



THE UNIVERSITY  
of EDINBURGH



# AI: From Zero to Aha!

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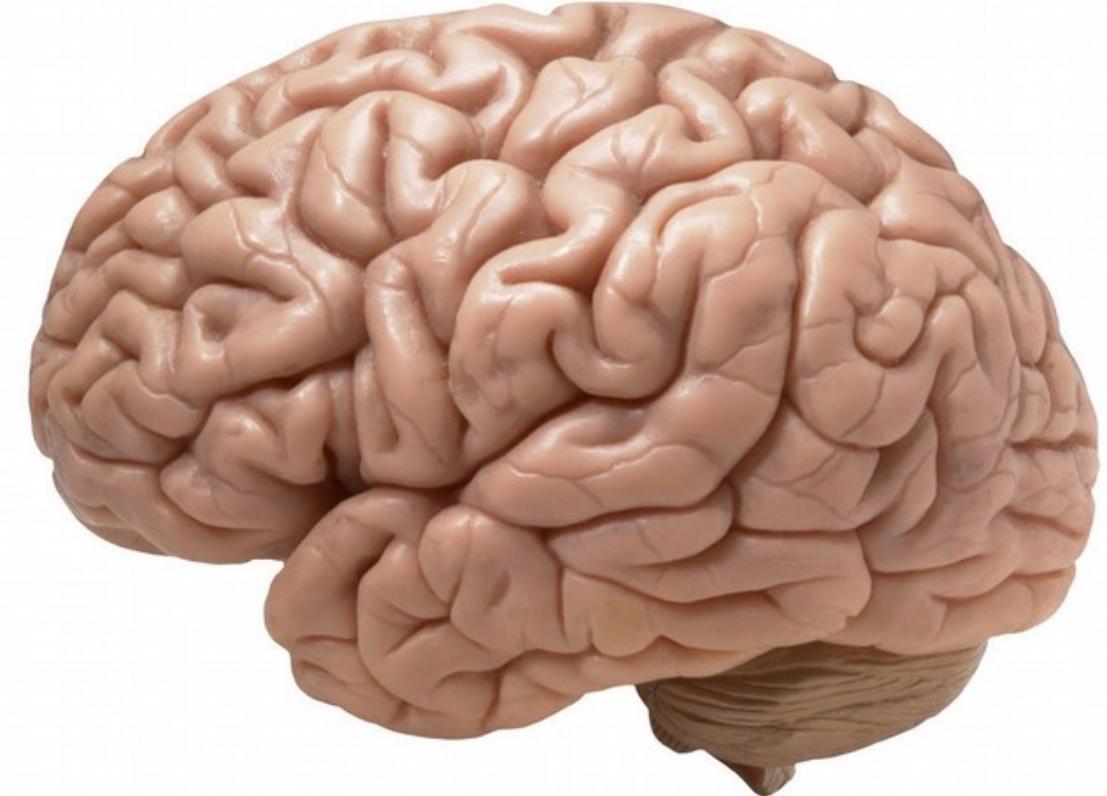


What is the **most complex creation** in the known universe?

# The Most Complex Creation in the Known Universe ...

## Human Brain

- 86B Neurons
- 86,000B Synapses





# Difference Engine

(Mechanical Computer, Mid 19<sup>th</sup> century)



