



**POLITECNICO**  
MILANO 1863

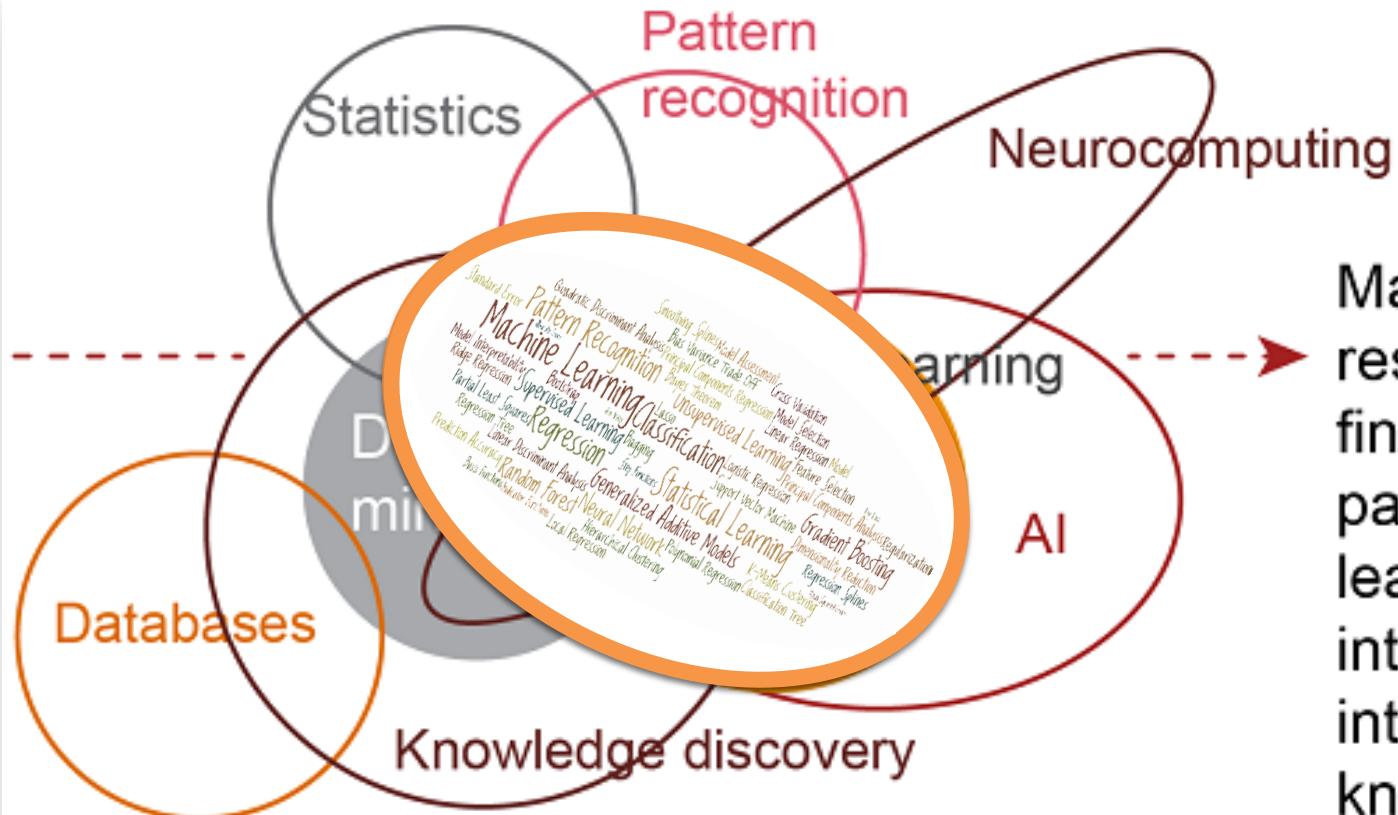
# Artificial Neural Networks and Deep Learning

- Machine Learning vs Deep Learning-

Matteo Matteucci, PhD ([matteo.matteucci@polimi.it](mailto:matteo.matteucci@polimi.it))

*Artificial Intelligence and Robotics Laboratory  
Politecnico di Milano*

# Machine Learning



Machine learning is a category of research and algorithms focused on finding patterns in data and using those patterns to make predictions. Machine learning falls within the artificial intelligence (AI) umbrella, which in turn intersects with the broader field of knowledge discovery and data mining.

Source: SAS, 2014 and PwC, 2016 *and Matteucci, 2017*

# Machine Learning



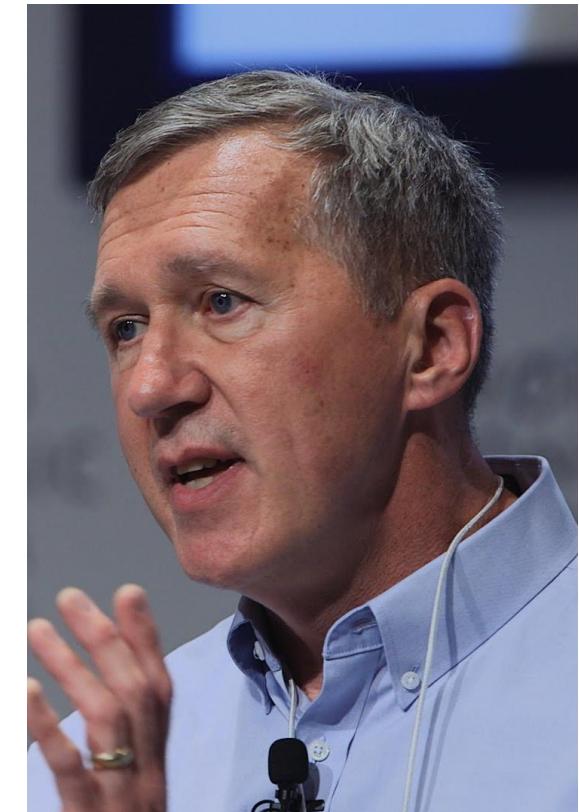
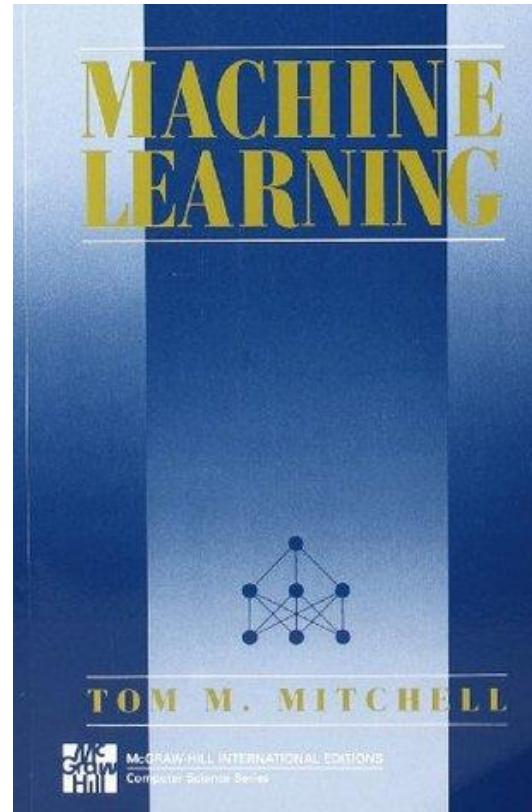
# Machine Learning (Tom Mitchell – 1997)

$T$  = Regression/Classification/...

$E$  = Data

$P$  = Errors/Loss

"A computer program is said to learn from experience  $E$  with respect to some class of task  $T$  and a performance measure  $P$ , if its performance at tasks in  $T$ , as measured by  $P$ , improves because of experience  $E$ ."



# Machine Learning Paradigms

Imagine you have a certain experience  $D$ , i.e., data, and let's name it

$$D = x_1, x_2, x_3, \dots, x_N$$

- **Supervised learning**: given the desired outputs  $t_1, t_2, t_3, \dots, t_N$  learn to produce the correct output given a new set of input
- **Unsupervised learning**: exploit regularities in  $D$  to build a representation to be used for reasoning or prediction
- **Reinforcement learning**: producing actions  $a_1, a_2, a_3, \dots, a_N$  which affect the environment, and receiving rewards  $r_1, r_2, r_3, \dots, r_N$  learn to act in order to maximize rewards in the long term



# Supervised learning: Classification



Cars



Motorcy...

*Learning is about  
modeling ...*



Hand-crafted  
Features

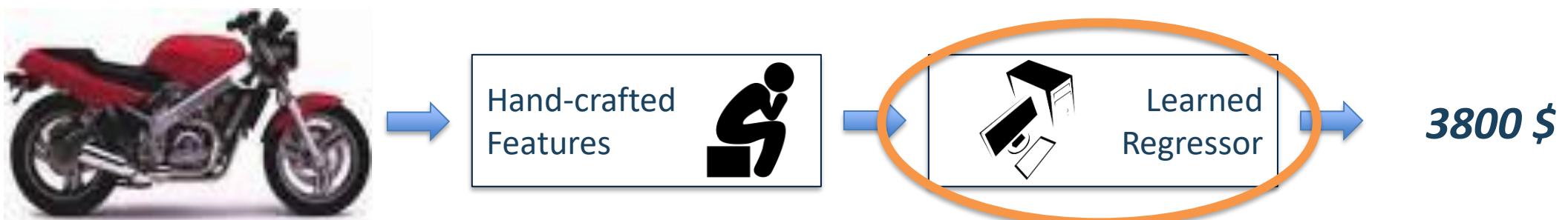


Learned  
Classifier



**Motorcycle**

# Supervised learning: Regression



# Machine Learning Paradigms

Imagine you have a certain experience E, i.e., data, and let's name it

$$D = x_1, x_2, x_3, \dots, x_N$$

- Supervised learning: given the desired outputs  $t_1, t_2, t_3, \dots, t_N$  learn to produce the correct output given a new set of input
- Unsupervised learning: exploit regularities in  $D$  to build a representation to be used for reasoning or prediction
- Reinforcement learning: producing actions  $a_1, a_2, a_3, \dots, a_N$  which affect the environment, and receiving rewards  $r_1, r_2, r_3, \dots, r_N$  learn to act in order to maximize rewards in the long term



# Unsupervised learning: Clustering



# Unsupervised learning: Clustering



# Unsupervised learning: Clustering



# Unsupervised learning: Clustering



# Unsupervised learning: Clustering



# Unsupervised learning: Clustering



# Unsupervised learning: Clustering



# Machine Learning Paradigms

Imagine you have a certain experience E, i.e., data, and let's name it

$$D = x_1, x_2, x_3, \dots, x_N$$

- **Supervised learning**: given the desired outputs  $t_1, t_2, t_3, \dots, t_N$  learn to produce the correct output given a new set of input
- **Unsupervised learning**: exploit regularities in  $D$  to build a representation to be used for reasoning or prediction
- **Reinforcement learning**: producing actions to the environment, and receiving rewards  $r_1, r_2, \dots$  to maximize rewards in the long term

*This course focuses most on Supervised Learning (with some unsupervised spots)*



# What about Deep Learning?



YAHOO!

