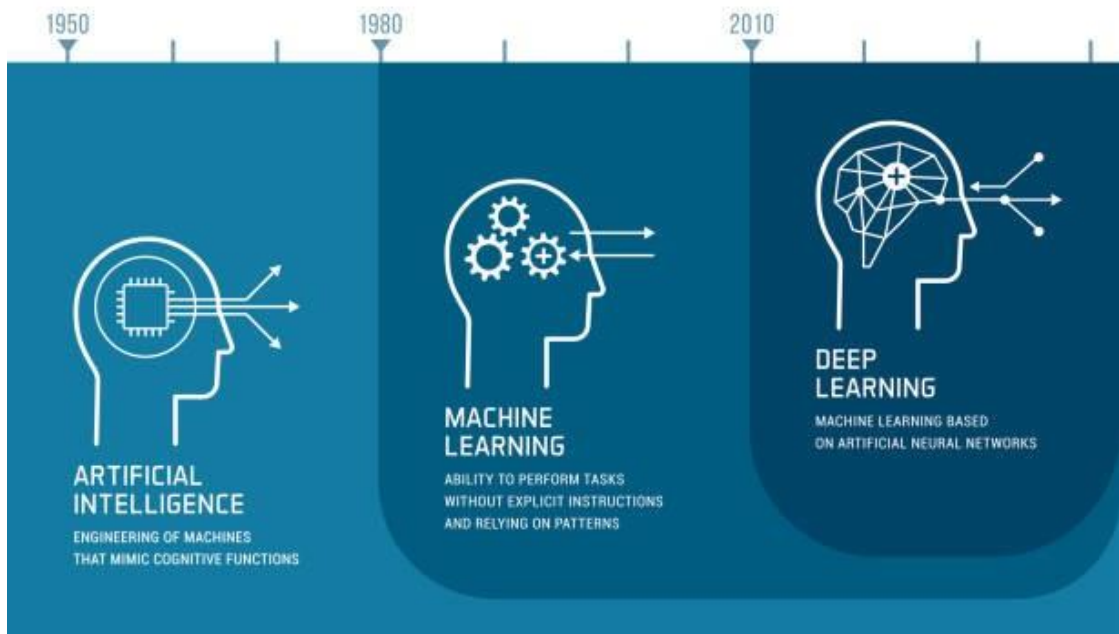


# Intro to Neural Networks

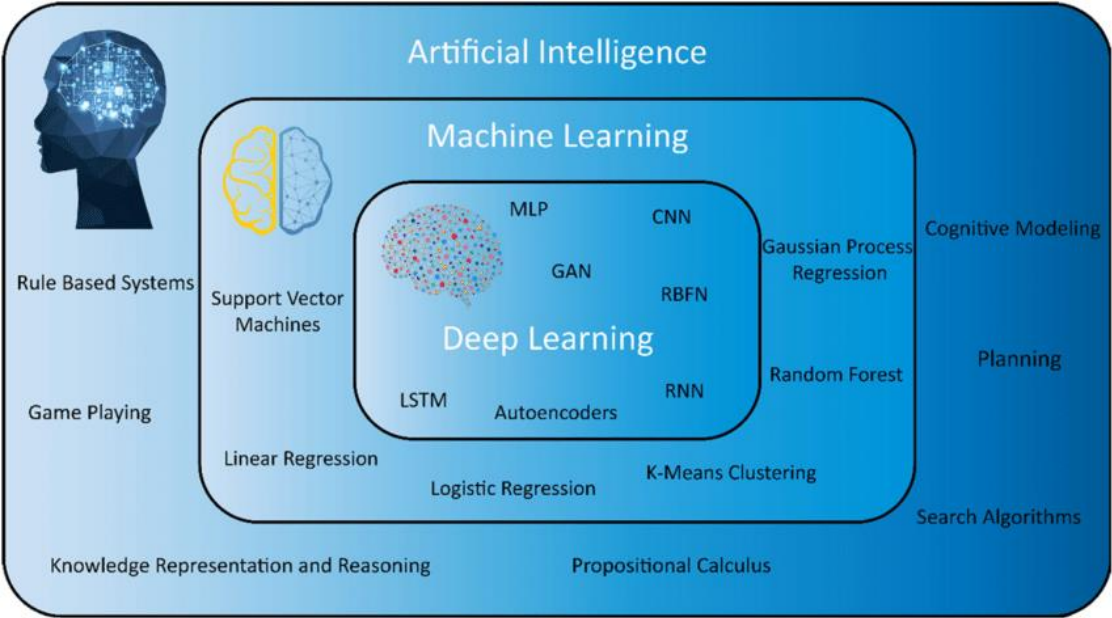
**BA865 – Mohannad Elhamod**

# Motivation

# What is Deep Learning?

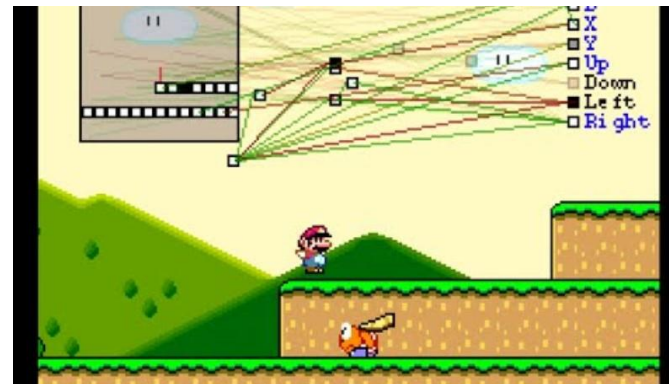
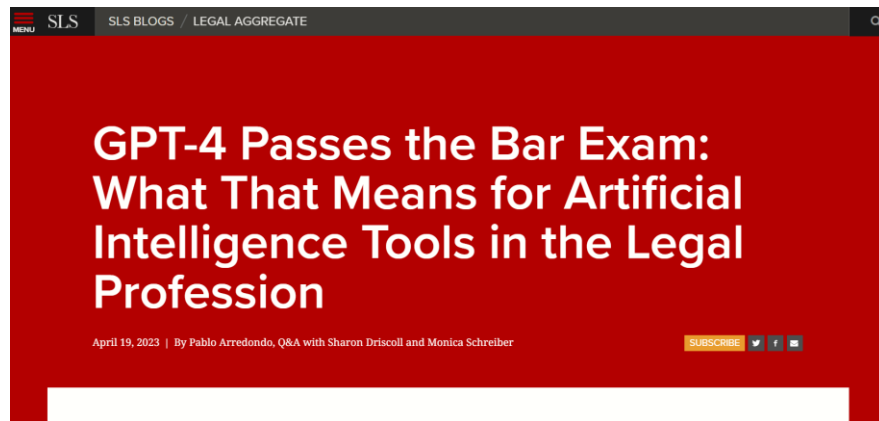


[LinkedIn](#)



[ResearchGate](#)

# Behold The Almighty Deep Learning!



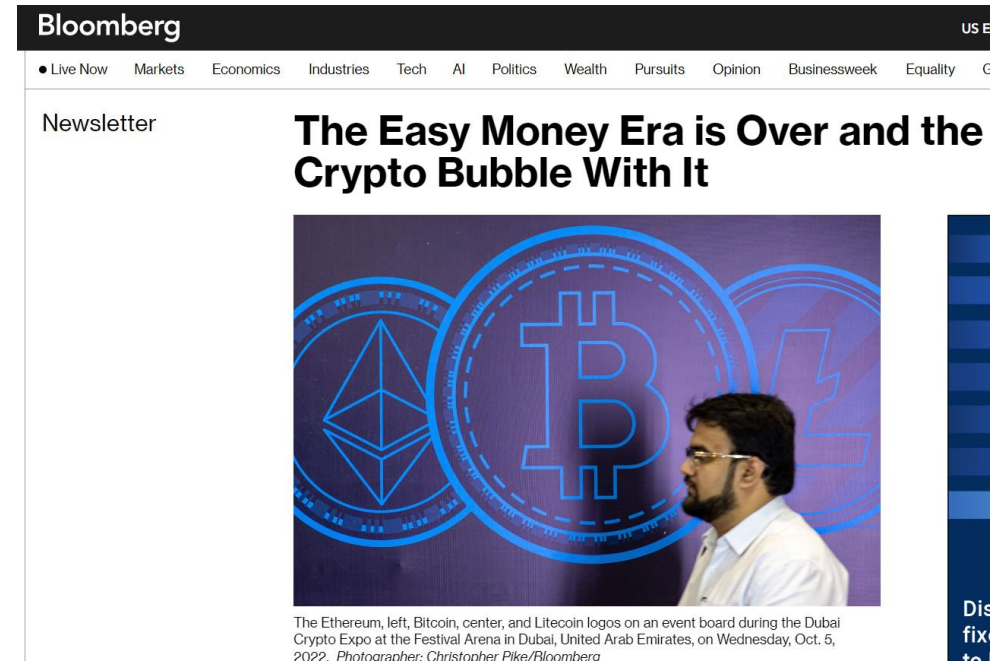
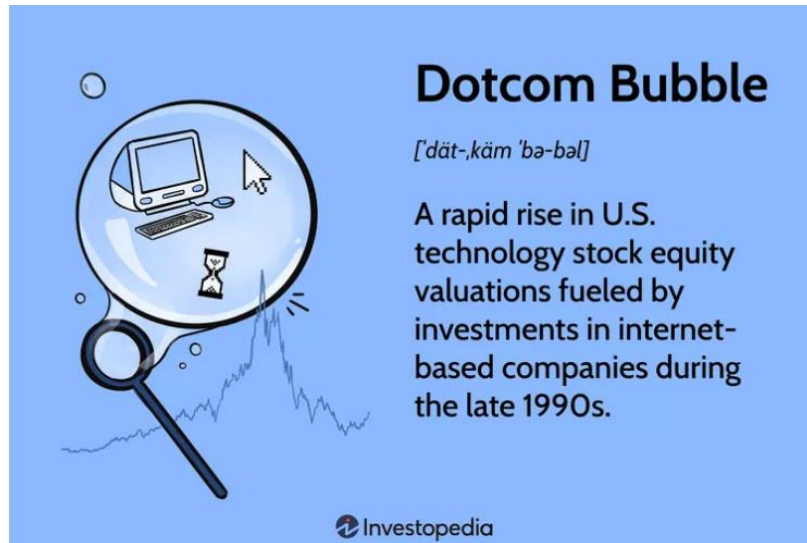
<https://thispersondoesnotexist.com>