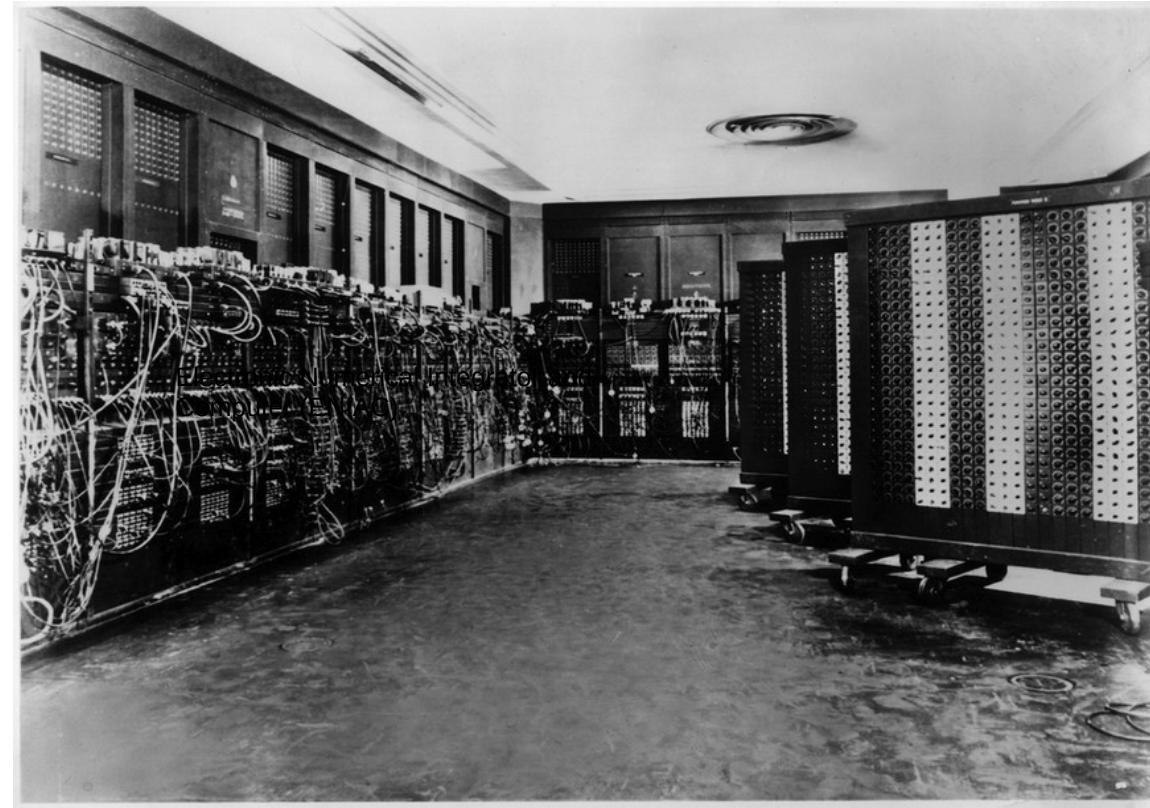
Charles Babbage (1791-1871)  
[Father of the computer]



Z3  
(ElectroMechanical Computer, 1941)

