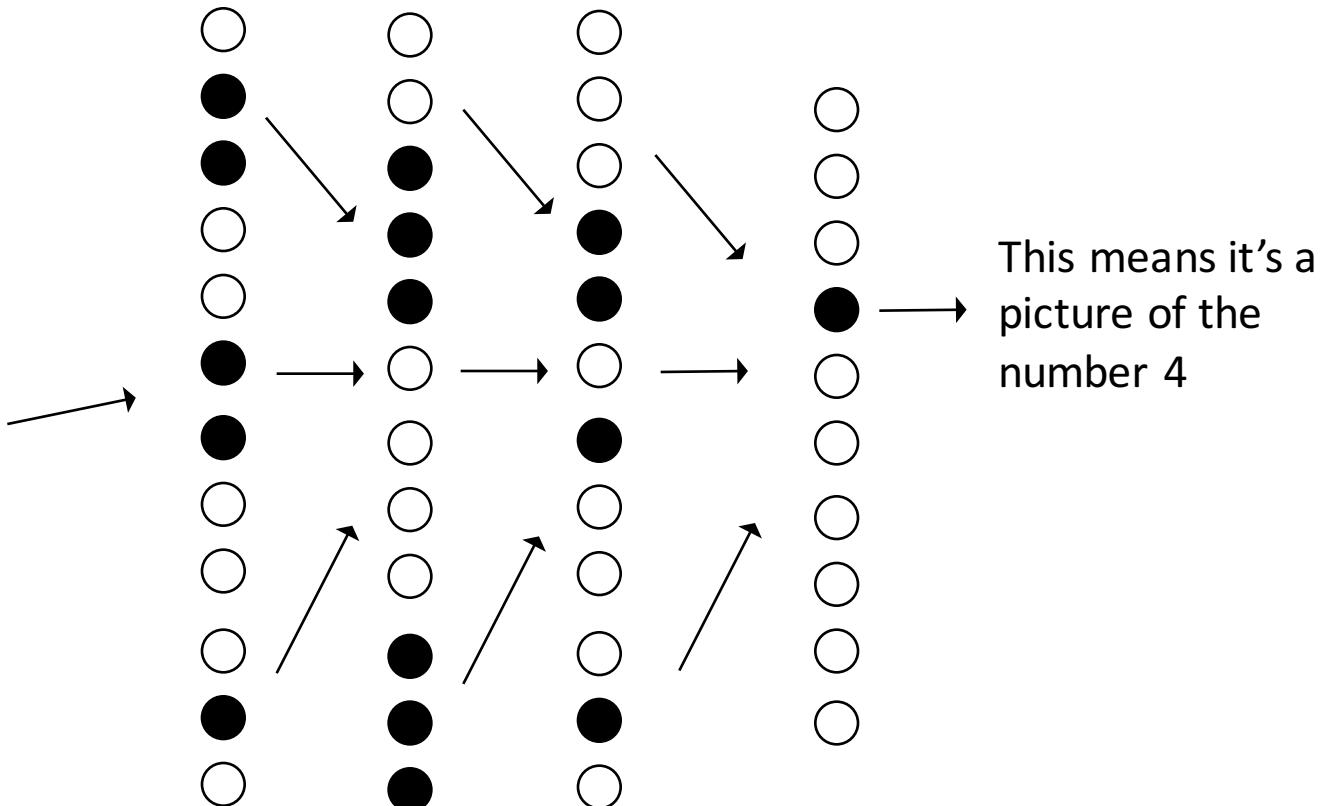
# Make It Useful

4

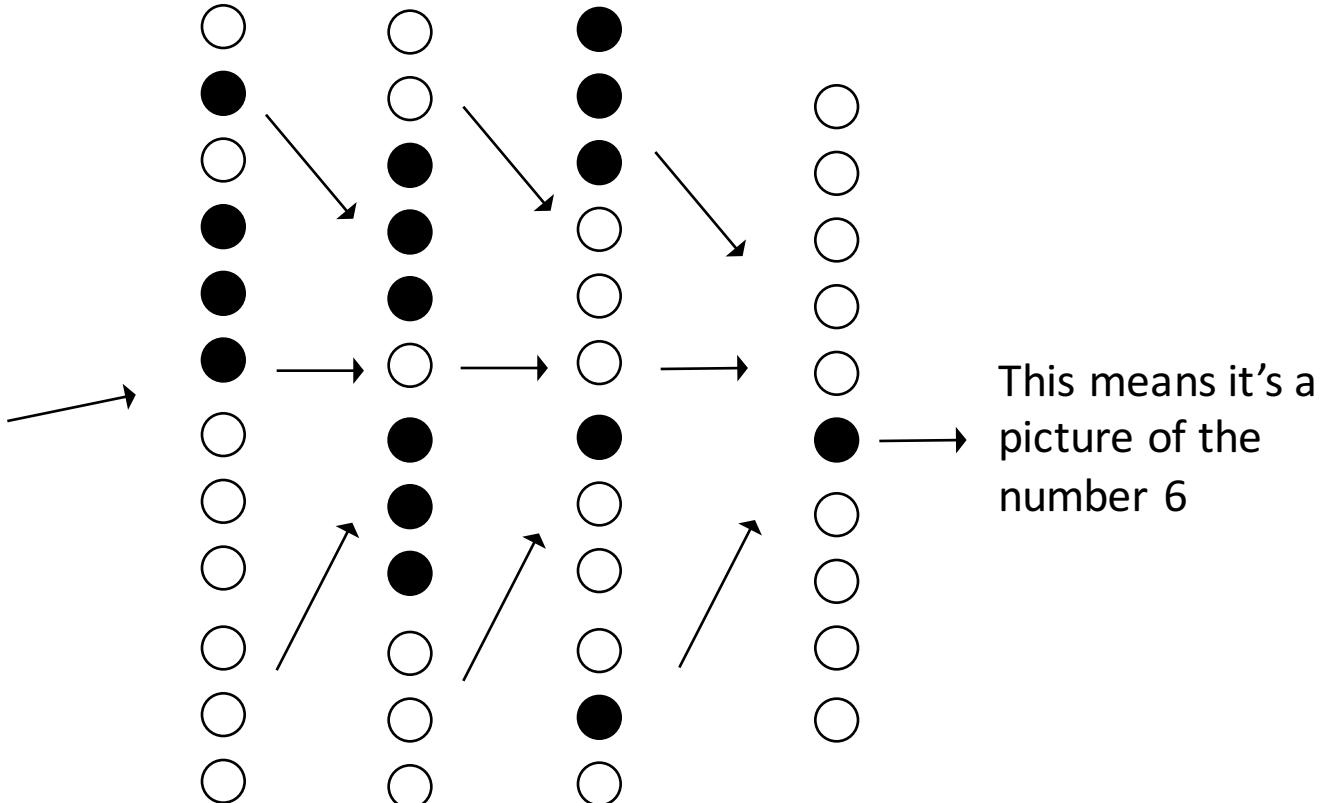
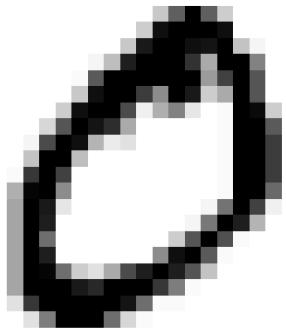