# Behold The Almighty Deep Learning!

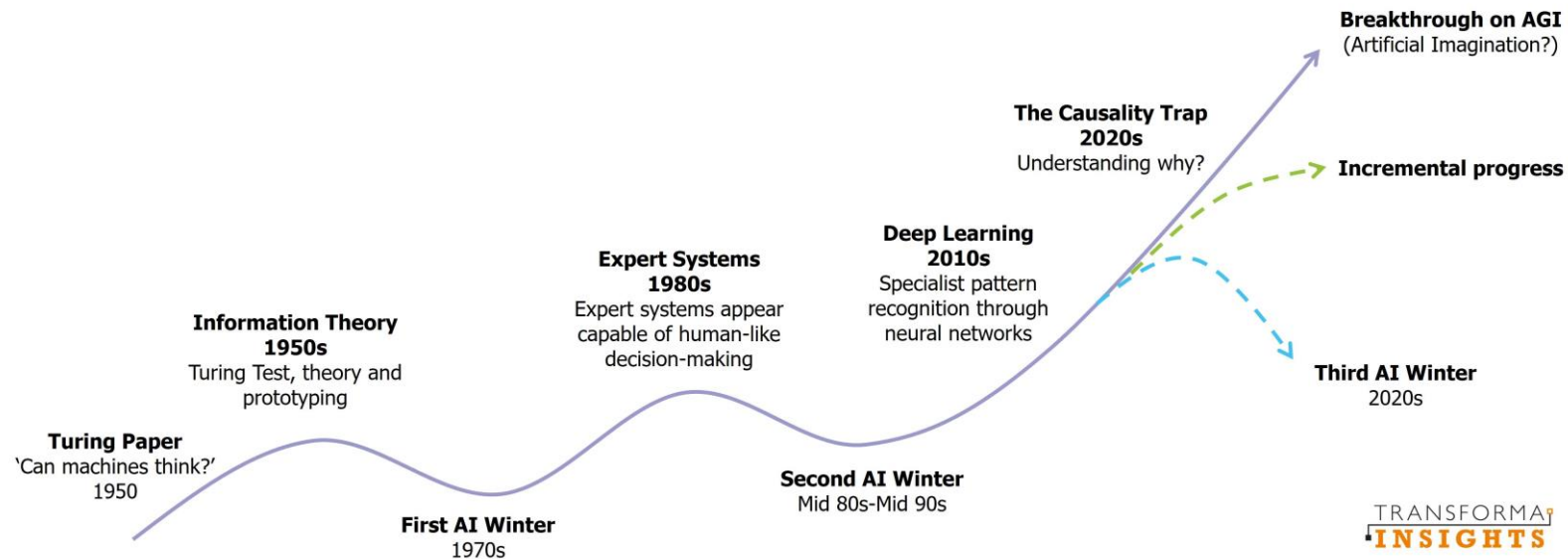
- [Generate music](#)
- [Classify images](#)
- [Classify images \(2\)](#)
- [Dimensionality Reduction](#)

# Beware The Hype!



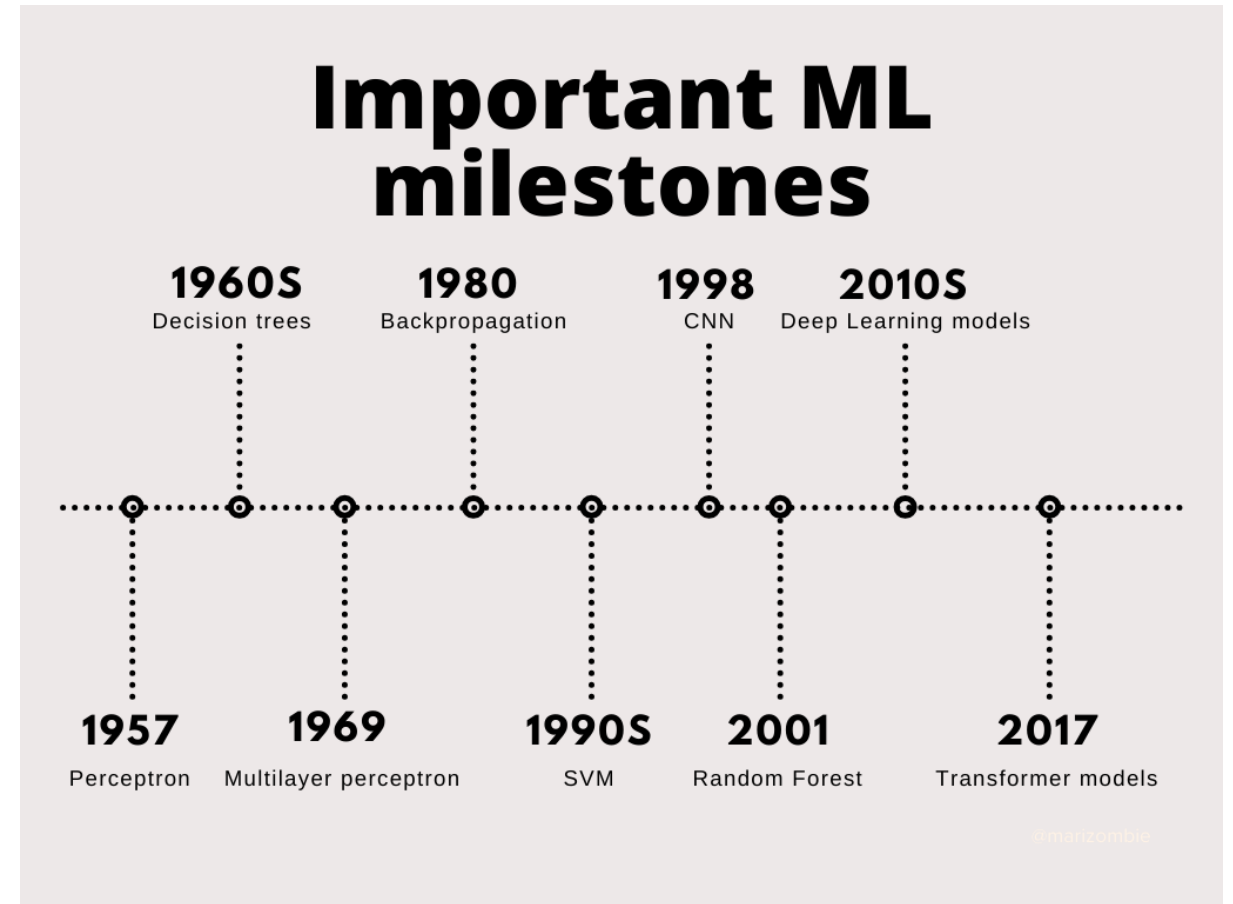
# Beware The Hype!

- It hasn't always looked rosy... There are some "hypes" along the way.



# Algorithms Come and Go...

- Different algorithms gain popularity at different periods of time.

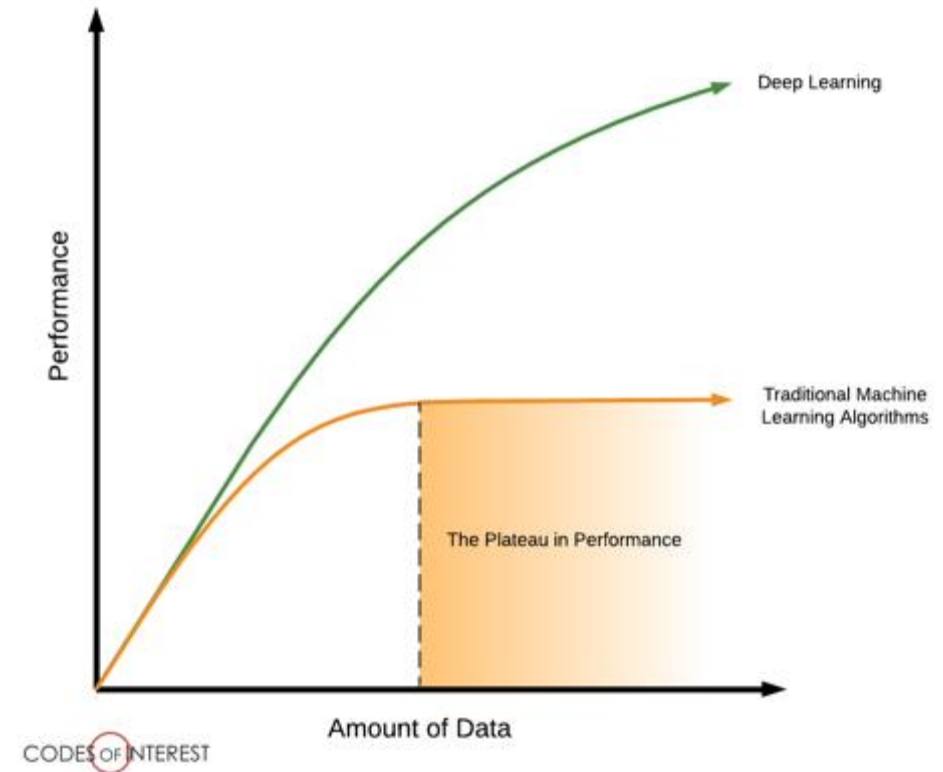


[medium.com](https://medium.com)



# Why Deep Learning?

- Traditional ML was found to plateau in performance in the “Big Data” realm.
- Deep Learning has shown a much better capacity for learning from large amounts of data.