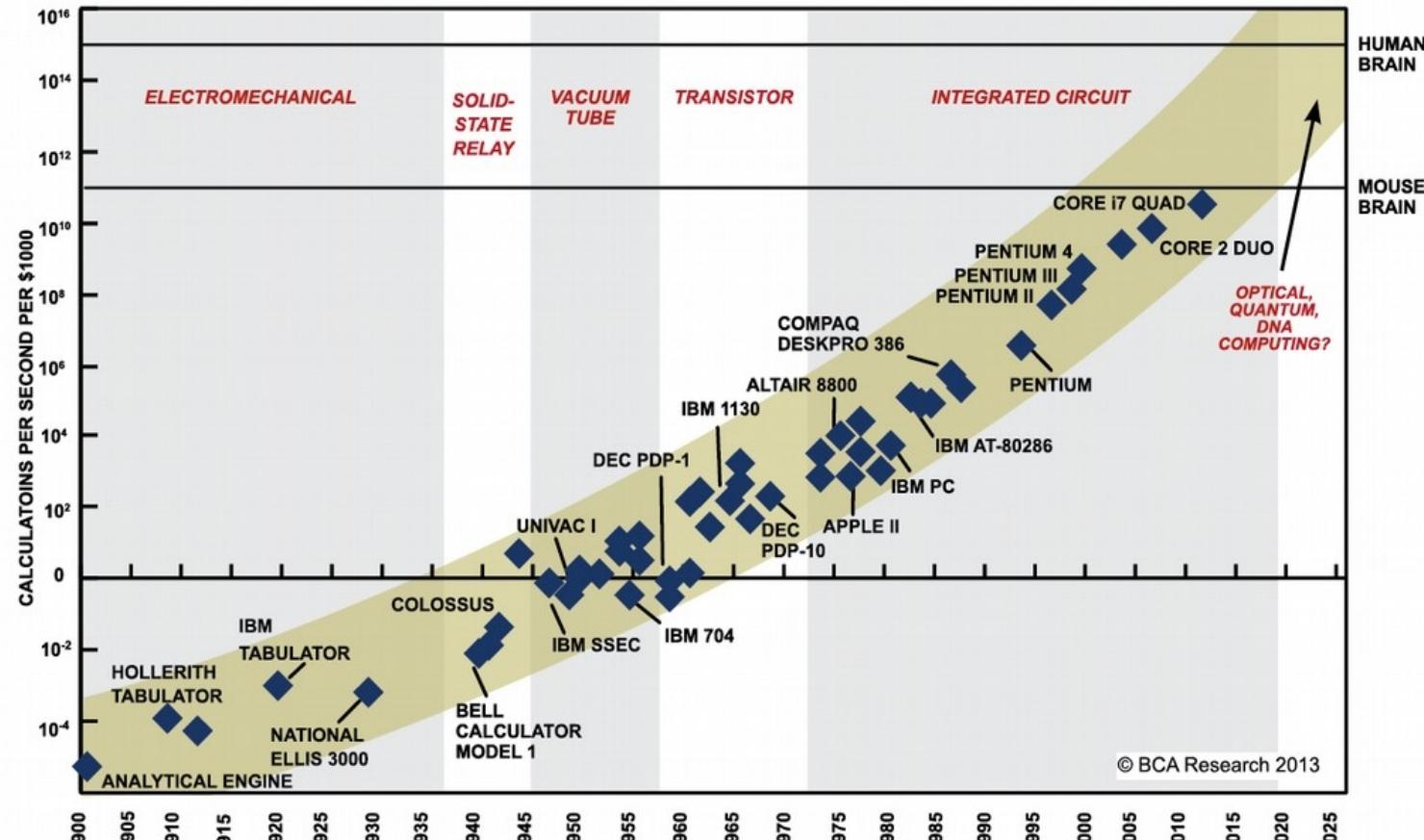


Konrad Zuse (1910-1995)