Google



Baidu 百度



darkAI

nervana

UMIND

SMALLESE

ersatz

isists

cocca

se taint

Numenta

OpenAI

MetaMind

DEEPMIND

AlchemyAPI™

An IBM Company

wit.ai DNNresearch

Acquired



MIT Technology Review

## 10 BREAKTHROUGH TECHNOLOGIES 2013

|  |  |   |   |   |
|--|--|---|---|---|
| <b>DeepLearning</b><br>With massive amounts of computational power, machines can now recognize objects and translate speech in real time. Artificial intelligence is finally getting smart.                              | <b>Temporary Social Media</b><br>Messages that quickly self-destruct could enhance the privacy of online communications and make people freer to be spontaneous. | <b>Prenatal DNA Sequencing</b><br>Reading the DNA of fetuses will be the next frontier of the genomic revolution. But do you really want to know about the genetic problems or musical aptitude of your unborn child? | <b>Additive Manufacturing</b><br>Skeptical about 3-D printing? GE, the world's largest manufacturer, is on the verge of using the technology to make jet parts.   | <b>Baxter: The Blue-Collar Robot</b><br>Rodney Brooks's newest creation is easy to interact with, but the complex innovations behind the robot show just how hard it is to get along with people. |
| <b>Memory Implants</b><br>A maverick neuroscientist believes he has deciphered the code by which the brain forms long-term memories. Next: testing a prosthetic implant for people suffering from long-term memory loss. | <b>Smart Watches</b><br>The designers of the Pebble watch realized that a mobile phone is more useful if you don't have to take it out of your pocket.           | <b>Ultra-Efficient Solar Power</b><br>Doubling the efficiency of a solar cell would completely change the economics of renewable energy. Nanotechnology just might make it possible.                                  | <b>Big Data from Cheap Phones</b><br>Collecting and analyzing information from simple cell phones can provide surprising insights into how people move about and behave – and even help us understand the spread of diseases. | <b>Supergrids</b><br>A new high-power circuit breaker could finally make highly efficient DC power grids practical.   |



# What is Deep Learning after all?

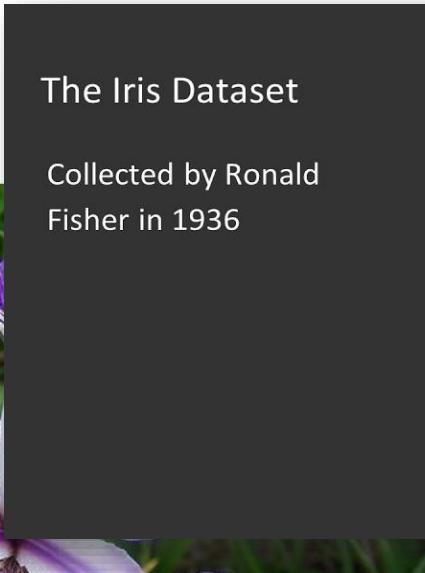
... let's say it with flowers!



*Iris Setosa*

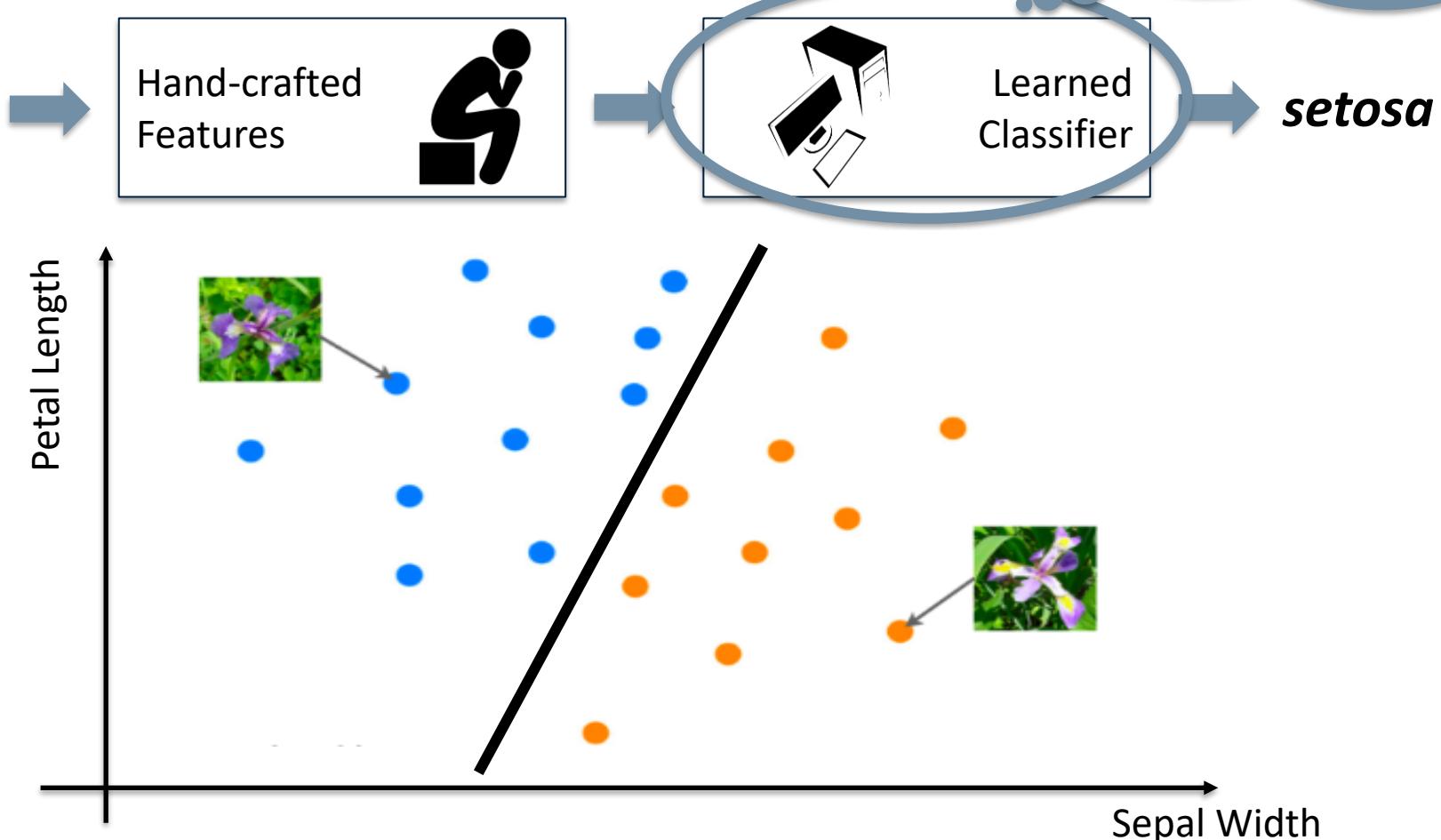
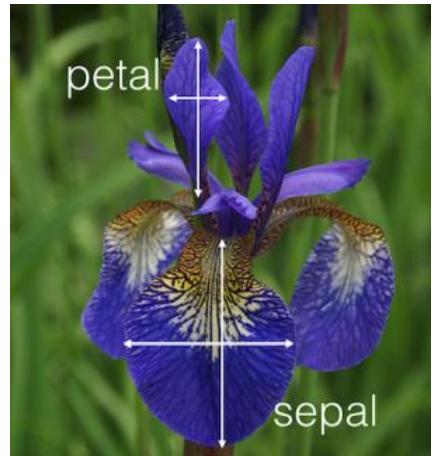