# Why Now?

Geoffrey Hinton, Godfather of AI.

## What was actually wrong with backpropagation in 1986?

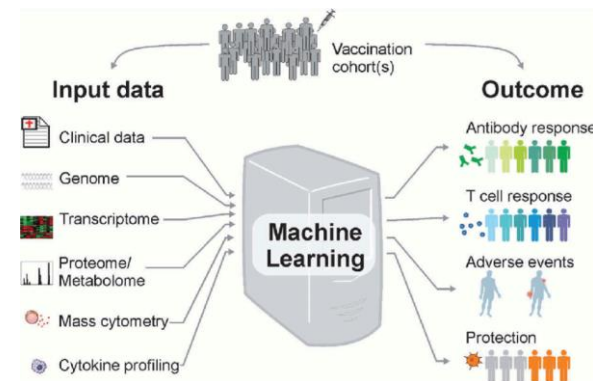
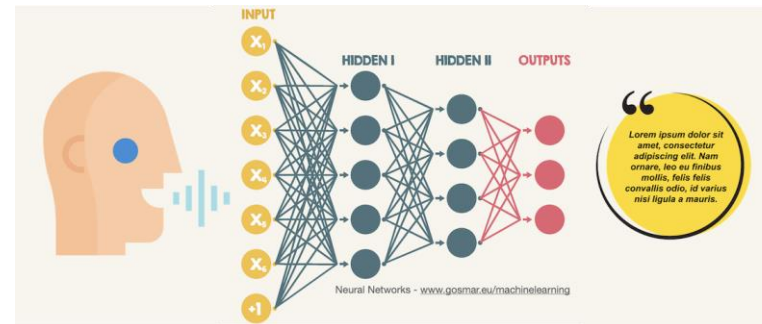
- We all drew the wrong conclusions about why it failed. The real reasons were:
  1. Our labeled datasets were thousands of times too small.
  2. Our computers were millions of times too slow.
  3. We initialized the weights in a stupid way.
  4. We used the wrong type of non-linearity.

THE  
ROYAL  
SOCIETY



# Where Can Deep Learning Be Applied?

- Almost anywhere where you have data to learn from and make decisions based on.

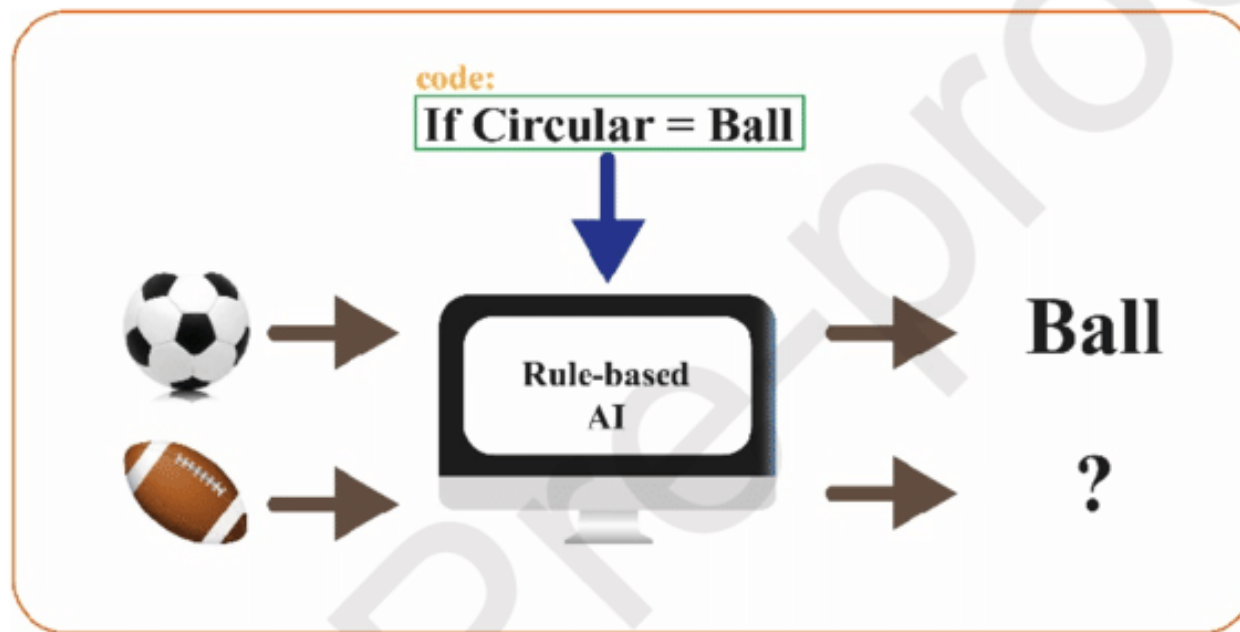


# Machine Learning:

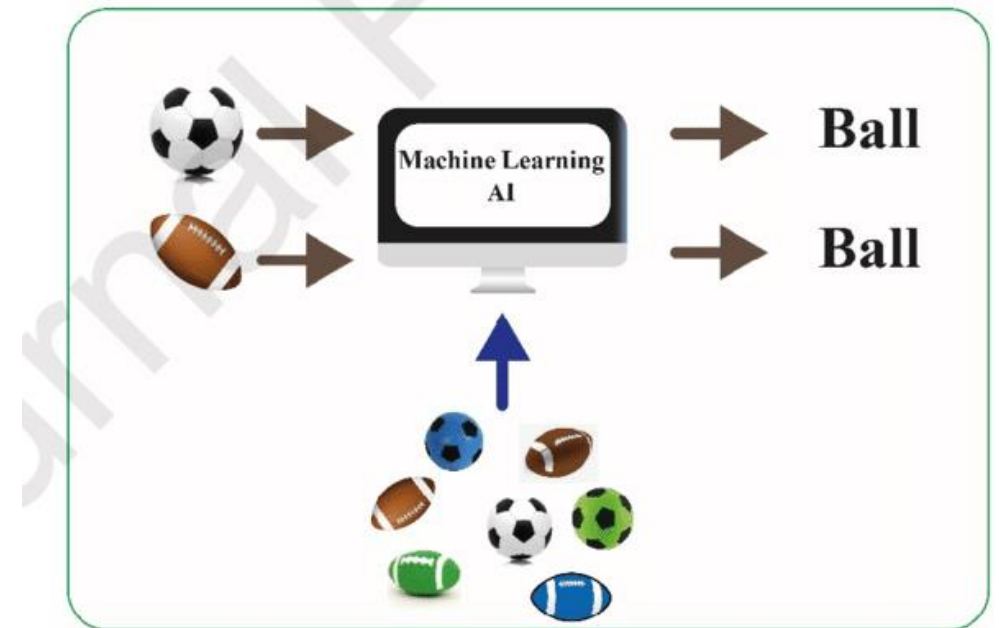
**An Essential Review!**

# What is Machine Learning?

Elbadawi, Moe & McCoubrey, Laura & Gavins, Francesca & Ong, Jun Jie & Goyanes, Alvaro & Gaisford, Simon & Basit, Abdul. (2021). Harnessing Artificial Intelligence for the Next Generation of 3D Printed Medicines. *Advanced Drug Delivery Reviews*. 175. 10.1016/j.addr.2021.05.015.



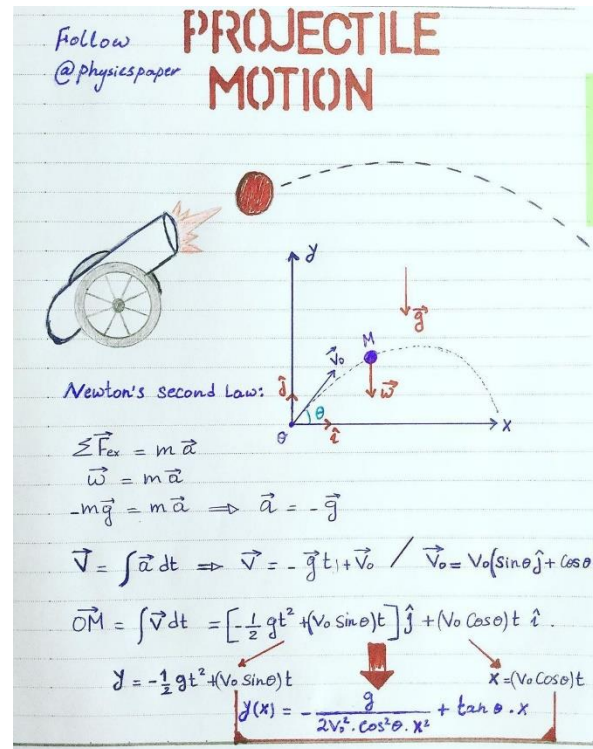
Knowledge-based modeling



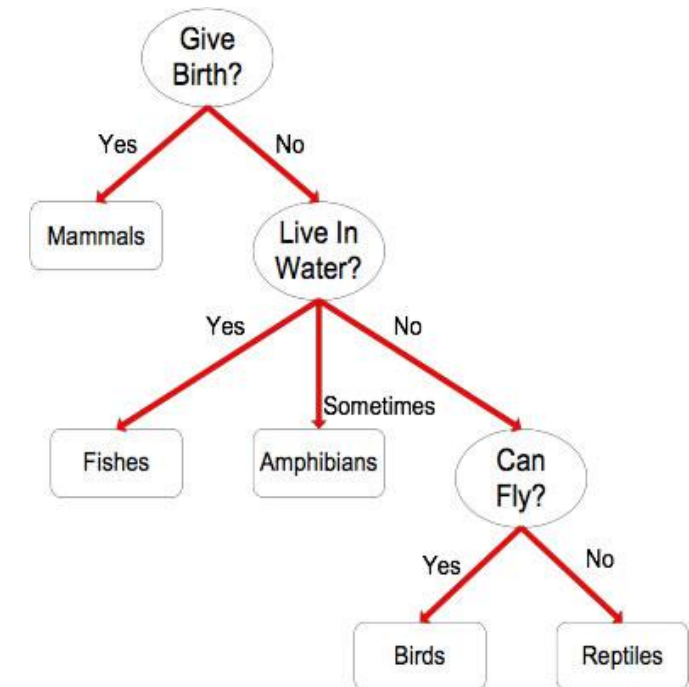
Data-driven modeling

# Knowledge-based Modeling

- What challenges you find with this approach?