# Make It Useful

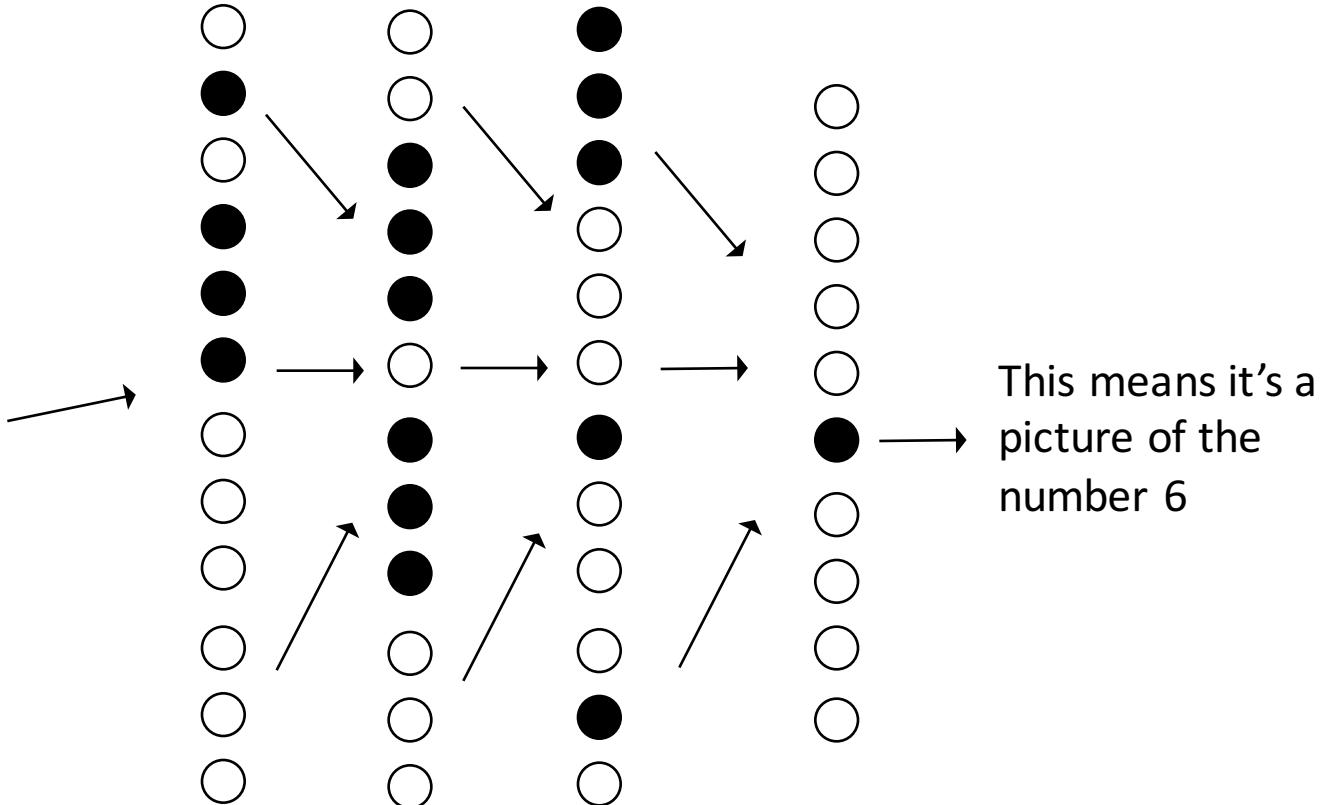
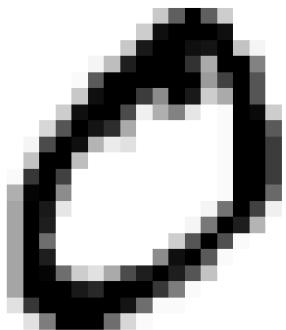
4