*Iris Virginica*



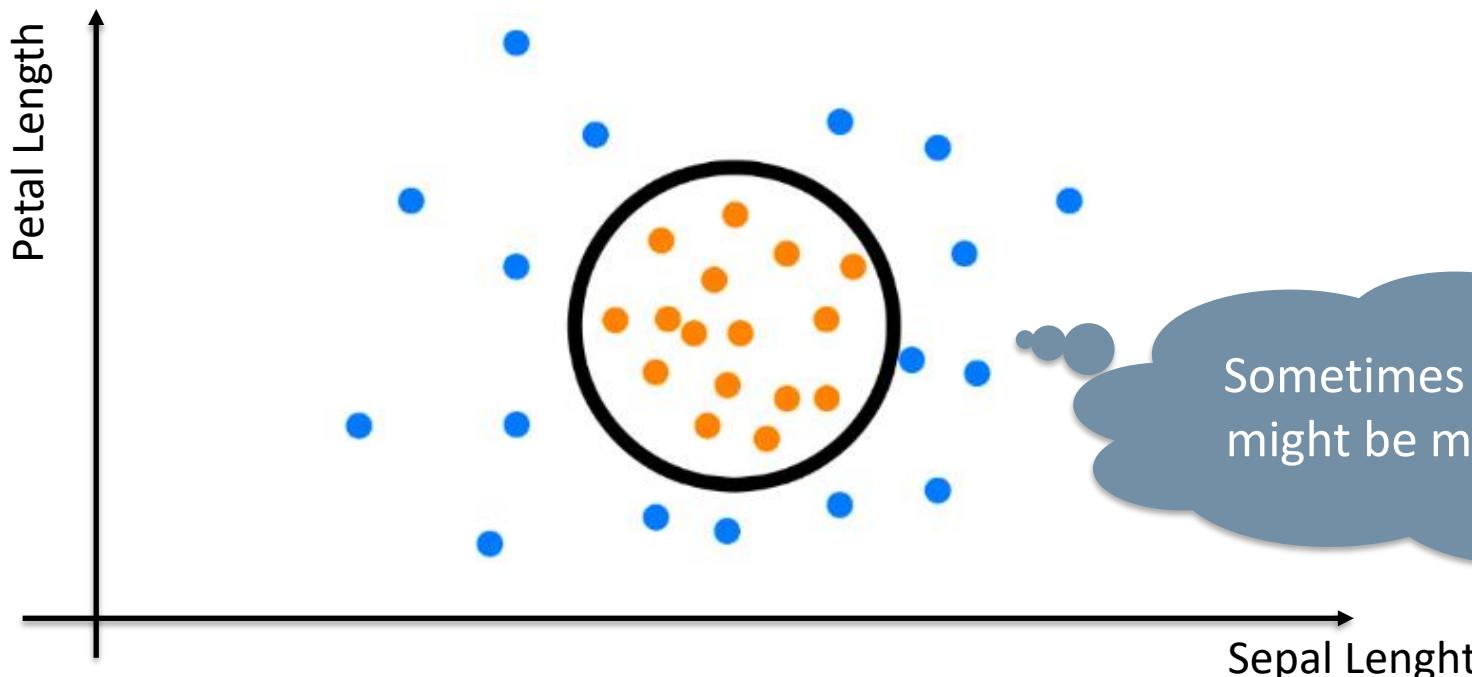
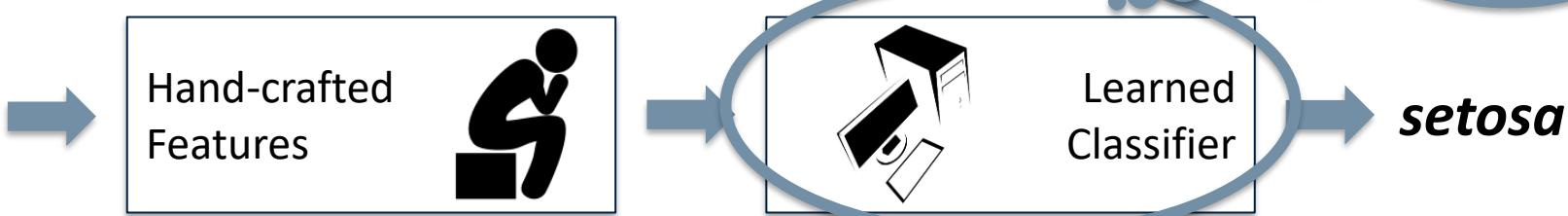
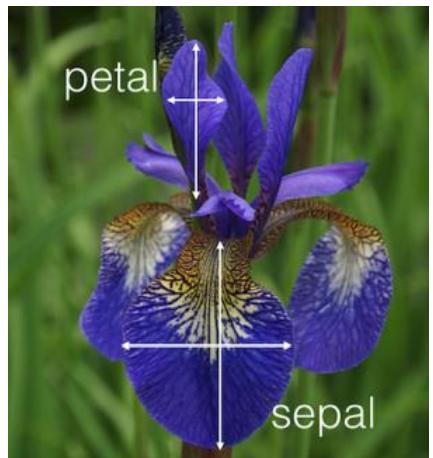
*Iris Versicolor*

# What is Deep Learning after all?



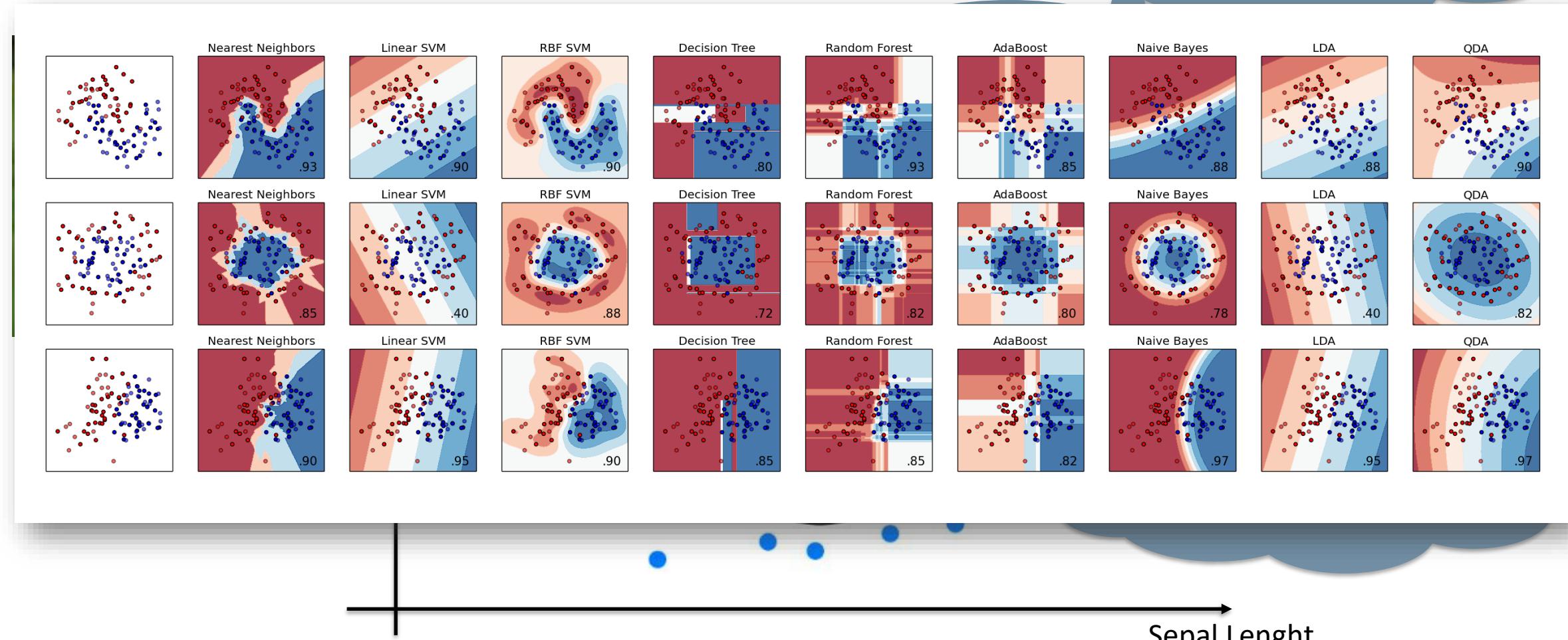
*Machine learns how to  
take the Iris apart*

# What is Deep Learning after all?

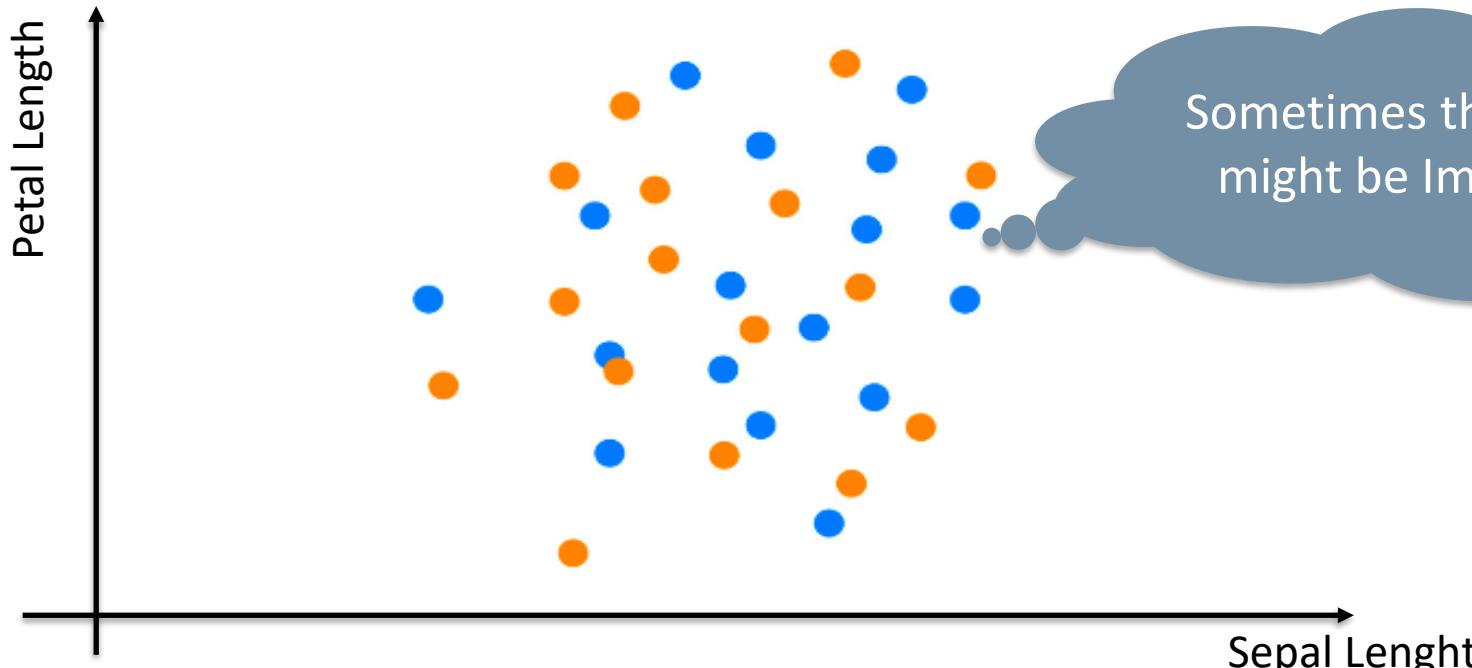
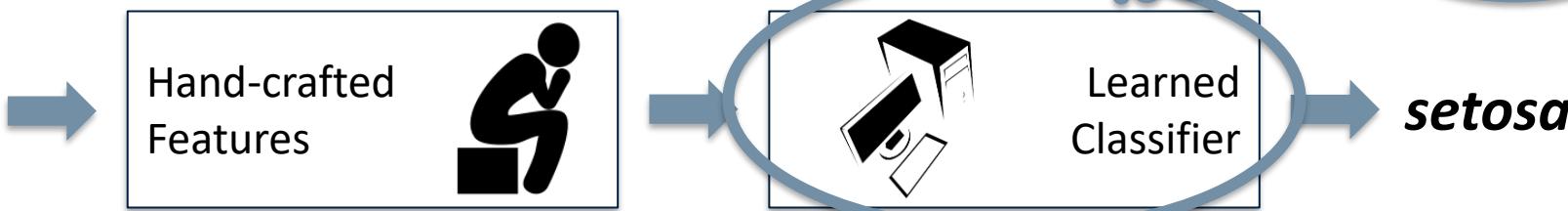
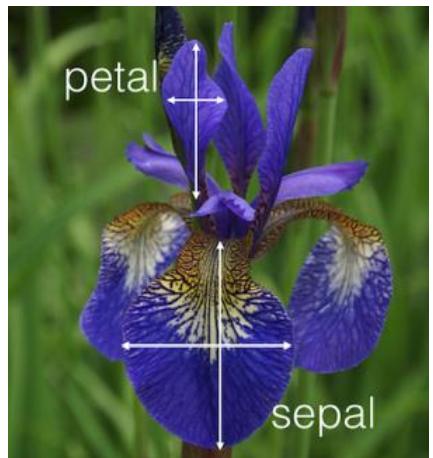