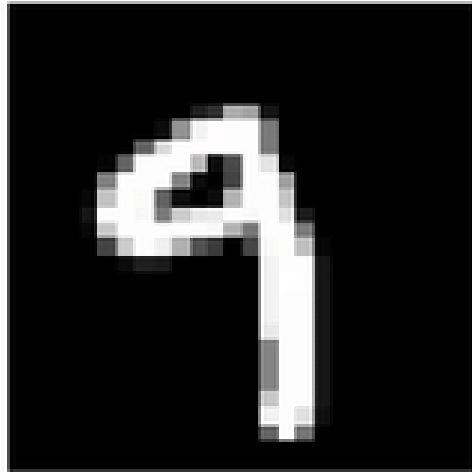


<http://jcsites.juniata.edu/faculty/rhodes/ml/rulebasedClass.htm>  
<https://www.pinterest.com/pin/598626975454754006/>

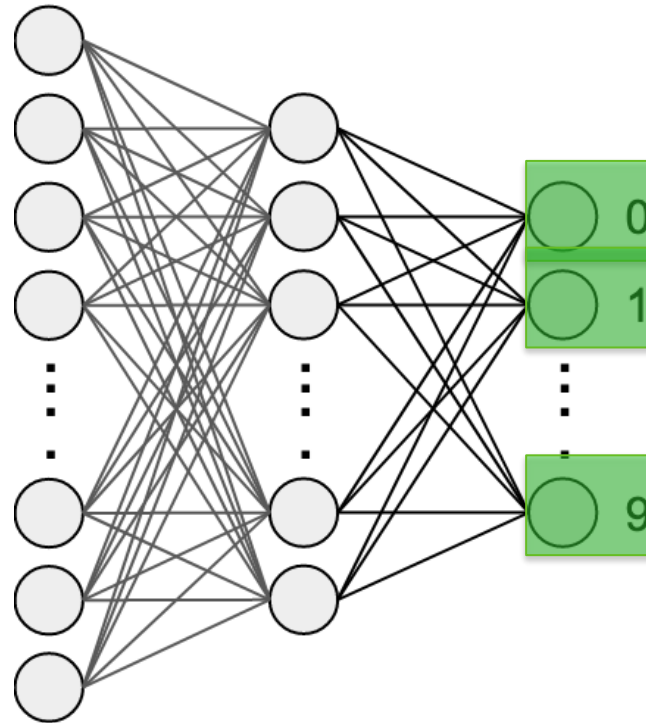




# Supervised Learning

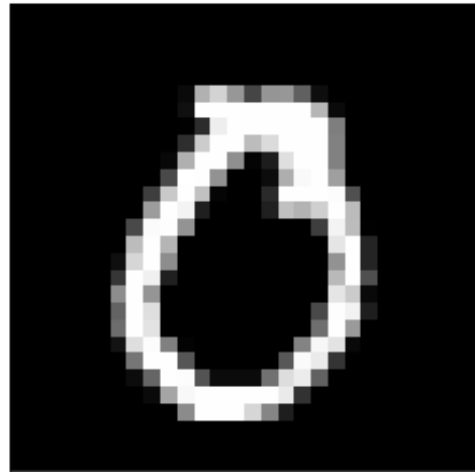


MNIST Dataset

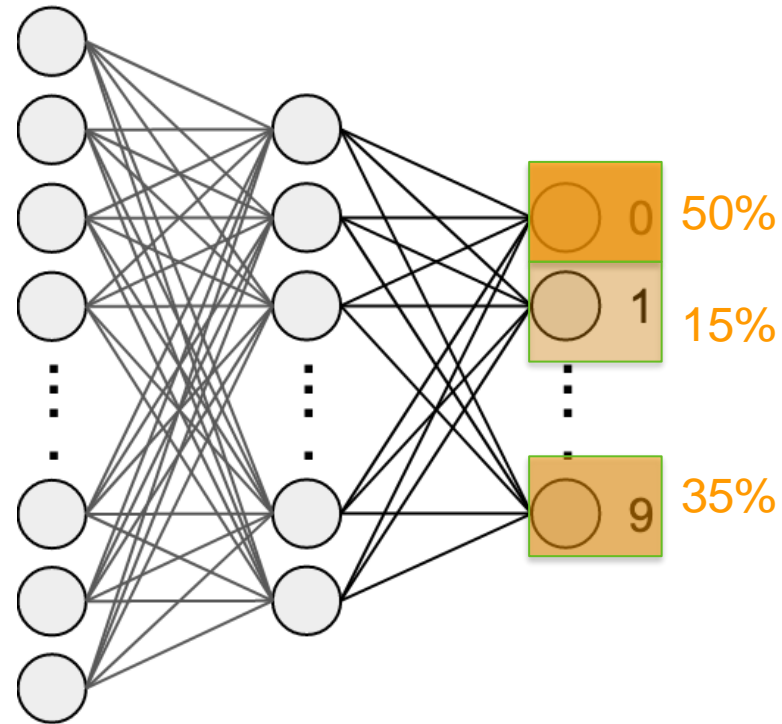


Phase 1: Training

# Supervised Learning



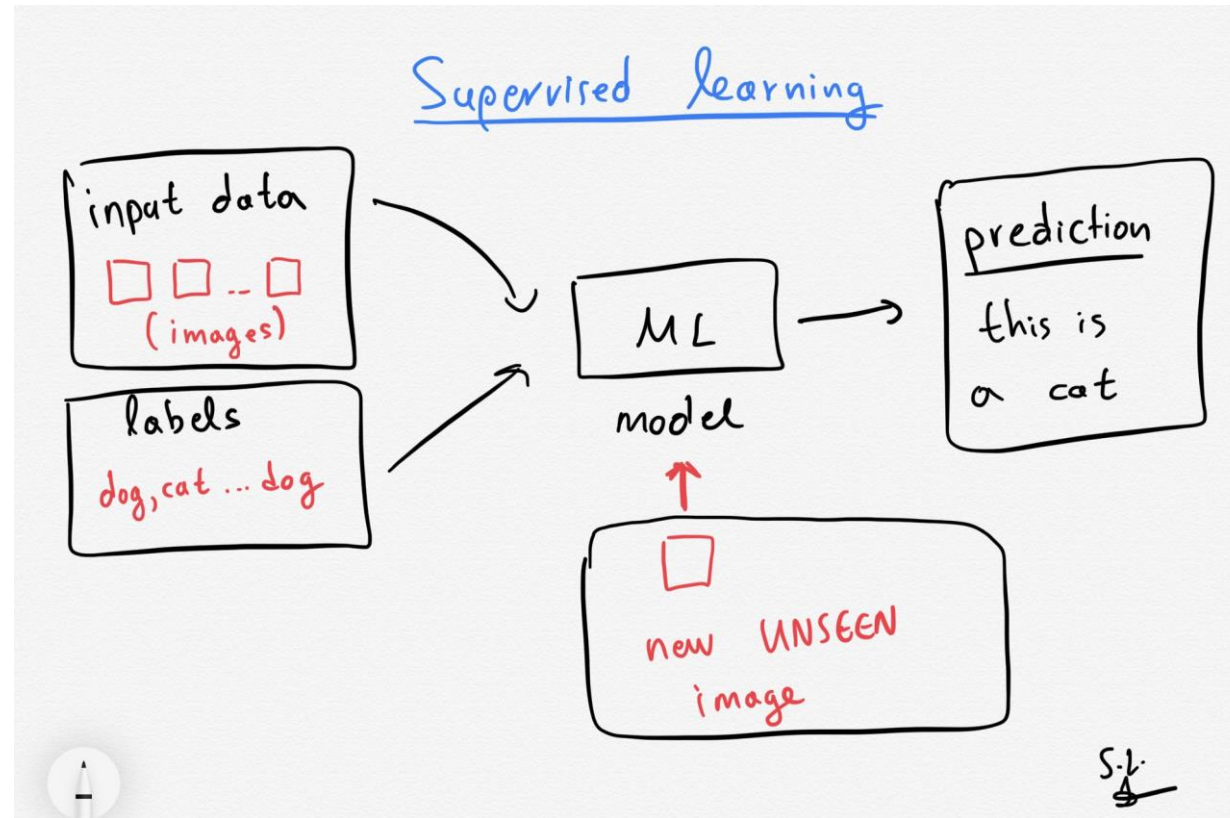
MNIST Dataset



## Phase 2: Validation/Testing

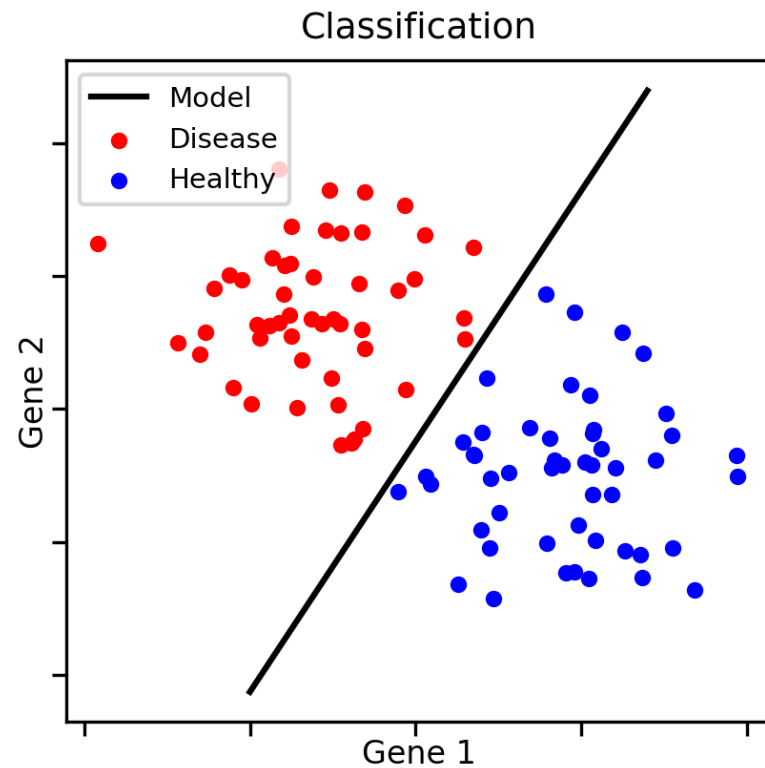


# Supervised Learning



<https://towardsdatascience.com/what-is-machine-learning-a-short-note-on-supervised-unsupervised-semi-supervised-and-aed1573ae9bb>