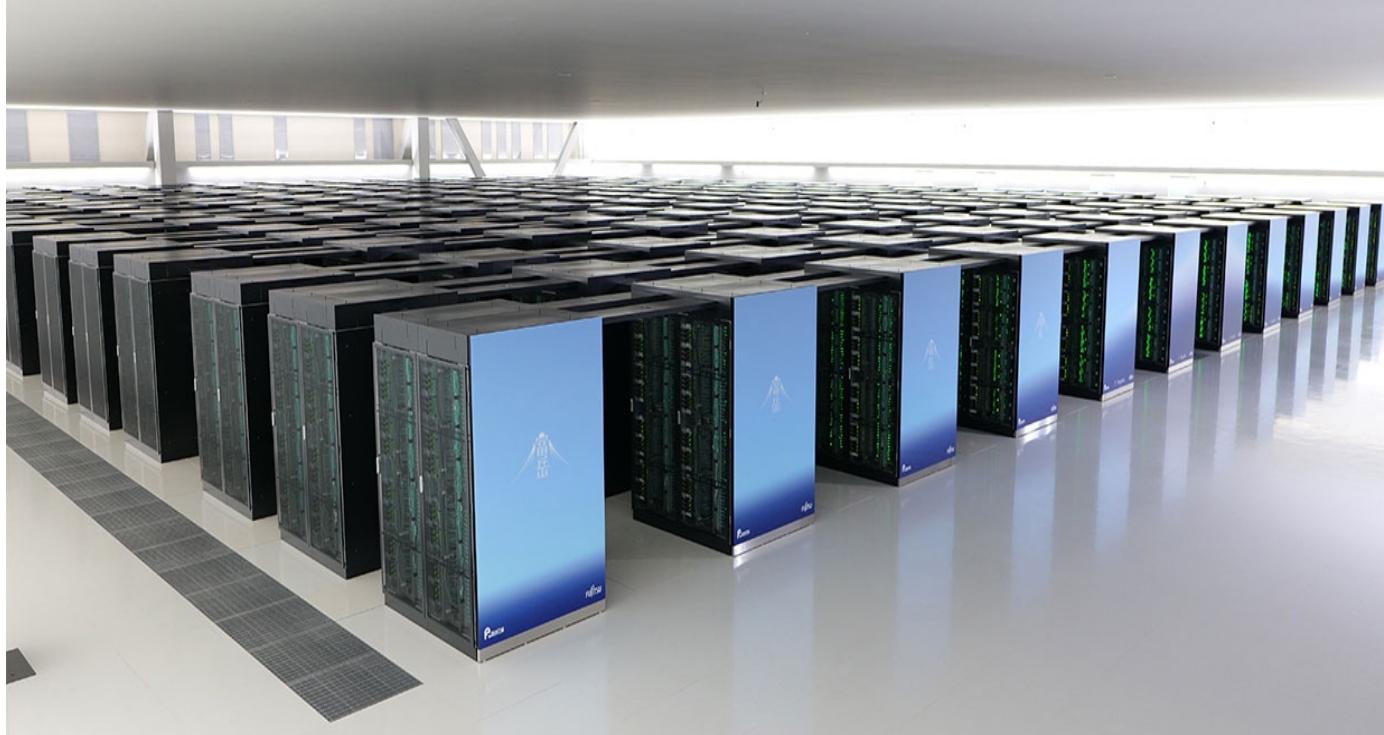
# ENIAC

## (Electronic Numerical Integrator and Computer, 1945)



SOURCE: RAY KURZWEIL, "THE SINGULARITY IS NEAR: WHEN HUMANS TRANSCEND BIOLOGY", P.67, THE VIKING PRESS, 2006. DATAPoints BETWEEN 2000 AND 2012 REPRESENT BCA ESTIMATES.

# Supercomputers: Fugaku



$\sim 0.5 \times 10^{18}$  FLOPS (Rmax)  
 $7.63 \times 10^6$  CPU Cores (ARM)

# Supercomputers: Frontier



$\sim 1.102 \times 10^{18}$  FLOPS (Rmax)  
600k CPU + 8.1M GPU Cores (AMD)



# Brain vs Supercomputers



0.5 x



$x = 1 \times 10^{18}$  FLOPS



1.1 x

FLOPS: Floating-point operations per second

# Problems to Solve

## Type I

568823471609458.2341112  
x 973221231.2431506879416

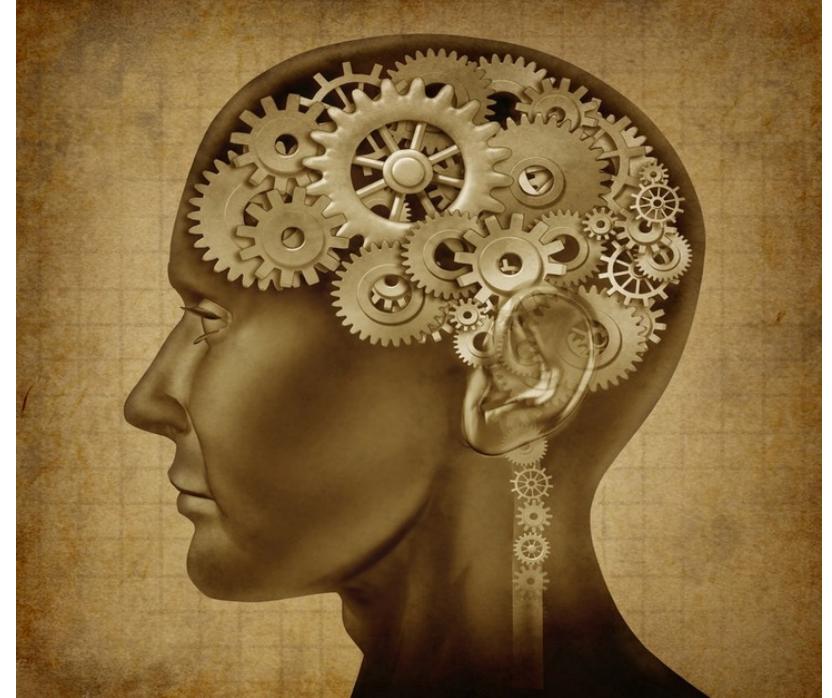
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A Well-Defined Problem  
with Clear Solution Steps