# What is Deep Learning after all?

*Machine learns how to  
take the Iris apart*



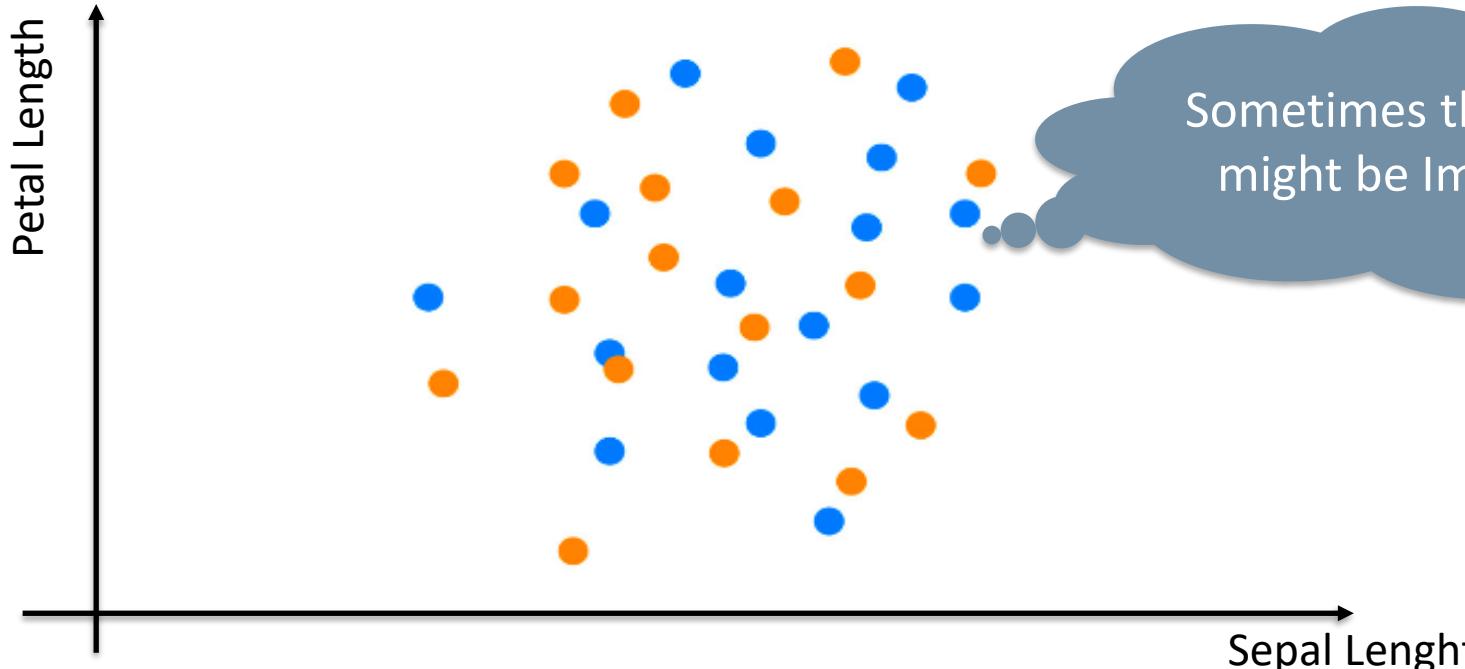
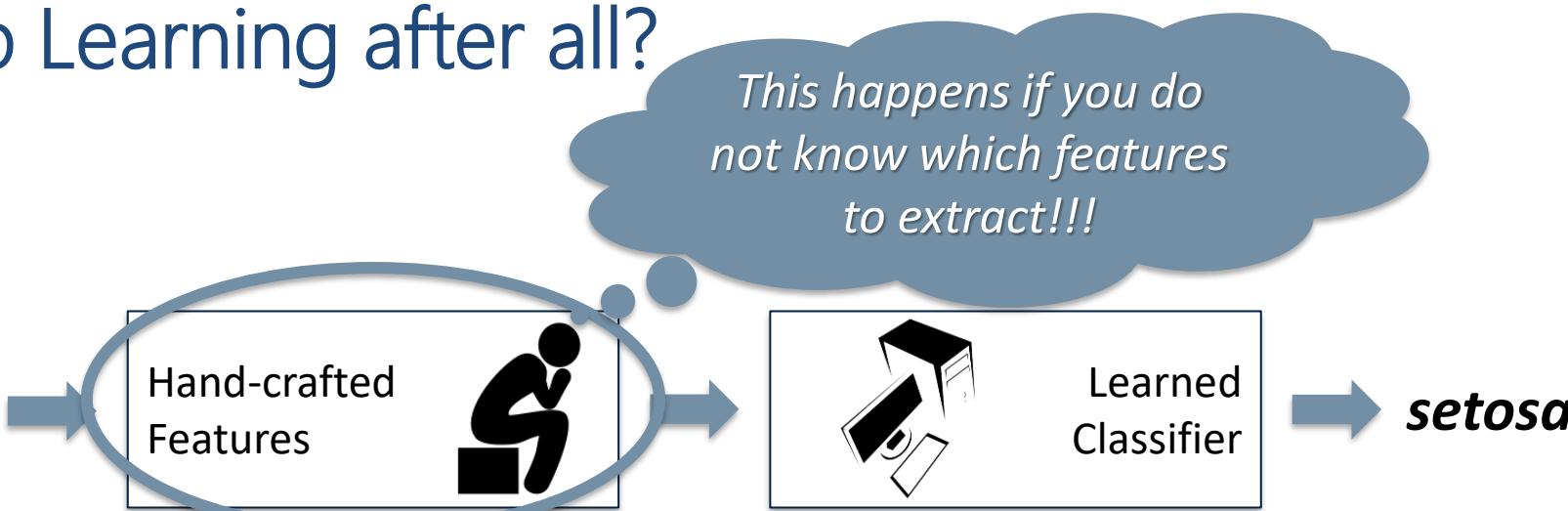
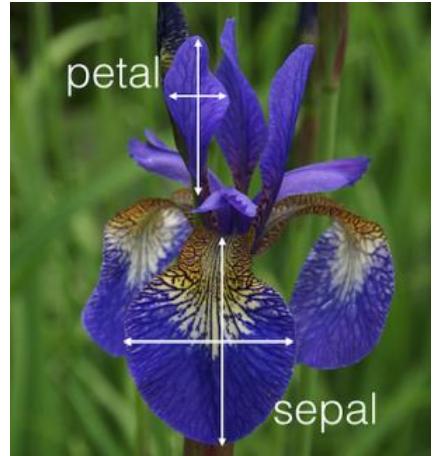
# What is Deep Learning after all?



*Machine learns how to take the Iris apart*

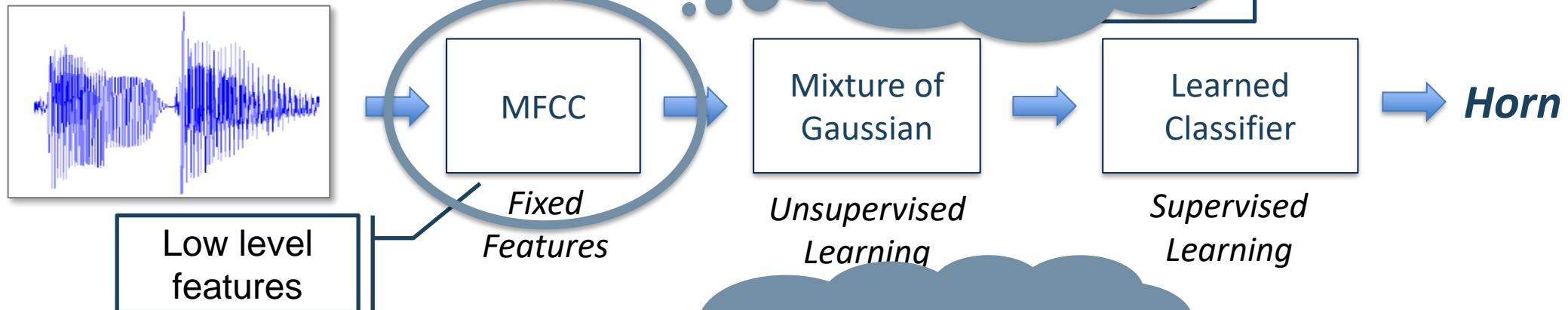
*Sometimes the decision might be Impossible!*