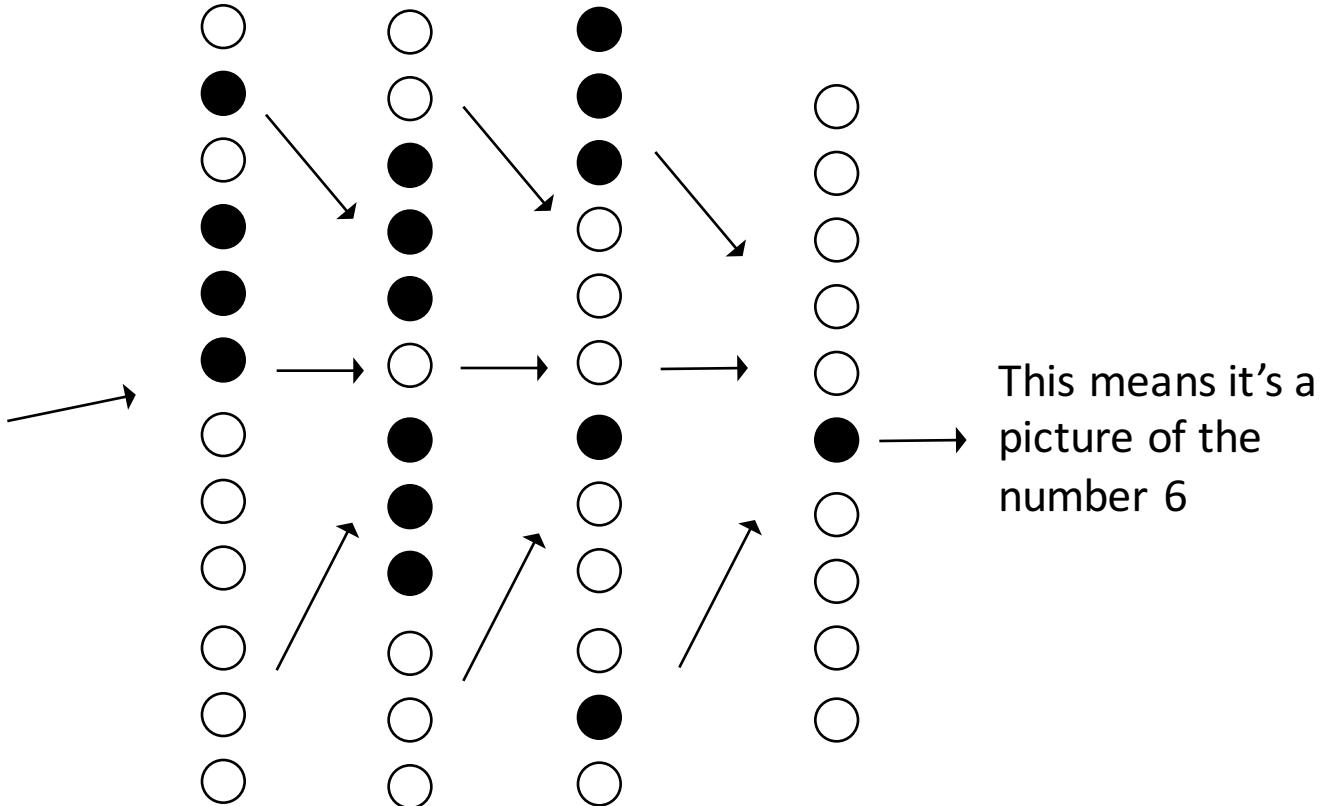
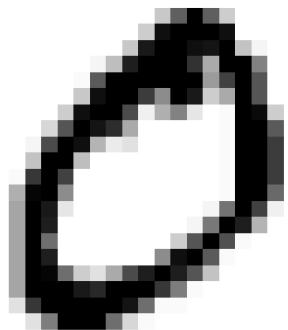
# Make It Useful



# When We Are Wrong...



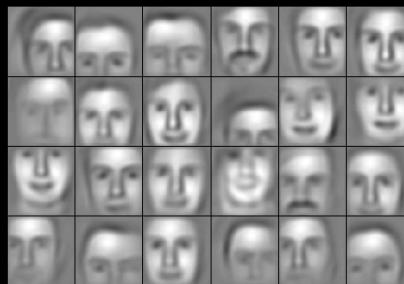
# Adjust Weights



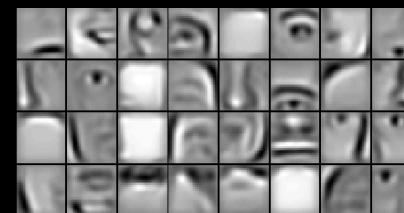
# Visualize the Weights



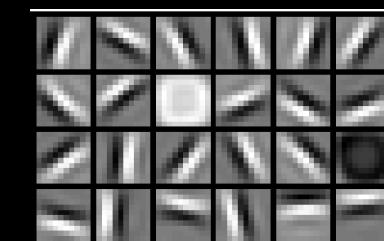
Training set: Aligned images of faces.



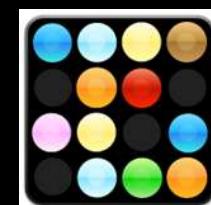
object models



object parts  
(combination  
of edges)