# Supervised Learning - Model Types



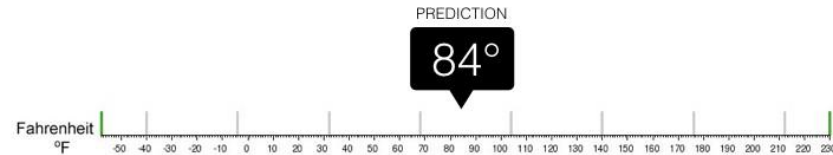
<https://aldro61.github.io/microbiome-summer-school-2017/sections/basics/>

# Supervised Learning - Model Types



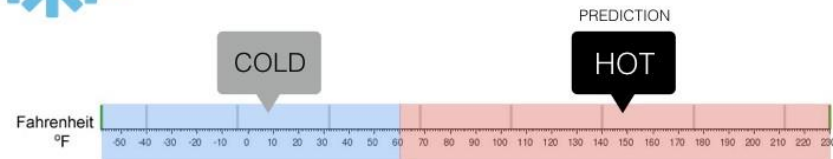
## Regression

What is the temperature going to be tomorrow?



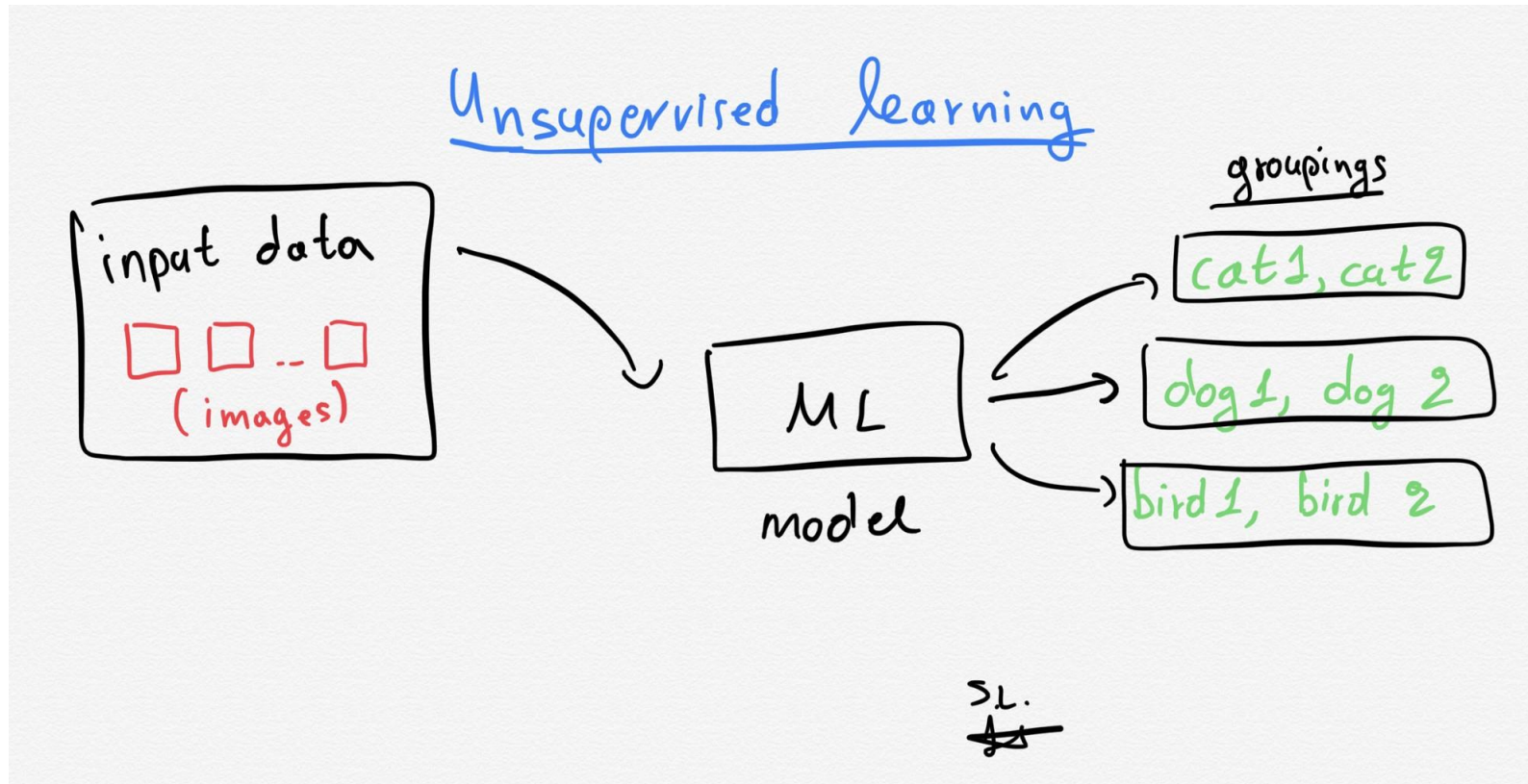
## Classification

Will it be Cold or Hot tomorrow?



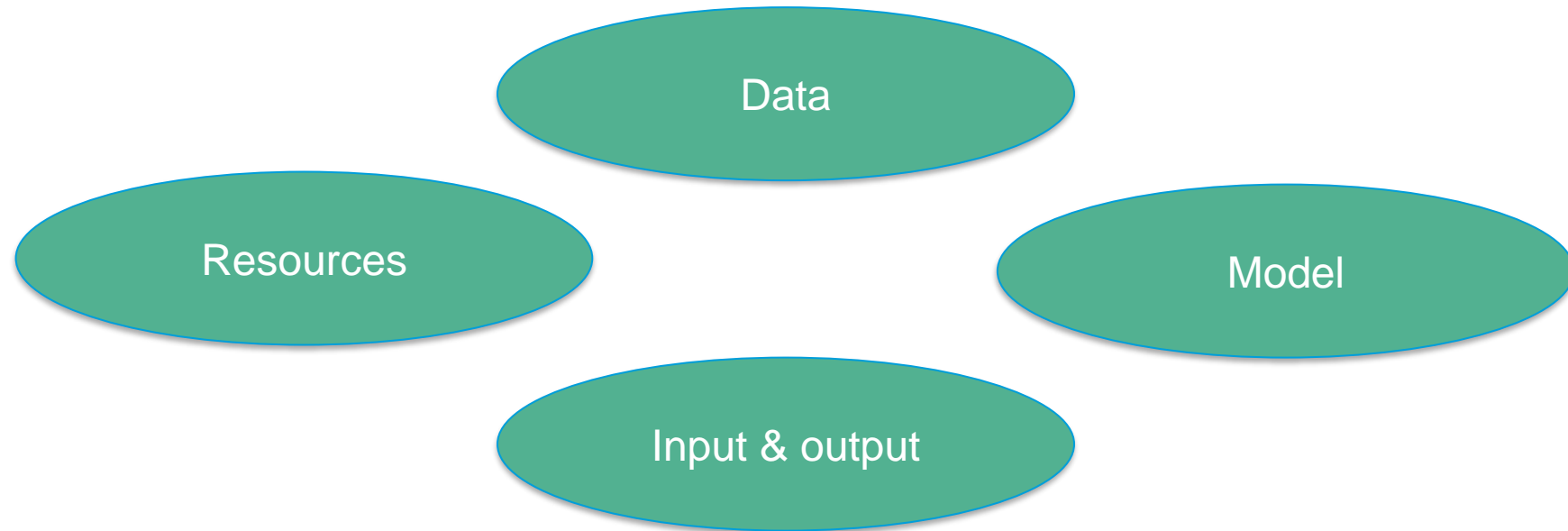
[https://medium.com/@ali\\_88273/regression-vs-classification-87c224350d69](https://medium.com/@ali_88273/regression-vs-classification-87c224350d69)