# What is Deep Learning after all?

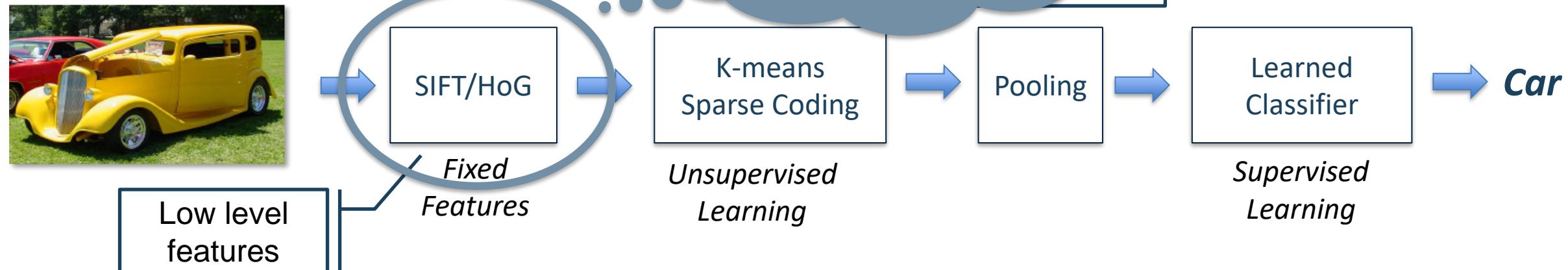


# Modern Pattern Recogniton

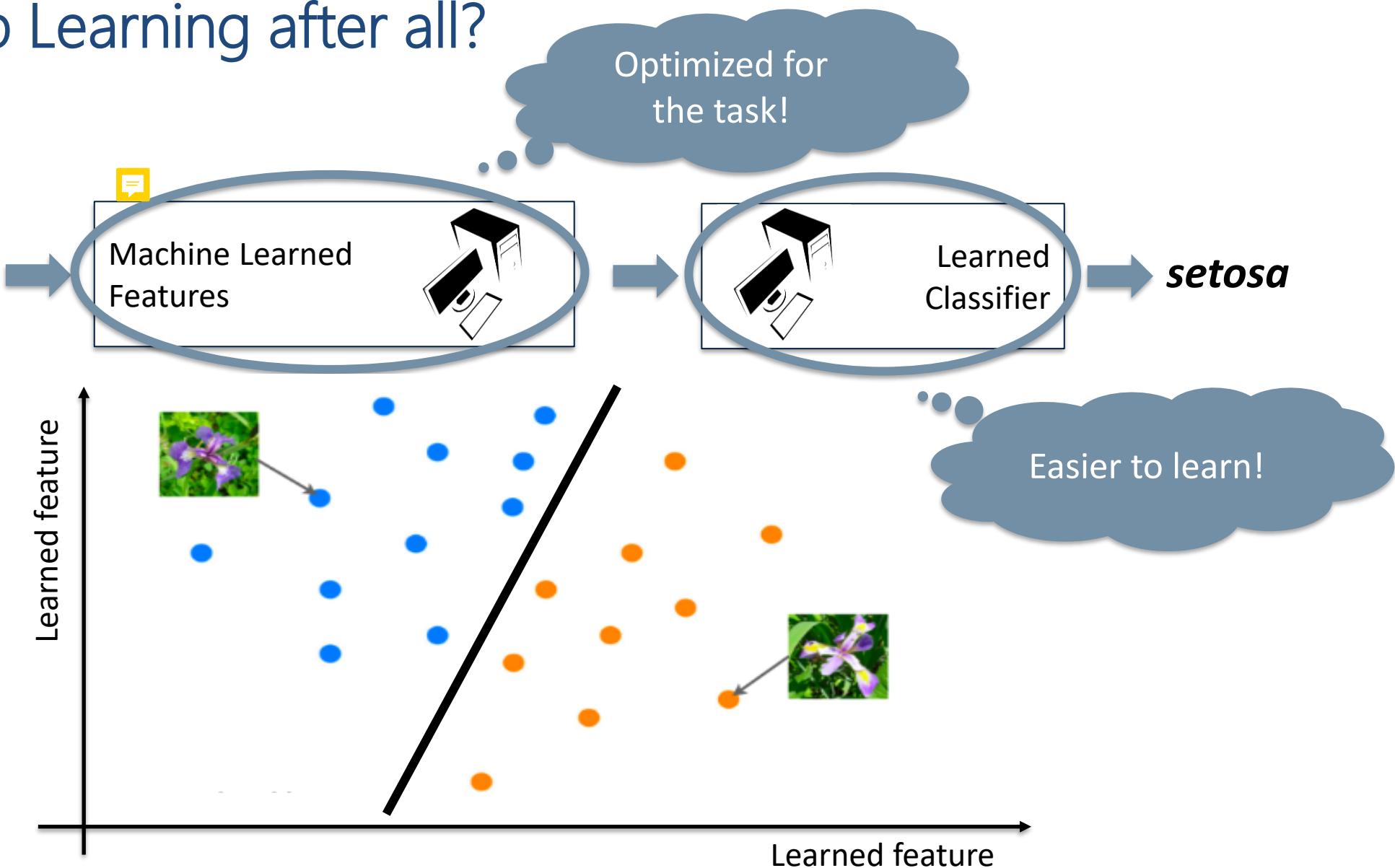
Speech recognition (early 90's – 2012)



Object recognition (2006 – 2012)

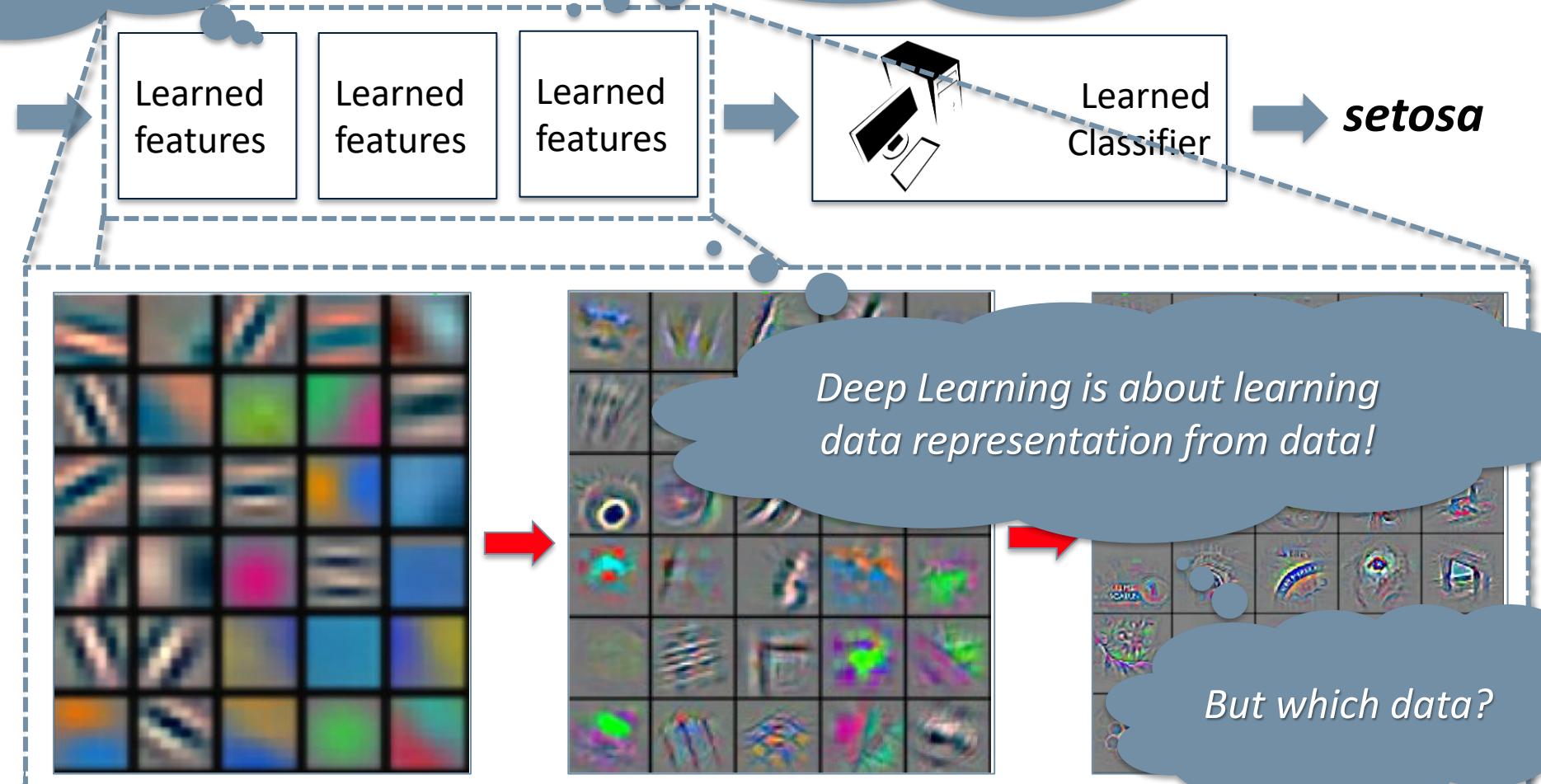


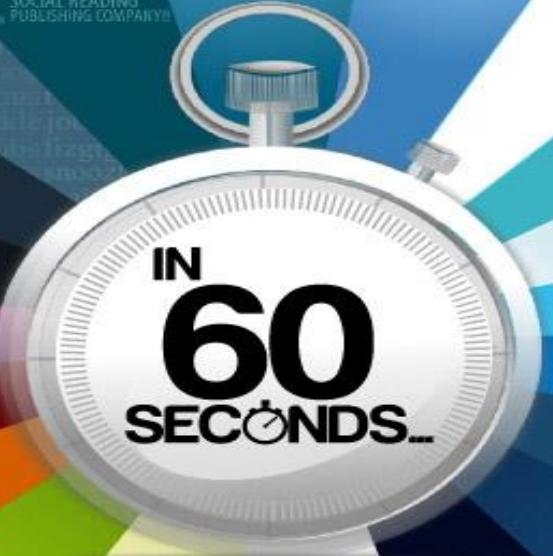
# What is Deep Learning after all?



# What is Deep Learning after all?

*Learn from data!*





# IN 60 SECONDS...

1  
**NEW**  
DEFINITION  
IS ADDED ON  
URBAN  
DICTIONARY

1,600+  
READS ON  
**Scribd.**

13,000+ HOURS  
**MUSIC**  
STREAMING ON  
PANDORA

12,000+  
**NEW ADS**  
POSTED ON  
craigslist

370,000+ MINUTES  
VOICE CALLS ON  
**skype**

98,000+  
**TWEETS**



320+  
**NEW**  
twitter  
ACCOUNTS



100+  
**NEW**  
Linked in  
ACCOUNTS



THE  
WORLD'S  
LARGEST  
COMMUNITY  
CREATED CONTENT!!