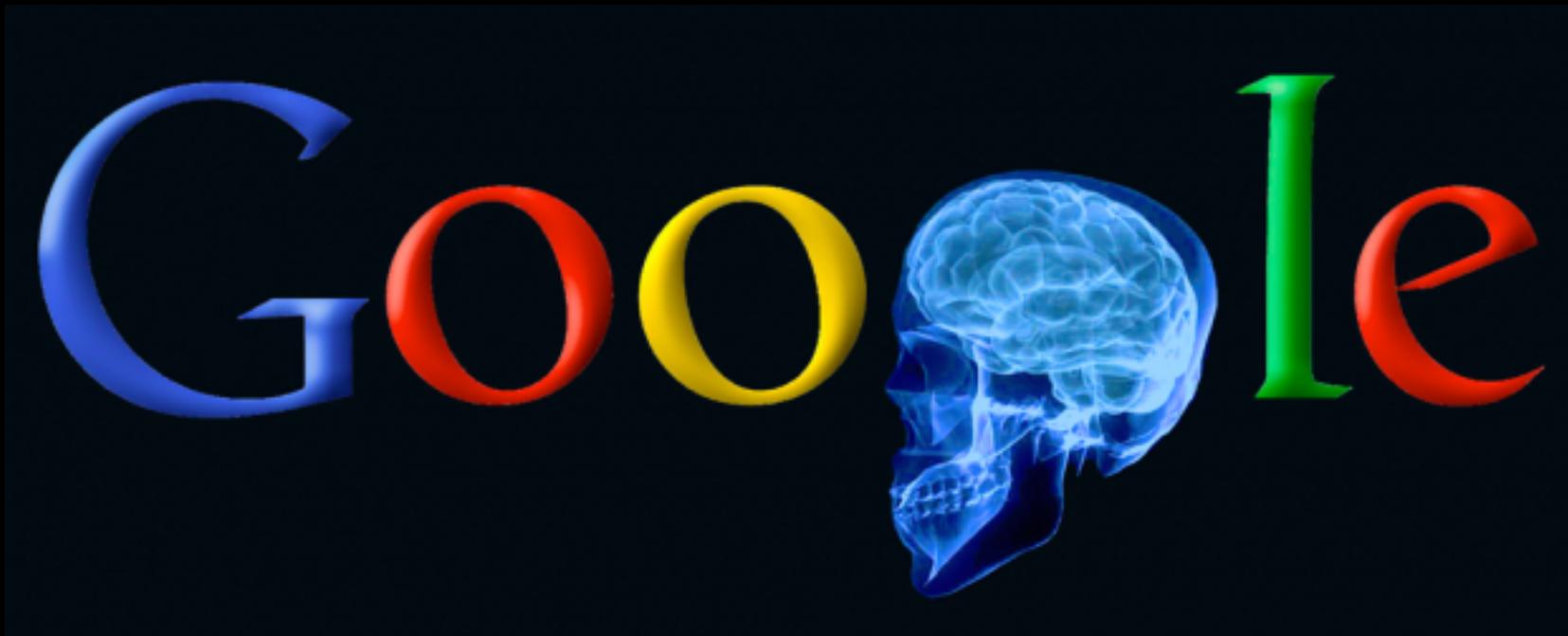


edges

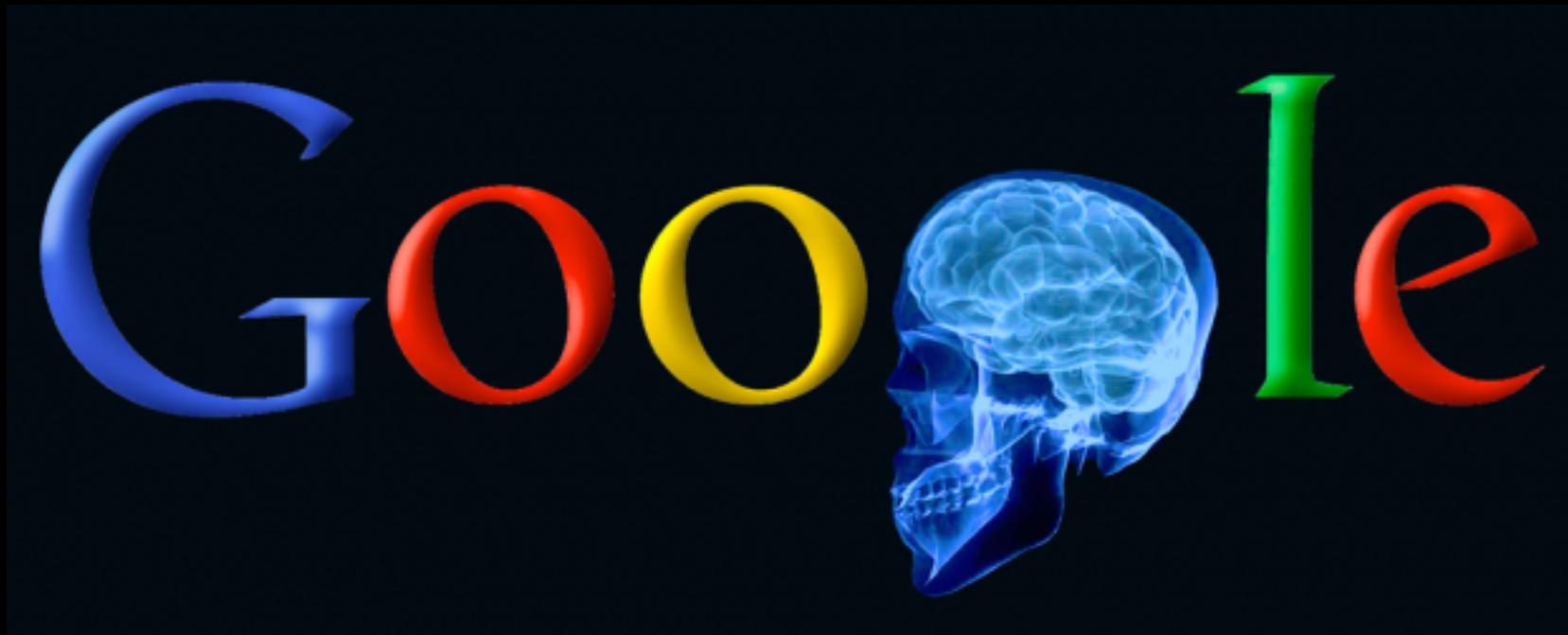


pixels

# Google Brain



# Google Brain



1 Trillion Artificial Neurons

# Watched YouTube



# A Neuron That Fires When It Sees Cats



Top stimuli from the test set



Optimal stimulus  
by numerical optimization



**We're essentially**

**a cat detection company**

# Other Neurons

Neuron 1



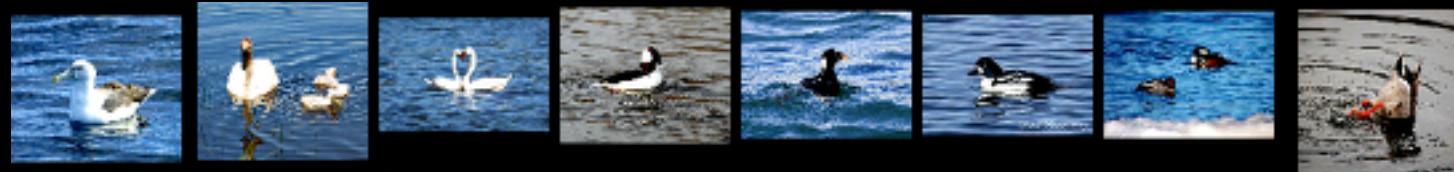
Neuron 2