# Unsupervised Learning



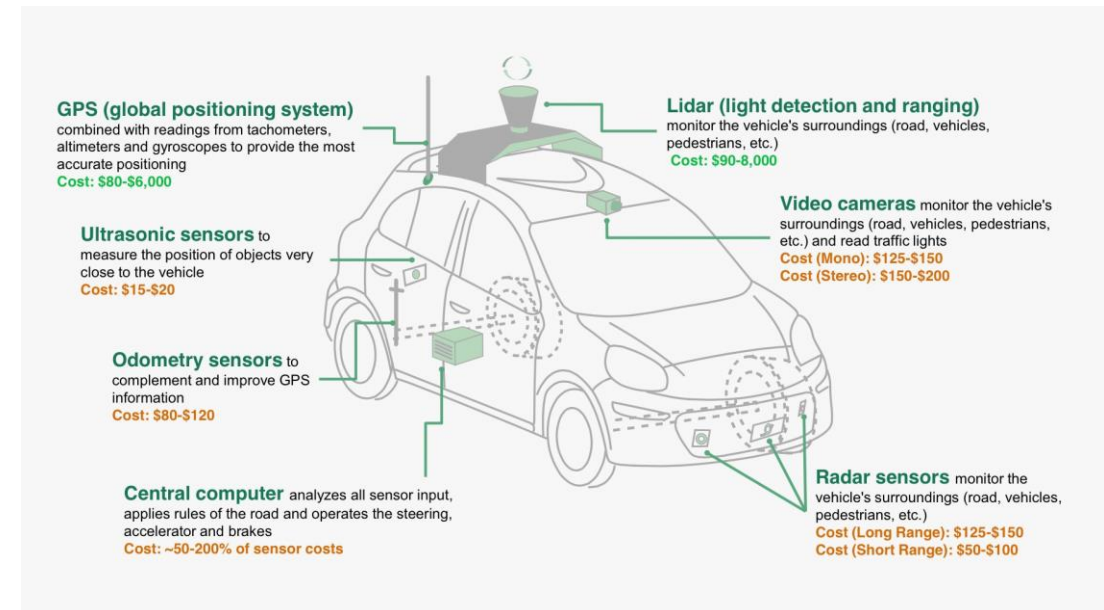
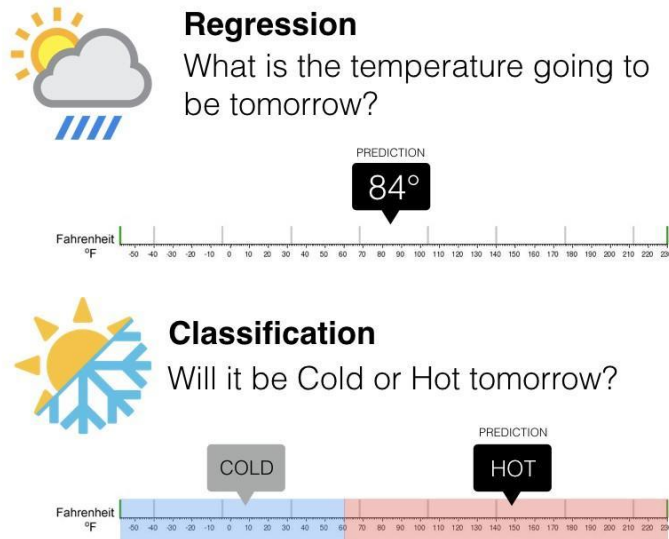
<https://towardsdatascience.com/what-is-machine-learning-a-short-note-on-supervised-unsupervised-semi-supervised-and-aed1573ae9bb>

# The Pillars of ML



# Input & Output

- What exactly are you trying to model?



<https://www.wired.com/2015/04/cost-of-sensors-autonomous-cars>  
[https://medium.com/@ali\\_88273/regression-vs-classification-87c224350d69](https://medium.com/@ali_88273/regression-vs-classification-87c224350d69)

# Data

- Is there enough of it?
- Does it need clean-up?



Damaged specimen

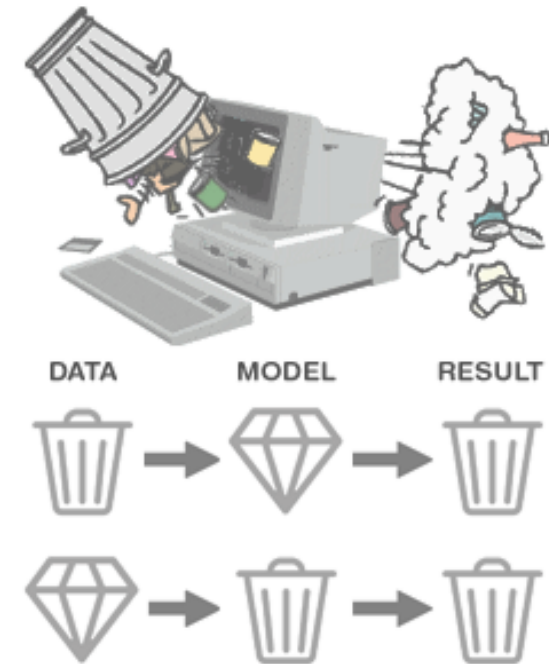


Missing Features



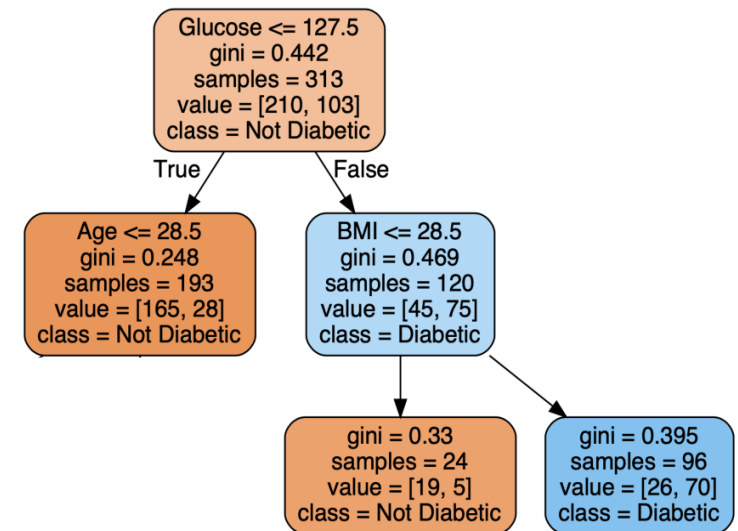
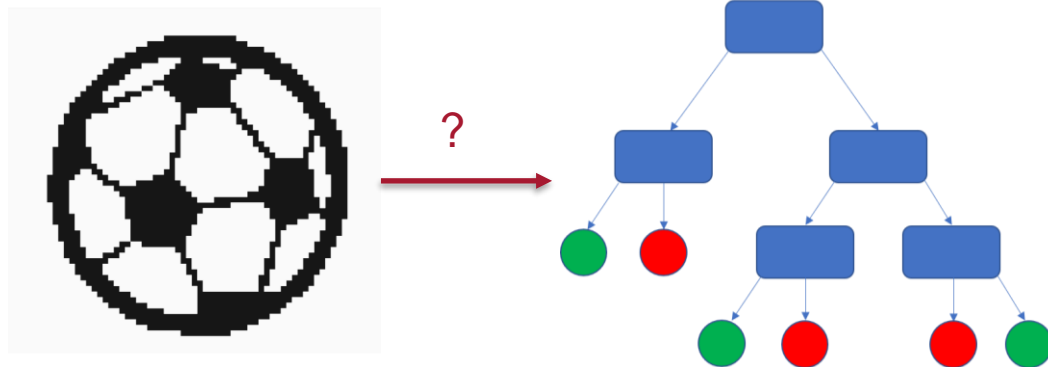
Occluded Features

Elhamod, M., Diamond, K. M., Murat Maga, A., Bakis, Y., Bart, H. L., Mabee, P., Dahdul, W., Leipzig, J., Greenberg, J., Avants, B., & Karpayne, A. (2022). Hierarchy-guided neural network for species classification. *Methods in Ecology and Evolution*, 13, 642–652. <https://doi.org/10.1111/2041-210X.13768>



# Model

- What kind of model would be sufficient/suitable for modeling your data?

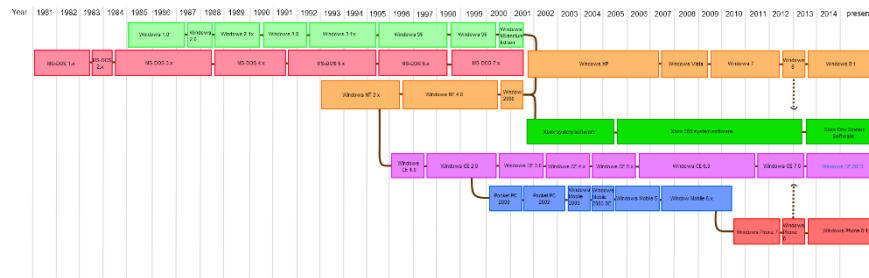


<https://statisticallyrelevant.com/decision-trees-in-python-predicting-diabetes/>

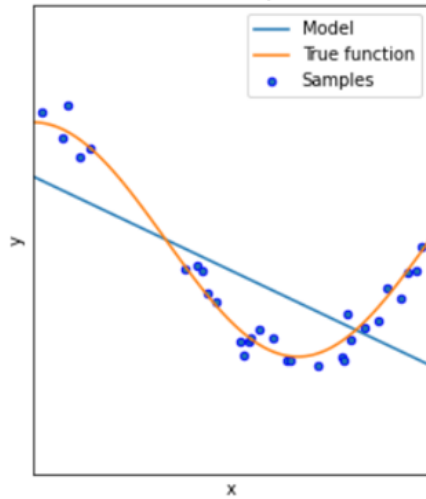


# Resources

- What compute resources are available?
- What is the project's timeline?