1  
associatedcontent  
**NEW**  
ARTICLE IS  
PUBLISHED



6,600+  
**NEW**  
PICTURES ARE  
UPLOADED ON  
flickr



50+  
**WORDPRESS**  
DOWNLOADS



=125+  
**PLUGIN**  
DOWNLOADS



QUESTIONS  
ASKED ON THE  
INTERNET...

100+  
Answers.com  
40+  
YAHOO! ANSWERS



600+  
**NEW**  
VIDEOS

25+ HOURS  
**TOTAL**  
DURATION

70+  
**DOMAINS**  
REGISTERED

60+  
**NEW**  
BLOGS

168 MILLION  
**EMAILS**  
ARE SENT

694,445  
**SEARCH**  
QUERIES

1,700+  
**Firefox**  
DOWNLOADS

695,000+  
**facebook**  
STATUS  
UPDATES

79,364  
**WALL**  
POSTS

510,040  
**COMMENTS**



1,500+  
**BLOG**  
POSTS



Google

Google Search



# What's behind Deep Learning?



YAHOO!

Google



Baidu 百度



darkAI

nervana

UMIND

SMALLESE

isys

codica

Every Image



MIT Technology Review

## 10 BREAKTHROUGH TECHNOLOGIES 2013

Introduction The 10 Technologies Past Years

DeepLearning

With massive amounts of computational power, machines can now recognize objects and translate speech in real time. Artificial intelligence is finally getting smart.

Memory Implants

A maverick neuroscientist believes he has deciphered the code by which the brain forms long-term memories. Next: testing a prosthetic implant for people suffering from long-term memory loss.

Smart Watches

The designers of the Pebble watch realized that a mobile phone is more useful if you don't have to take it out of your pocket.

Ultra-Efficient Solar Power

Doubling the efficiency of a solar cell would completely change the economics of renewable energy. Nanotechnology just might make it possible.

Big Data from Cheap Phones

Collecting and analyzing information from simple cell phones can provide surprising insights into how people move about and behave – and even help us understand the spread of diseases.

Baxter: The Blue-Collar Robot

Rodney Brooks's newest creation is easy to interact with, but the complex innovations behind the robot show just how hard it is to get along with people.

*According to MIT, it was all about massive computational power*



# What's behind Deep Learning?



MIT Technology Review

## 10 BREAKTHROUGH TECHNOLOGIES 2013

Introduction   The 10 Technologies   Past Years

**Deep Learning**

With massive amounts of computational power, machines can now recognize objects and translate speech in real time. Artificial intelligence is finally getting smart.

**Memory Implants**

A maverick neuroscientist believes he has

**Smart Watches**

Messages that quickly self-destruct could enhance the privacy of online communications and make people freer to be spontaneous.

**Ultra-Efficient Solar Power**

Doubling the efficiency of a solar cell would completely change the economics of renewable energy. Nanotechnology just might make it possible.

**Big Data from Cheap Phones**

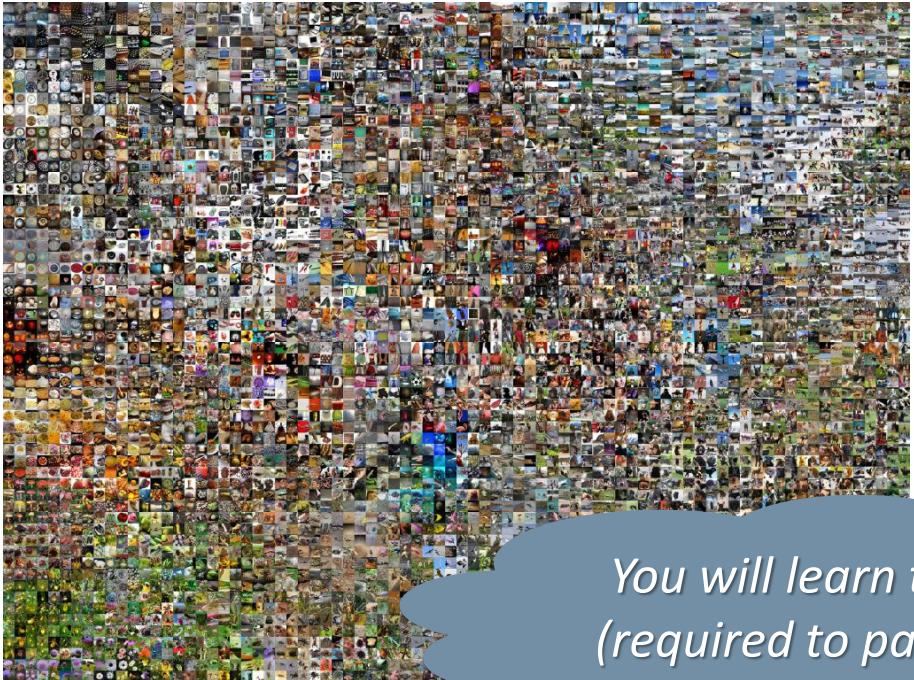
Collecting and analyzing information from simple cell phones can provide surprising insights into how people move about and behave – and even help us understand the spread of diseases.

**Baxter: The Blue-Collar Robot**

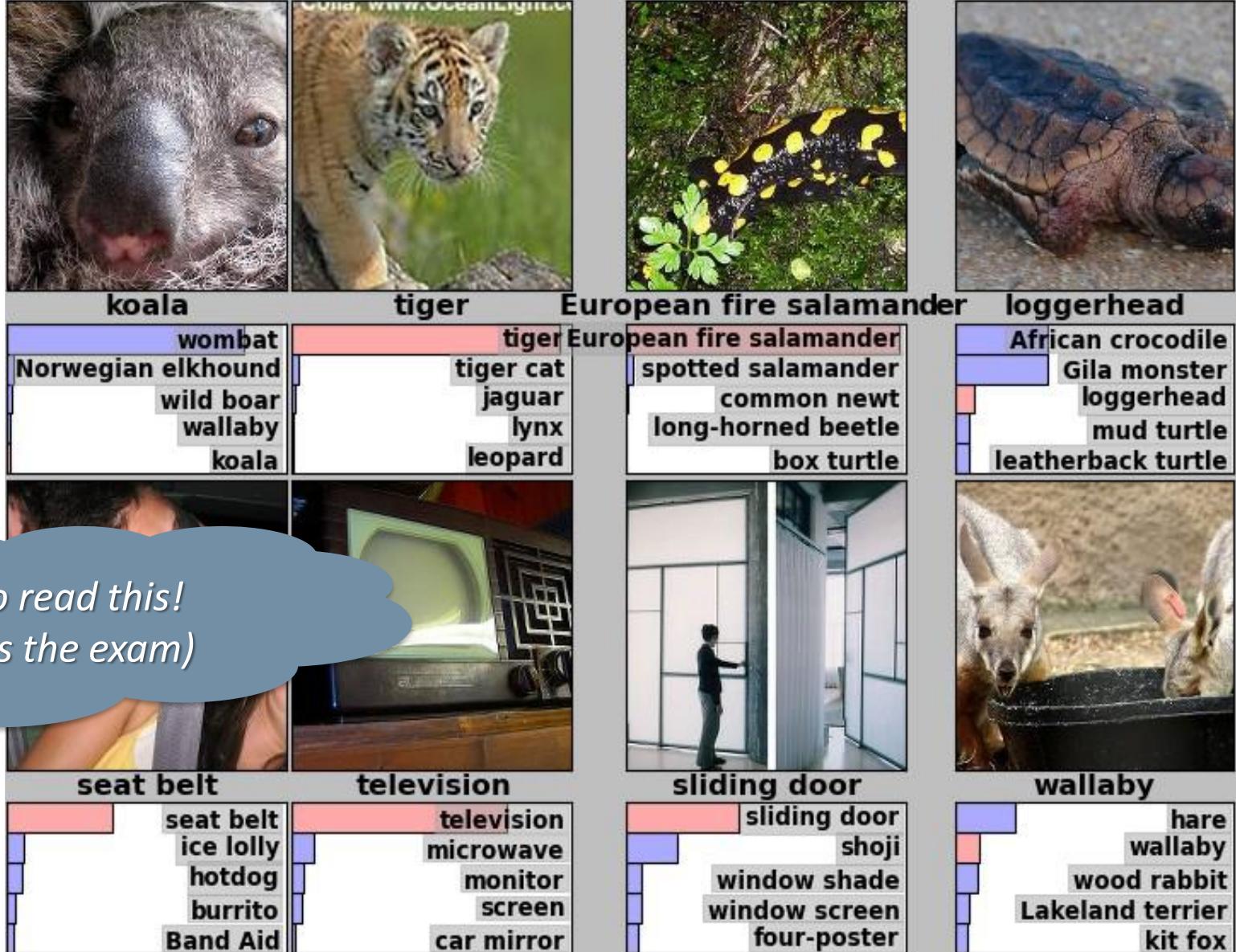
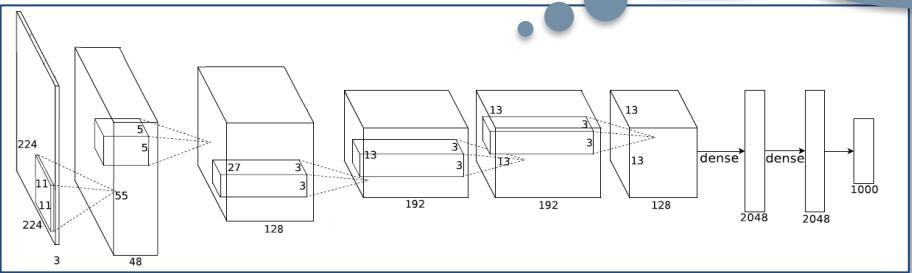
Rodney Brooks's newest creation is easy to interact with, but the complex innovations behind the robot show just how hard it is to get along with people.