Neuron 3



Neuron 4



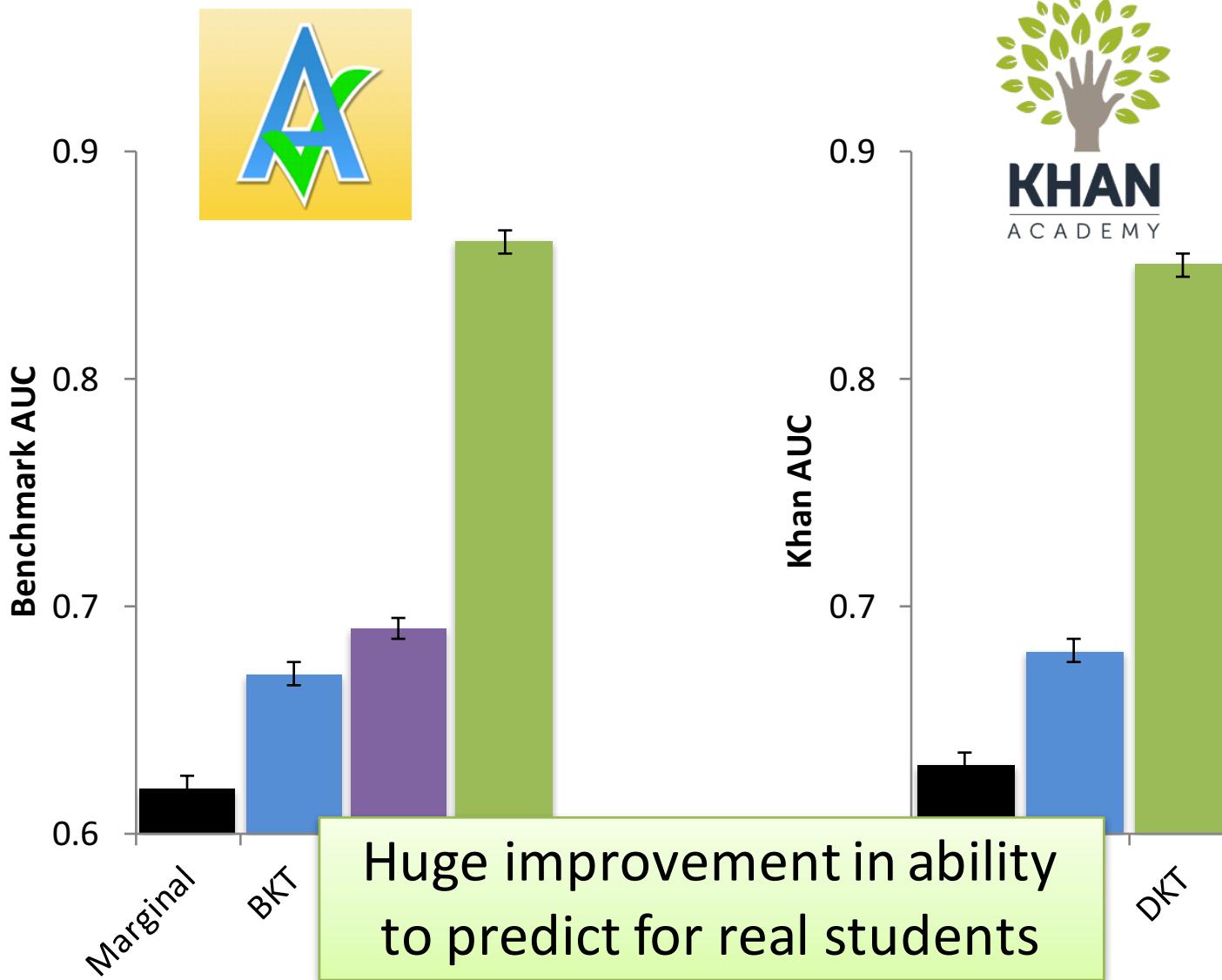
Neuron 5



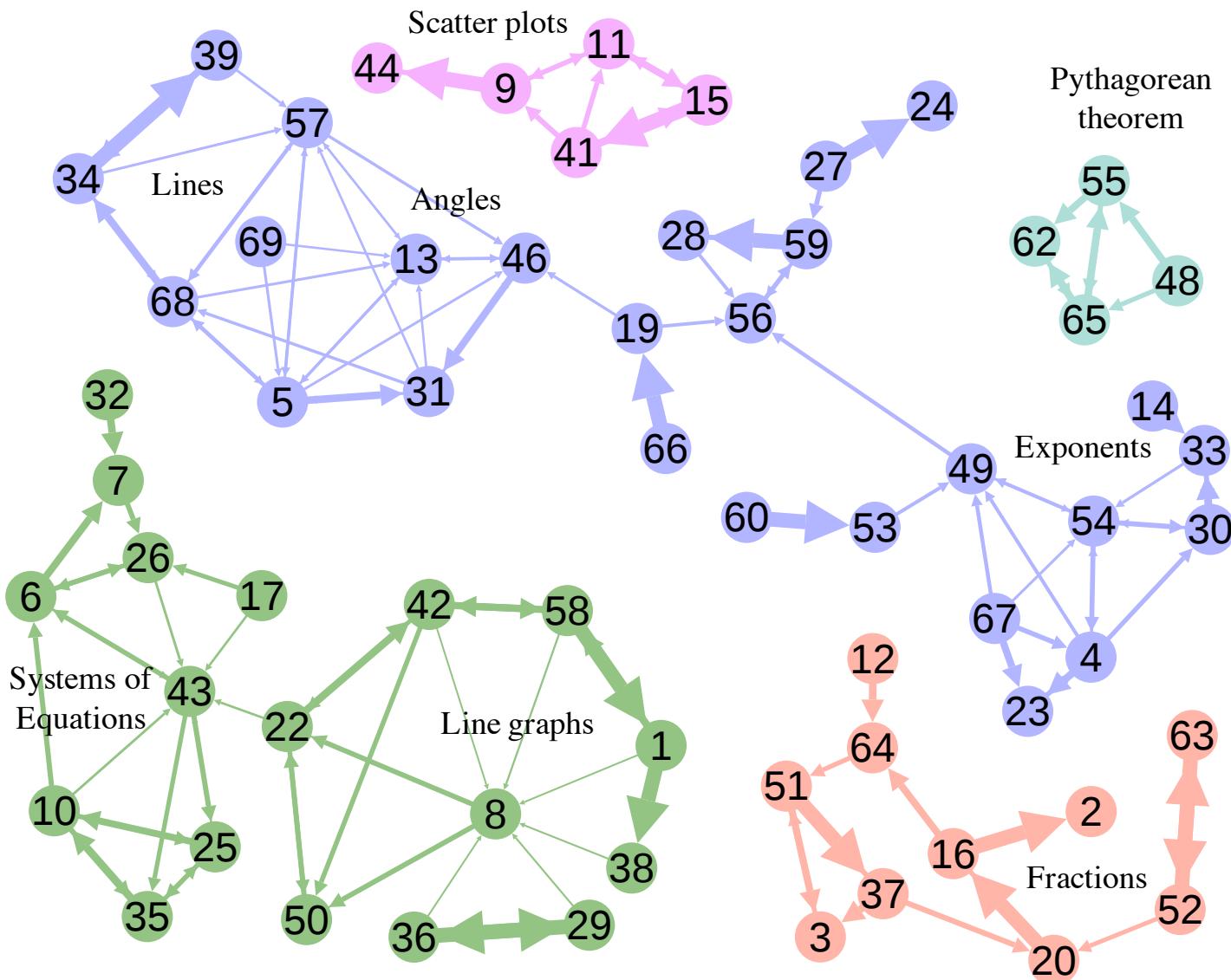
# Autonomous Tutor



# Prediction Results



# Autonomous Tutor



Not once, but twice, AI was revolutionized by people who understood probability theory.

End of Story

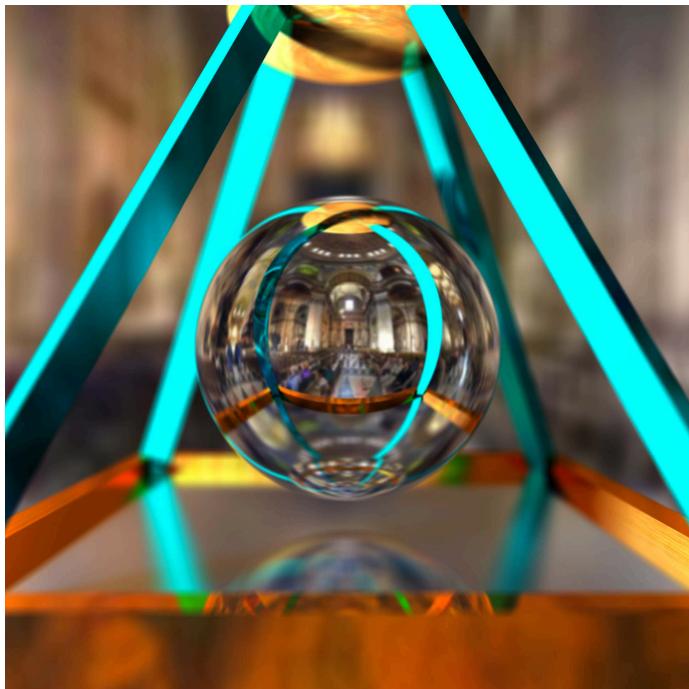
Probability is more than just machine learning

# Abundance of Important Problems

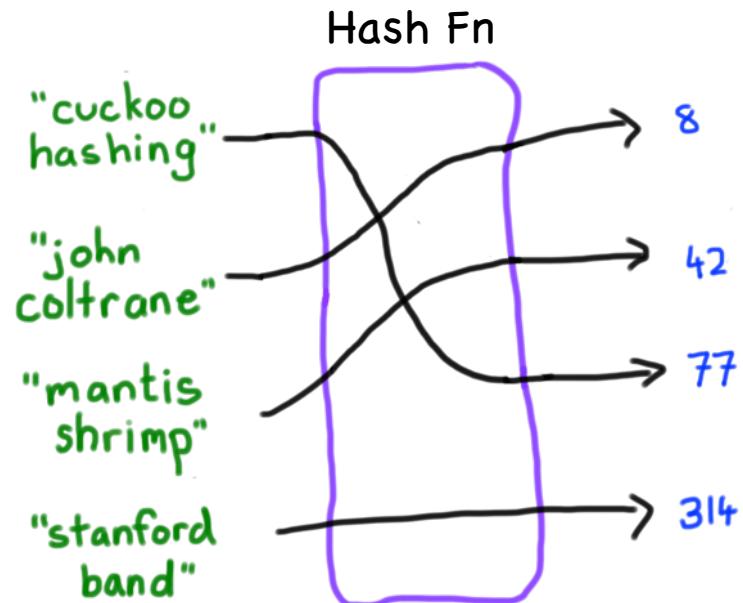


# Algorithms and Probability

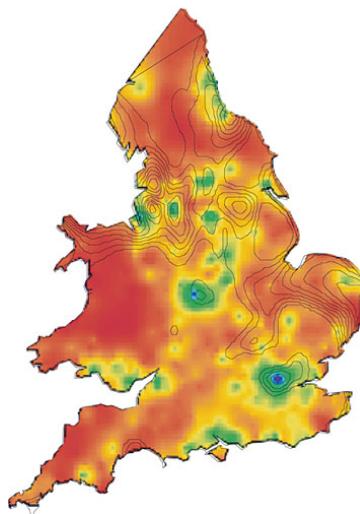
Eg Raytracing



Eg HashMaps



# Medicine and Probability



# Autocomplete



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# Probability in Practice

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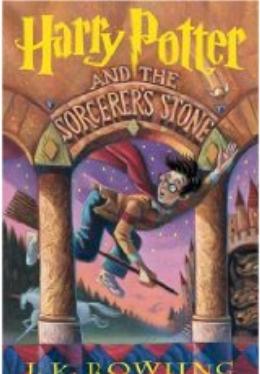
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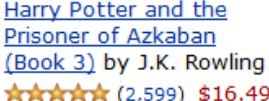
  