## Type II

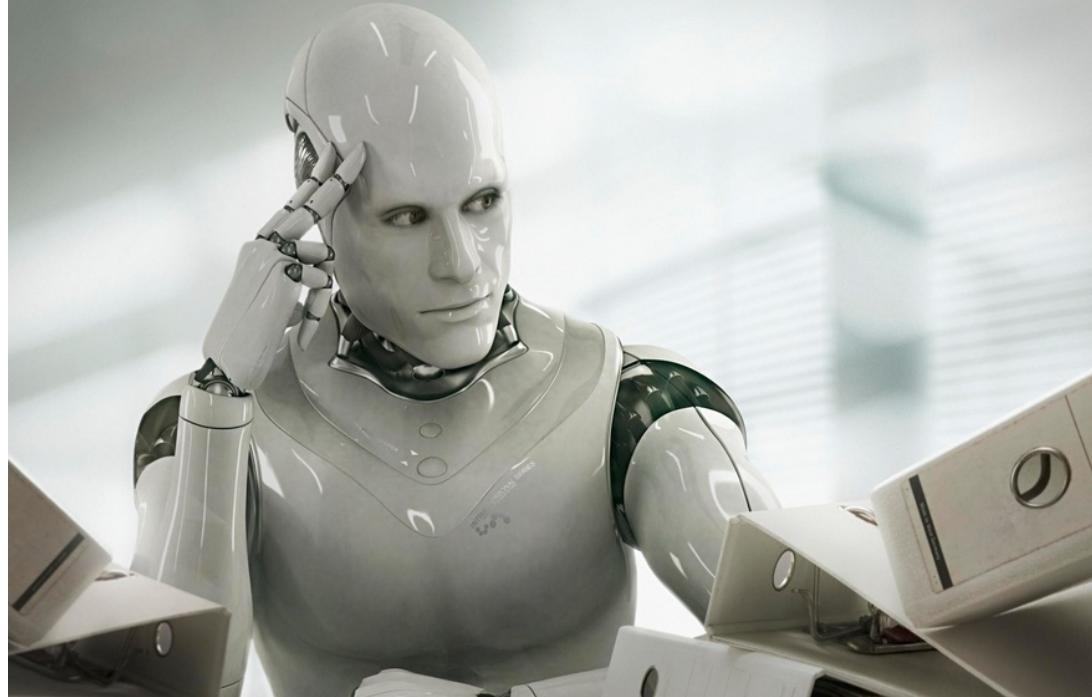


Pattern Recognition  
Solution Steps?



# Physiology

# Engineering

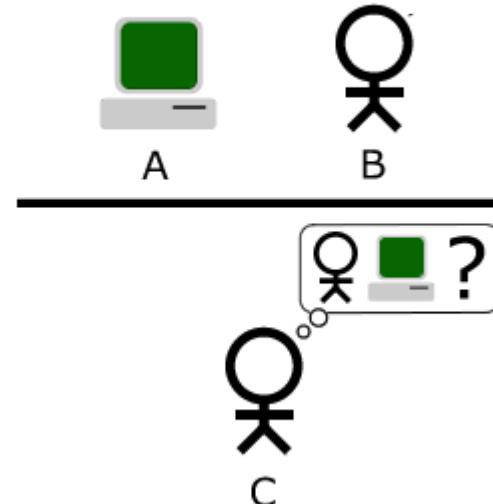


# *Artificial Intelligence*

# Engineering

# What does Intelligence Mean?

## Turing Test (The Imitation Game)



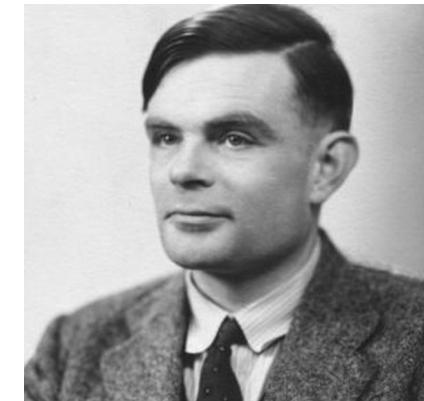
Turing, A.M. (1950). Computing machinery and intelligence. *Mind*, 59, 433-460.

### COMPUTING MACHINERY AND INTELLIGENCE

By A. M. Turing

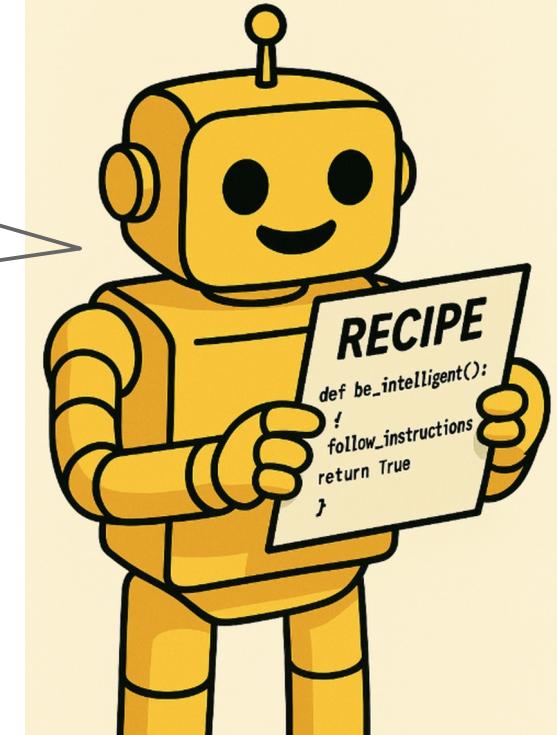
#### 1. The Imitation Game

I propose to consider the question, "Can machines think?" This should begin with definitions of the meaning of the terms "machine" and "think."