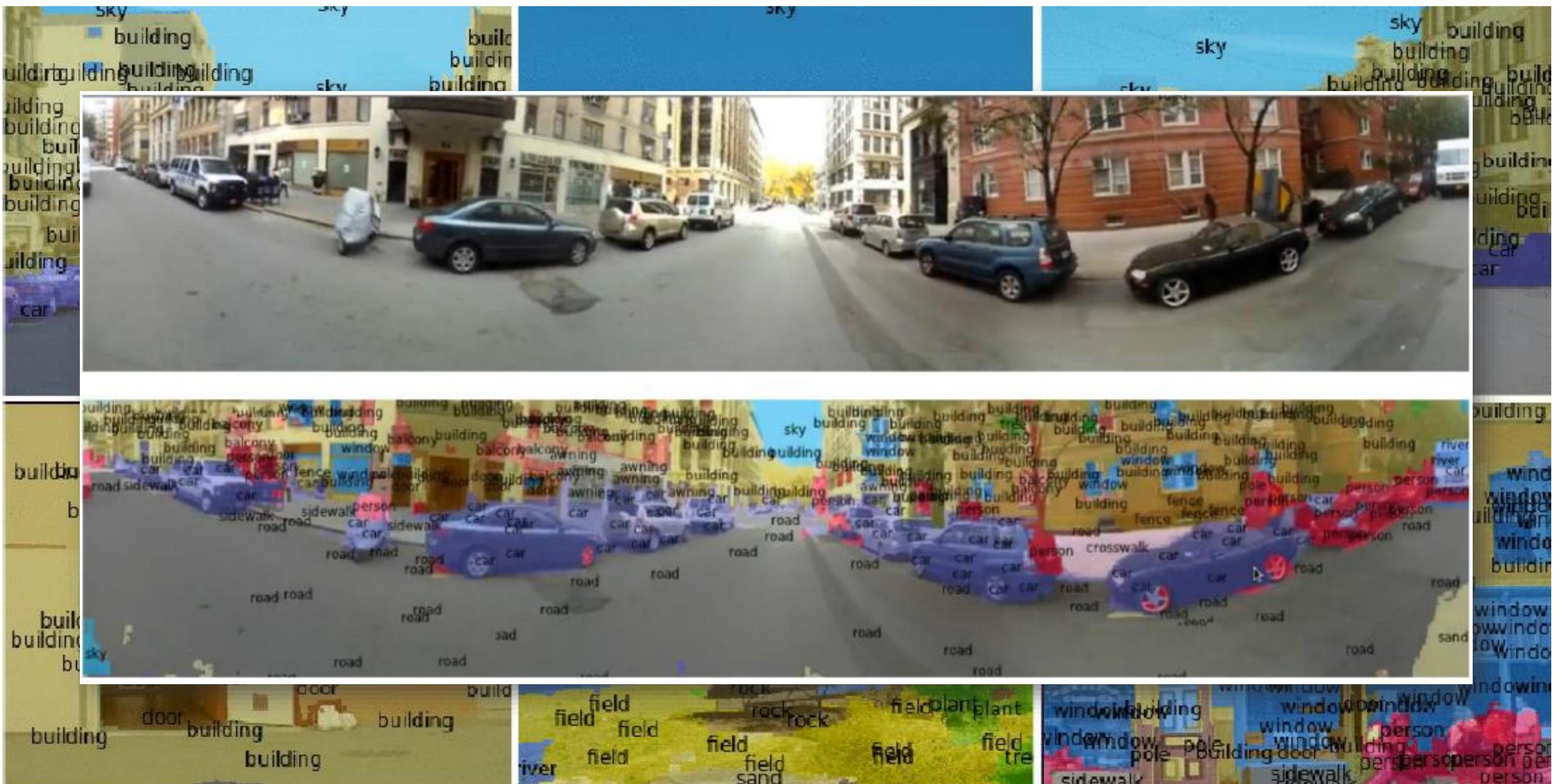
*According to MIT, it is all about massive computational power*

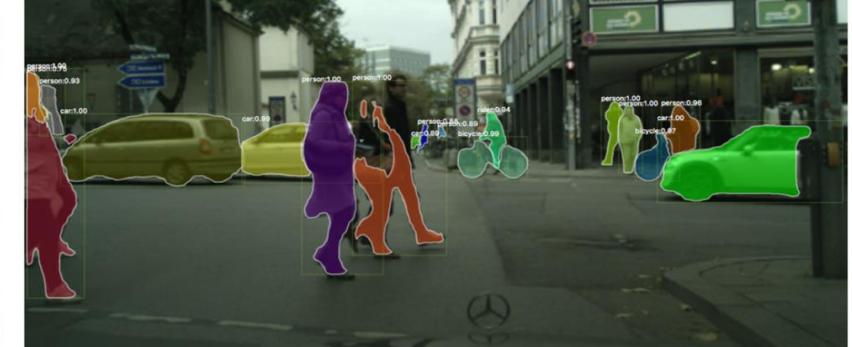
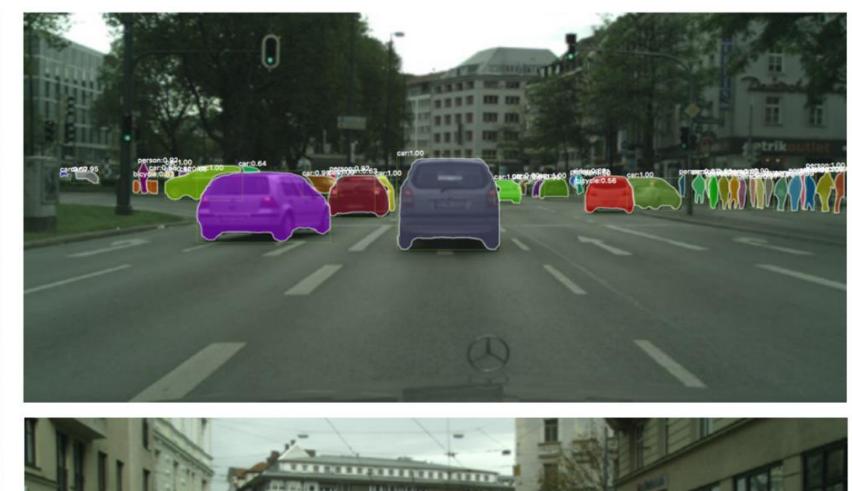
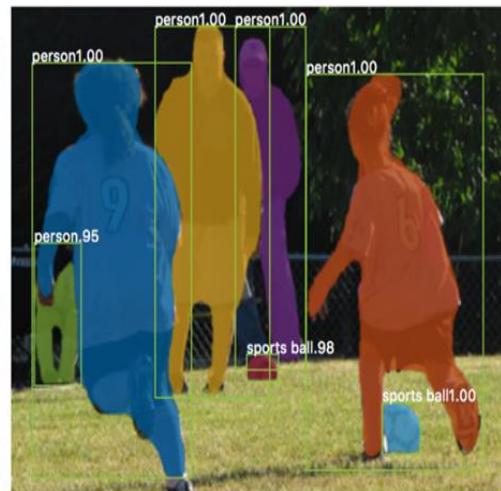
*The Economist got it right! It is all about (Big) Data*