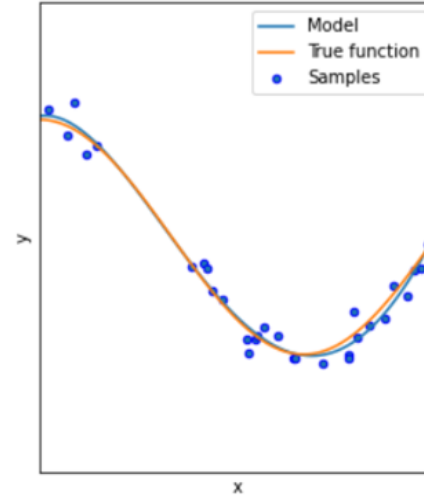


# Model Generalization



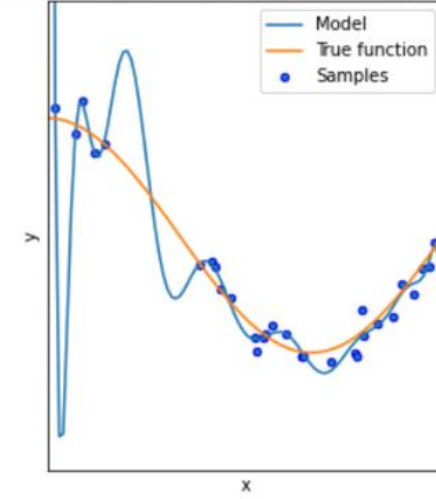
Underfitting

$$\theta_0 + \theta_1 x$$



Well-fitted

$$\theta_0 + \theta_1 x + \theta_2 x^2$$



Overfitting

$$\theta_0 + \theta_1 x + \theta_2 x^2 + \theta_3 x^3 + \theta_4 x^4$$

<https://datascience.foundation/sciencewhitepaper/underfitting-and-overfitting-in-machine-learning>

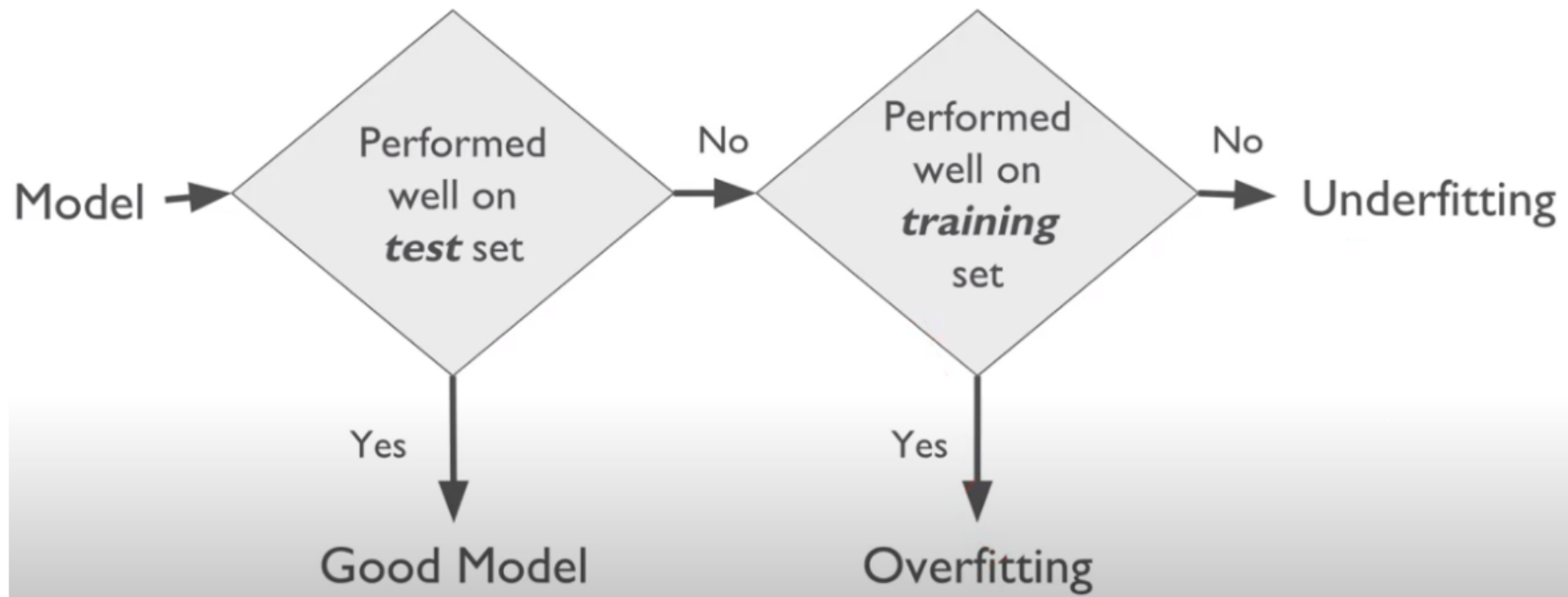
# What is Model Complexity?

- It is the degrees of freedom, the “flexibility” of the model to fit the data.
- Bigger datasets or datasets with more attributes need more complex models, and vice versa.
- [Try it.](#)

# Demo

**Put Your Own Subtitle In This Box**

# Are We Overfitting or Underfitting?



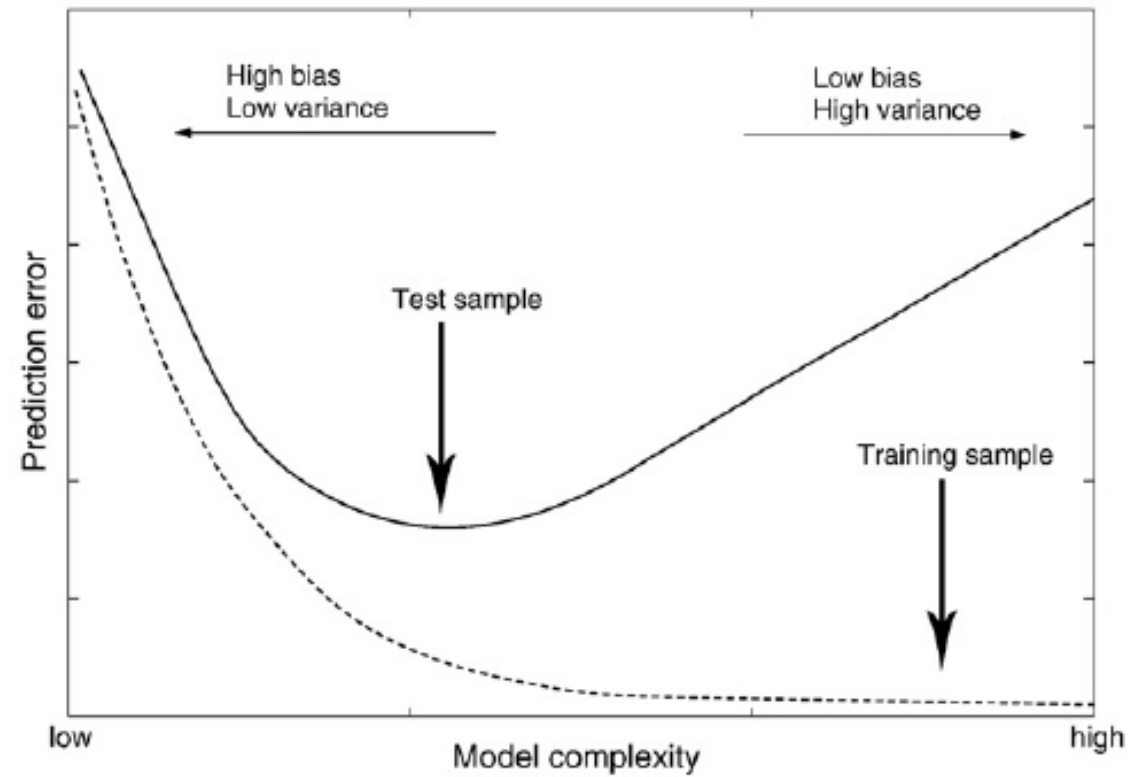
# So What If We Overfit?

- Without validation/testing, you could overfit
  - In other words, you could learn the wrong patterns in the data!



<https://medium.com/trusted-ai/explaining-ai-model-behaviour-with-ibm-watson-openscale-86515702c177>

# Training vs. Test Errors



[www.researchgate.net](http://www.researchgate.net)

# Training vs Test vs. ....?

- How do we test the model's performance?
- How do we assess the model's fine-tuning?



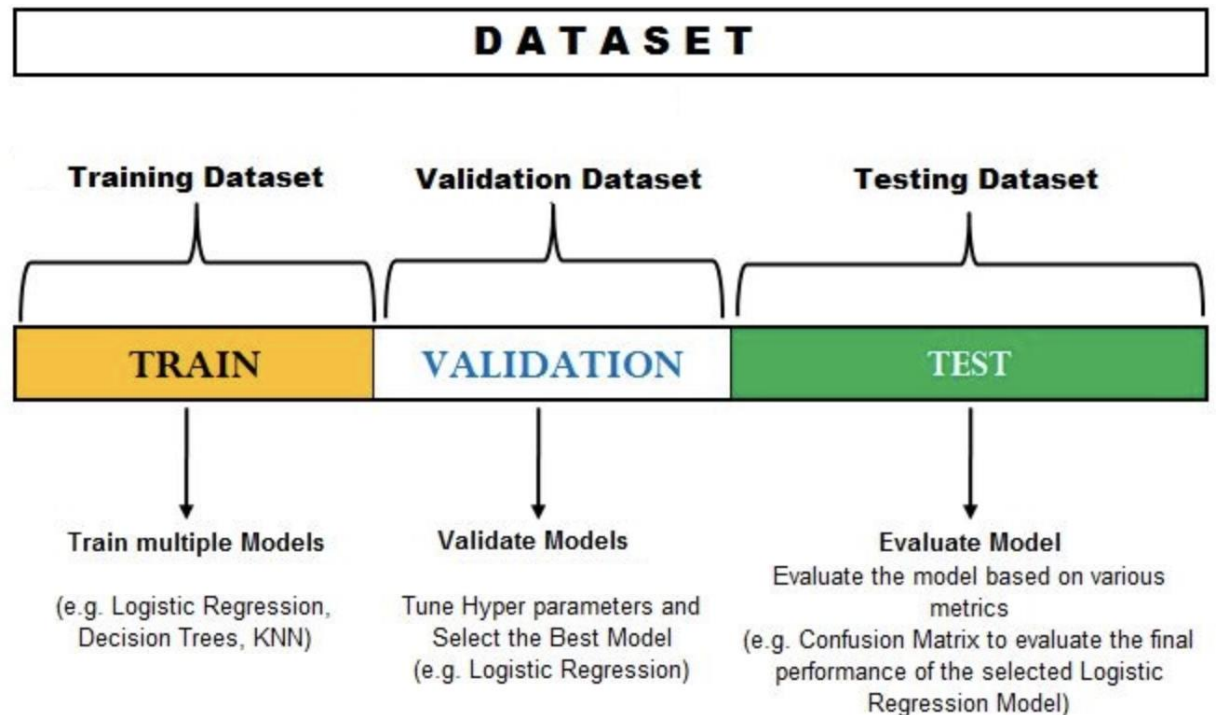
Full dataset

<https://www.machinecurve.com/index.php/2020/11/16/how-to-easily-create-a-train-test-split-for-your-machine-learning-model/>



# Training vs Test vs. Validation?

- The test set should only be used once our model is ready, it should not be used to “tune” the model.
- Hence, we need a third “validation” dataset, which is a split of the training set.