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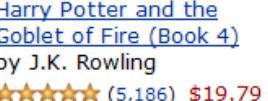
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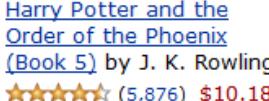
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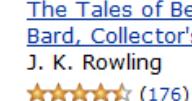
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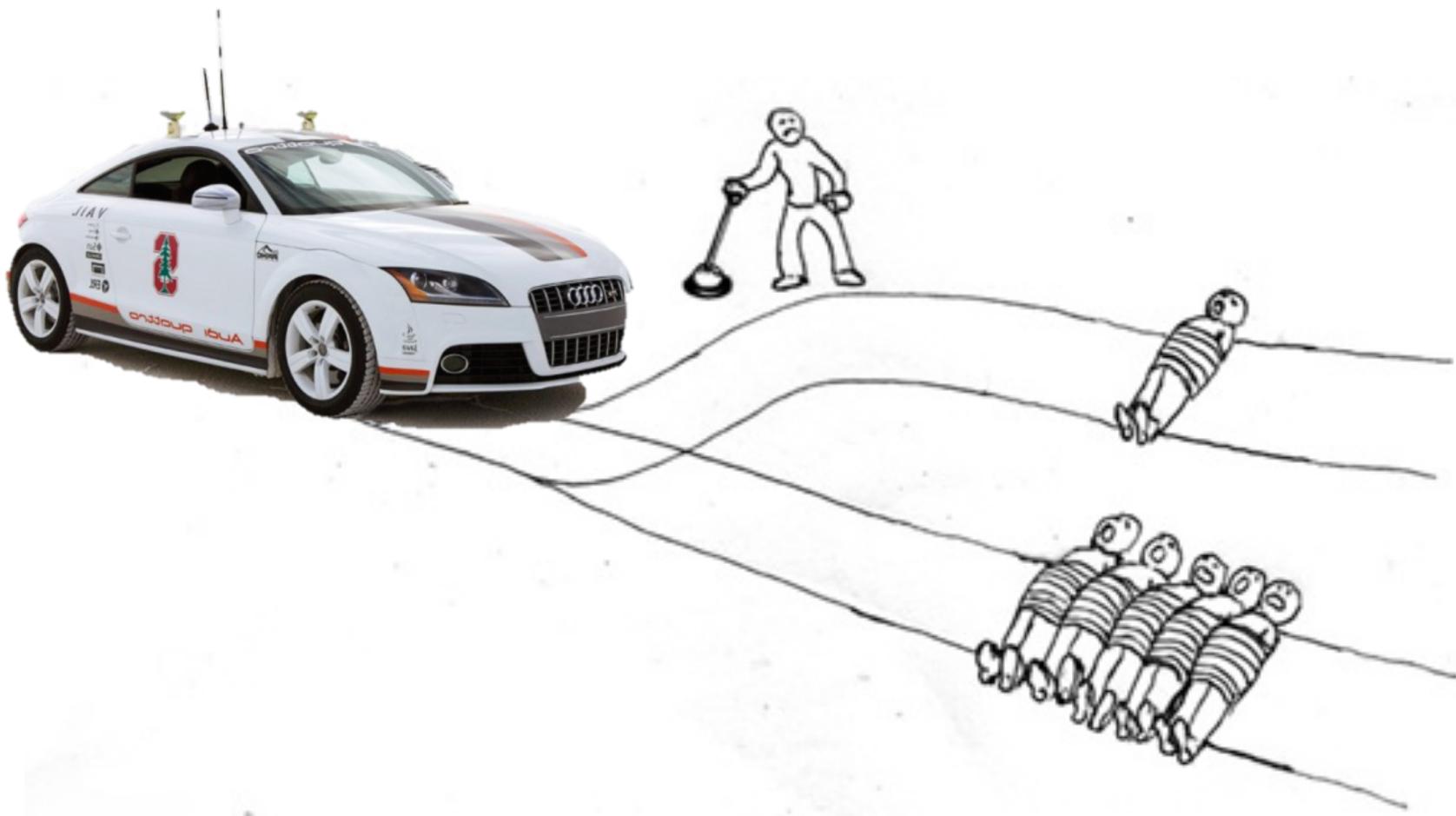
  