*You will learn to read this!  
(required to pass the exam)*







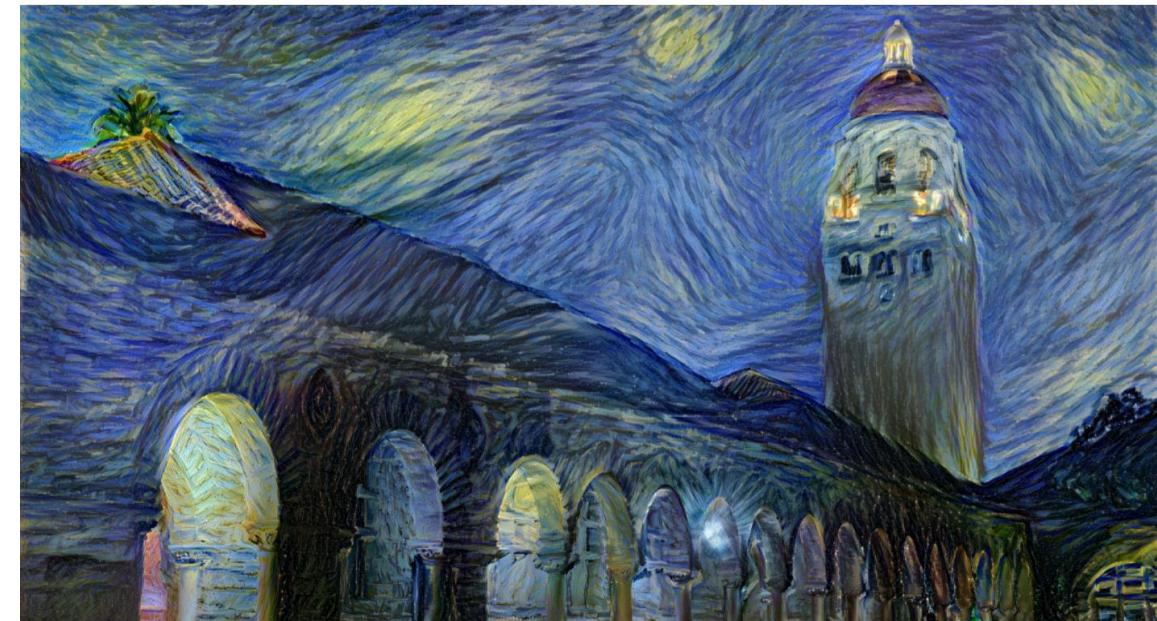


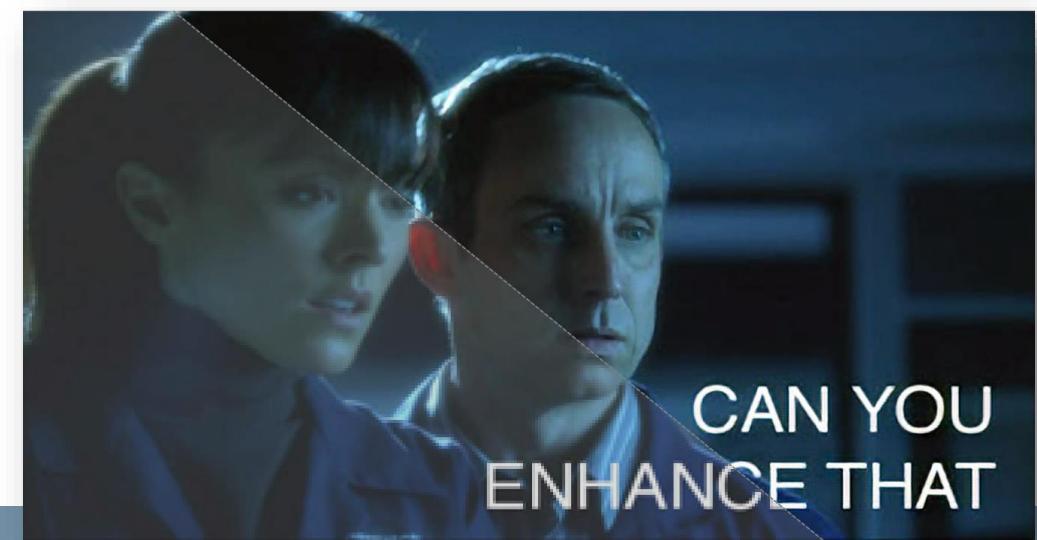
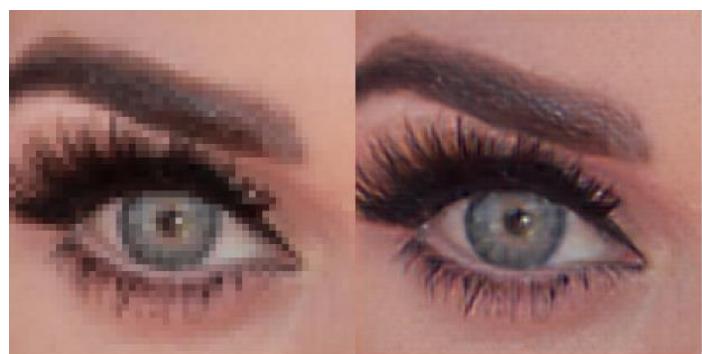
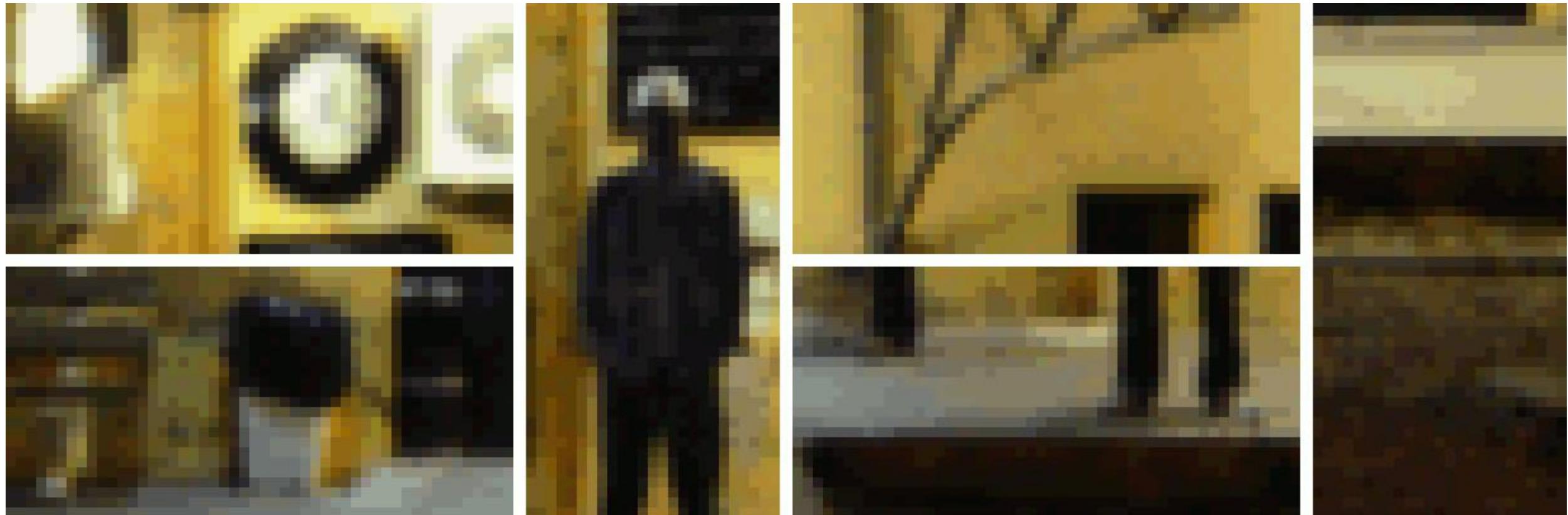
<https://github.com/luanfujun/deep-photo-styletransfer>

<https://github.com/jcjohnson/neural-style>

<https://github.com/jcjohnson/fast-neural-style>

[https://ml4a.github.io/ml4a/style transfer/](https://ml4a.github.io/ml4a/style_transfer/)





<https://github.com/alexjc/neural-enhance>



POLITECNICO MILANO 1863

Text  
description

This flower has petals that are white and has pink shading

This flower has a lot of small purple petals in a dome-like configuration

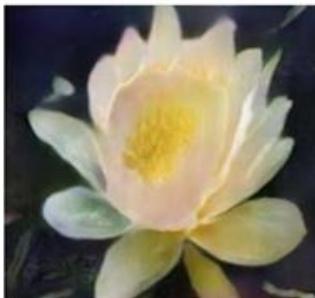
This flower has long thin yellow petals and a lot of yellow anthers in the center

This flower is pink, white, and yellow in color, and has petals that are striped

This flower is white and yellow in color, with petals that are wavy and smooth

This flower has upturned petals which are thin and orange with rounded edges

This flower has petals that are dark pink with white edges and pink stamen



256x256  
StackGAN

This bird is red and brown in color, with a stubby beak

The bird is short and stubby with yellow on its body

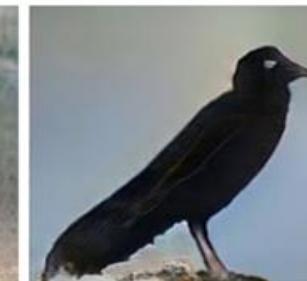
A bird with a medium orange bill white body gray wings and webbed feet

This small black bird has a short, slightly curved bill and long legs

A small bird with varying shades of brown with white under the eyes

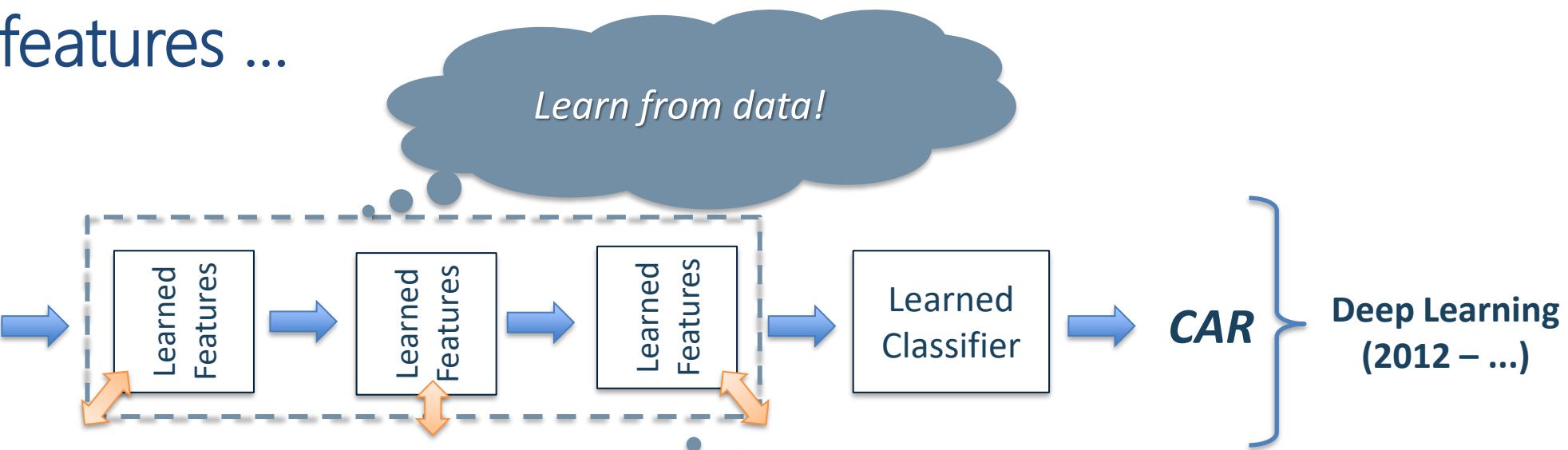
A small yellow bird with a black crown and a short black pointed beak

This small bird has a white breast, light grey head, and black wings and tail

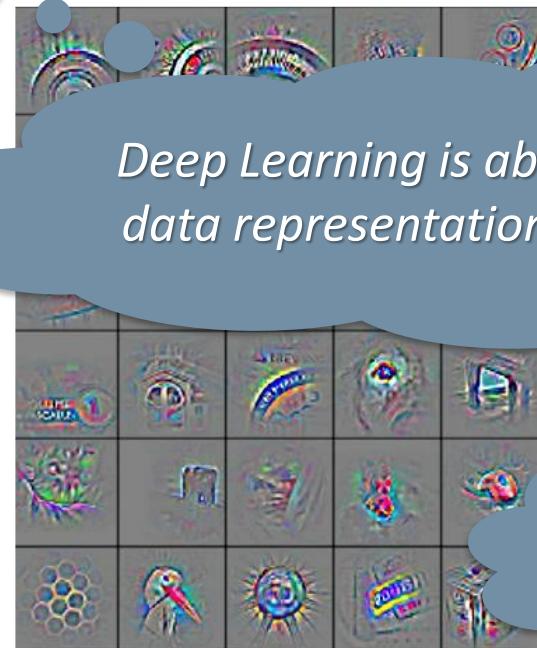


256x256  
StackGAN

# It's all about features ...



That's what you'll  
learn in this course!



*Deep Learning is about learning  
data representation from data!*

*But which data?*