<https://vitalflux.com/hold-out-method-for-training-machine-learning-model/>

# Logistics

**Put Your Own Subtitle In This Box**

# Who is your professor?



# Why are you here?

- I am sure it eventually leads to money....
- Not a required class. So, hopefully based on interest!
- Nonetheless, understanding how things work is essential for decision making and innovation.



Someone who had begun to [study] geometry asked Euclid, 'What shall I get by learning these things?' Euclid called his slave and said, 'Give him [some money], since he must make gain out of what he learns'.

(Heath, 1981, loc. 8625)



Euclid

# Fundamentals are important!

- The more foundational knowledge you skip, the more fundamental errors you will make.
- Work hard. **Be patient!**



## Zen Speaks: Shouts of Nothingness

# Your professor is not a God

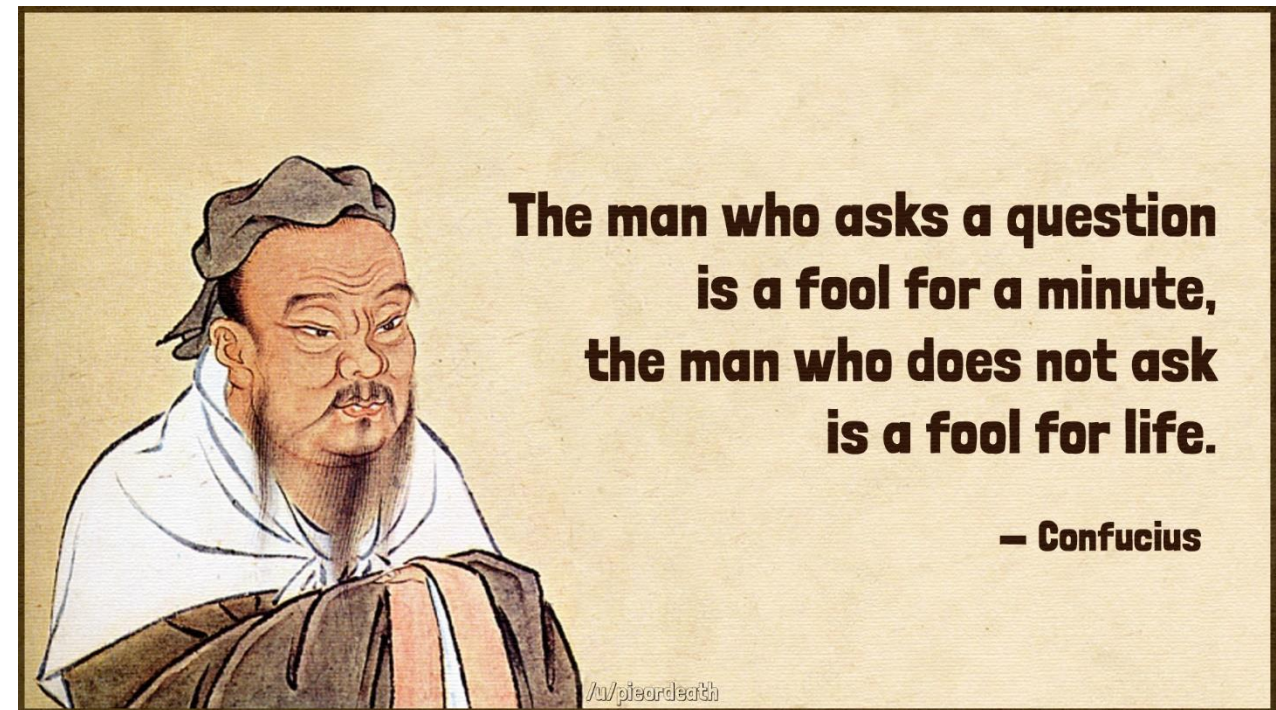
- Deep Learning is a fast-growing domain.
- The internet nowadays has all kinds of learning material.
- Your professor is **NOT** here as a walking encyclopedia. He is here to guide your learning experience and build you a solid foundation, so you could continue learning on your own later.





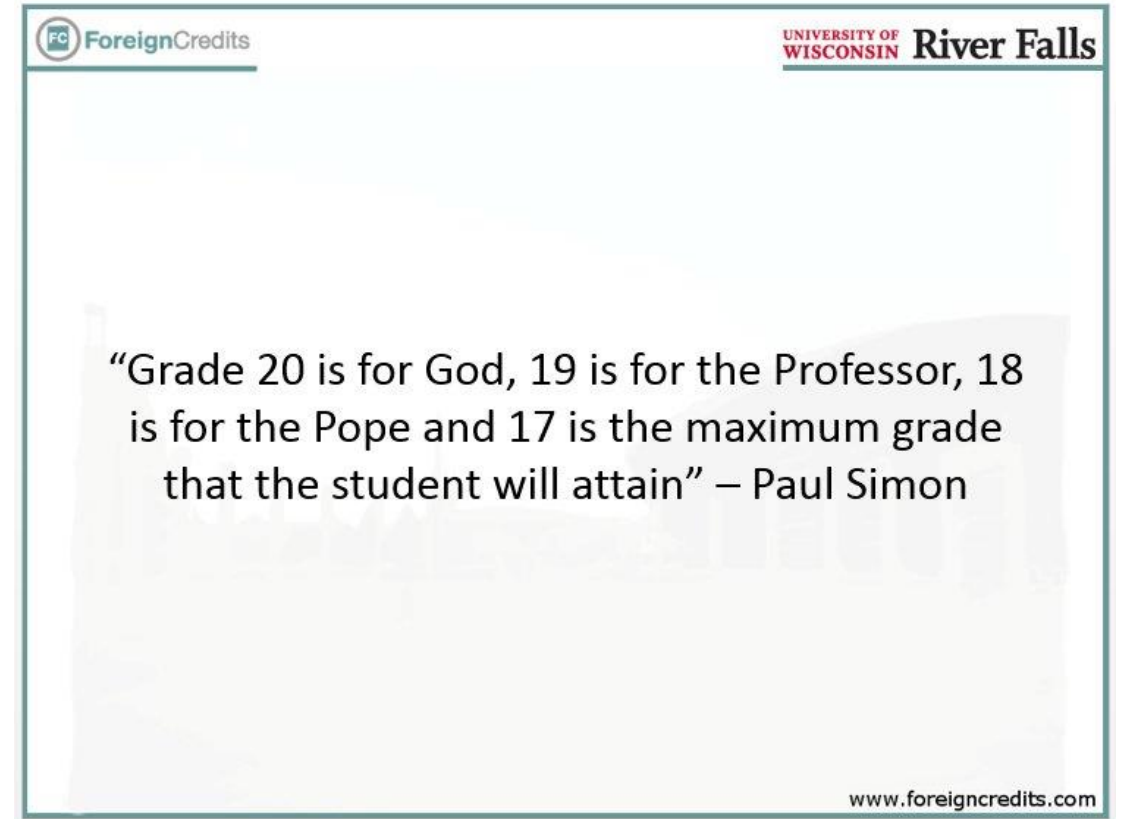
# No Question is Foolish

- Other might have the same question.
- Knowledge is hierarchical.



# Can I get an A?

- [Questrom policy](#)
- But you will get your fair chance.





# Participation is Essential!

- 7.5% of your grade!
- The instructor reserves the right to cold-call.



# Office Hours

- They are for you to take advantage of!
- However, to make the best of your and the TA's/instructor's time, do your homework before dropping in:
  - If you have a question about your project, make sure you have synched with your colleague in advance.
  - If you have question about assignments, make sure you have done your best and that your question is specific rather than “How do I solve this?”.



# Syllabus

- [Here](#)
  - Pay attention to [Piazza](#)!
  - Attendance and participation.
  - The class is somewhat more technical than BA820 and BA810.
  - Zero tolerance for cheating (AI or peers).
  - 5%-20% Penalties for deviating from assessment instructions!

# Shared Computing Cluster (SCC)

- BU's computing cluster with access to CPUs and GPUs.
- We have a limited number of compute hours. Use your allocations wisely!
- When facing issues, ask the professor or TA for help first, not IT support!
- **Don't leave things till last minute!**



# Coding Environments

- <https://www.simplilearn.com/keras-vs-tensorflow-vs-pytorch-article>
  - Keras is easier to use for non-CS users. It is good at an introductory level.
  - PyTorch is most commonly used for research as it provides powerful low-level API.
- We will also use some more advanced packages that help us diagnose and use more advanced models.



**Hugging Face**



**Weights & Biases**