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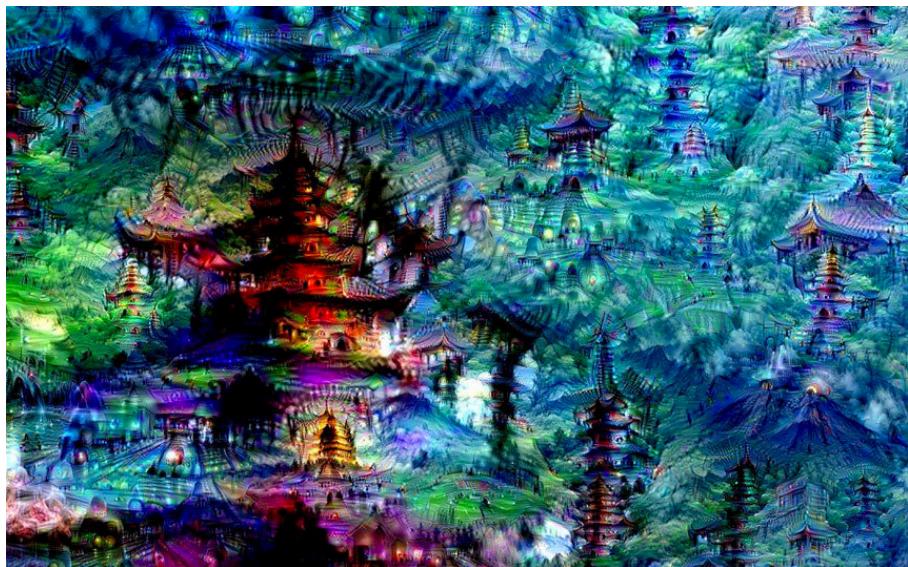
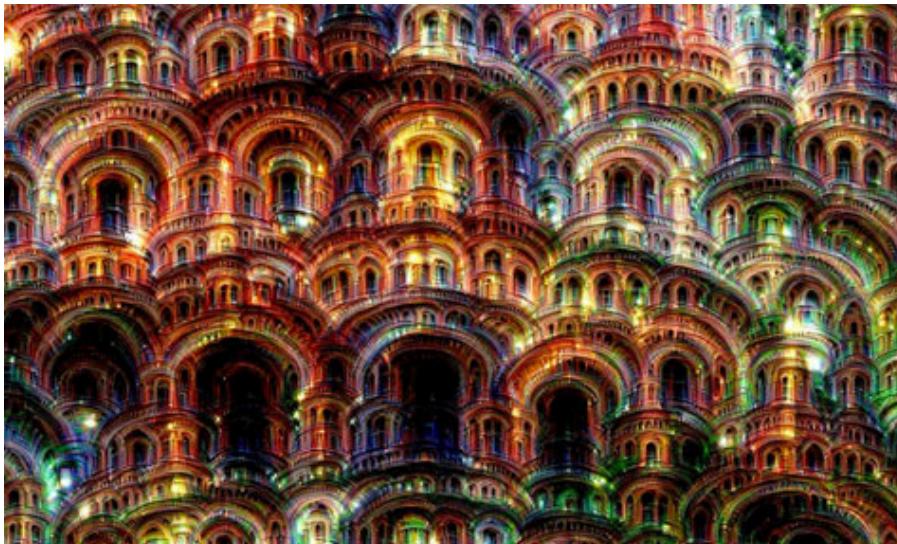
  
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# Philosophy and Probability



# Art and Probability



# #1 Most Desired Skill in Industry

*Microsoft's competitive advantage, [Bill Gates] responded, was its expertise in "Bayesian [probabilistic] networks."*

(from Los Angeles Times, Oct. 28, 1996)

*"The sexy job in the next 10 years will be statisticians."*

-Hal Varian, Chief Economist at Google  
(from New York Times, August 6, 2009)

# #1 Most Desired Skill in Industry

*“I believe over the next decade computing will become even more ubiquitous and intelligence will become ambient. The coevolution of software and new hardware form factors will intermediate and digitize — many of the things we do and experience in business, life and our world. This will be made possible by an ever-growing network of connected devices, incredible computing capacity from the cloud, insights from big data, and intelligence from machine learning.”*

-- Satya Nadella (CEO, Microsoft)

Email to all employees on first day as CEO (Feb. 04, 2014)

# #1 Most Desired Skill in Academia

Most CS PhD students list their highest desiderata upon graduation as:

“Better understanding of probability”

# Foundation for future classes

But its not always intuitive

# Mammogram Test



Positive Mammogram.

*What is the probability of cancer?*

- 
- *0.08% of women have breast cancer*
  - *90% positive rate for women with breast cancer*
  - *7% positive rate for women without breast cancer*

The right answer is 9%

Probability = Important + Needs Study

# What is CS109?

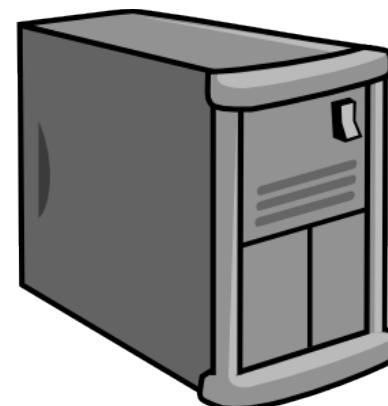
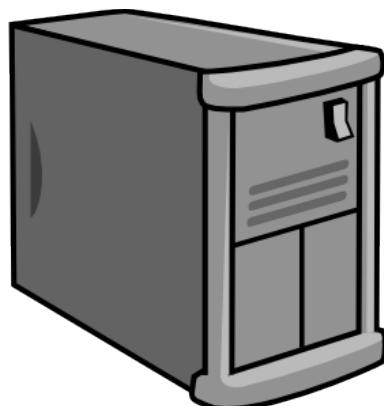
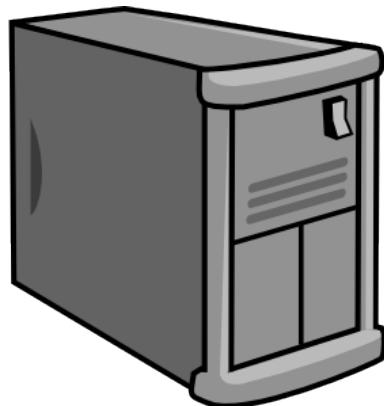
# Traditional View of Probability



# CS View of Probability

<http://www.site.com>

Give you the tools necessary to build and understand probabilistic CS algorithms.



# Pedagogy

Give you the tools necessary to build and understand probabilistic CS algorithms.

Clarity of concepts



# Spring vs Winter?



*Chris took first  
CS109 class*

You are going to learn these tools.

Lets dive in...

# Counting