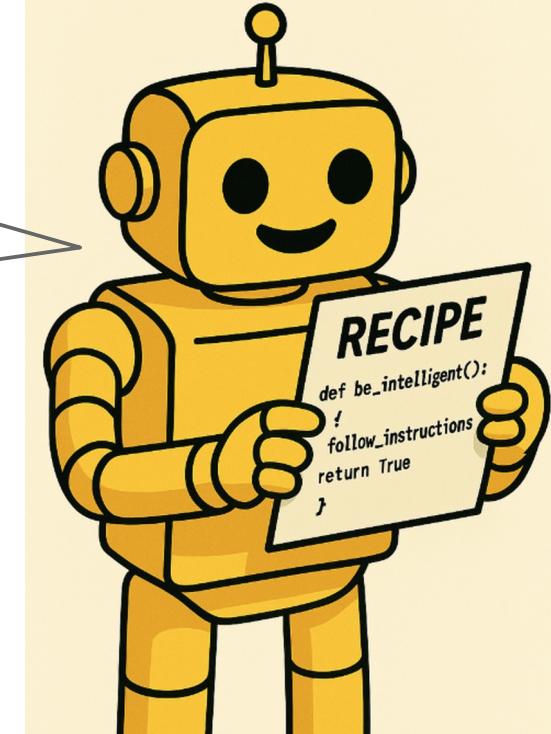
Alan Turing (1912-1954)  
[Father of the computer science]

# How to Build an Intelligent Machine?



Generated by ChatGPT  
(DALL·E 3, OpenAI)

# How to Build an Intelligent Machine?



AI as a **Programming** Problem

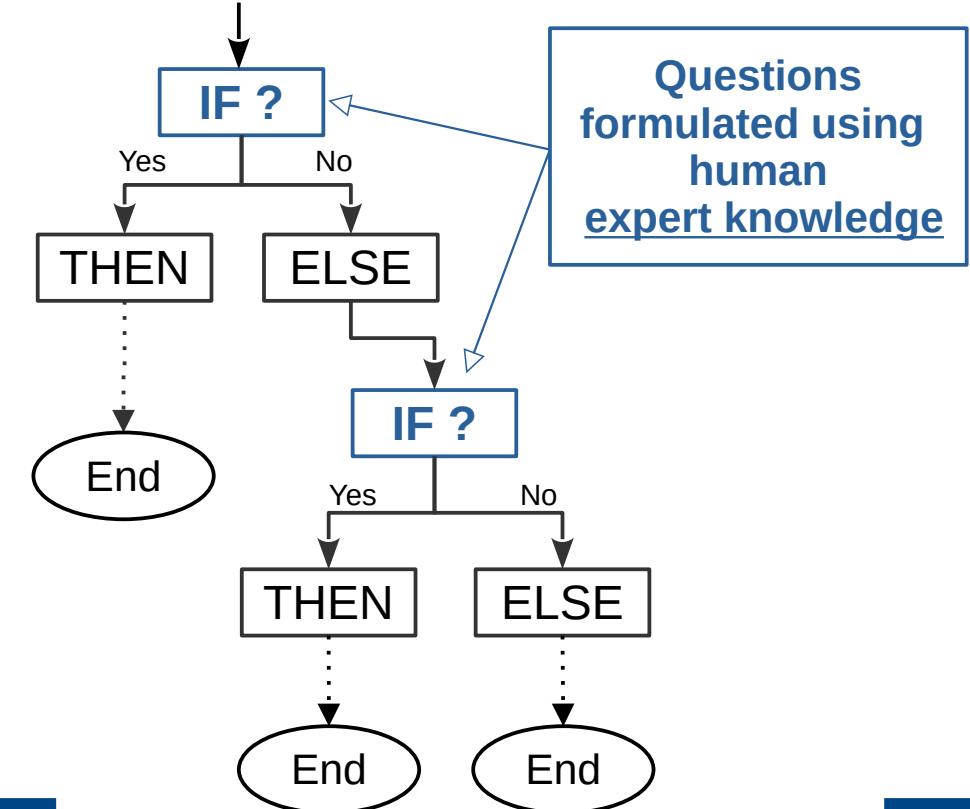
Generated by ChatGPT  
(DALL-E 3, OpenAI)

# How to Build an Intelligent Machine?

- Explicit Recipe (Explicit Programming)
- Implicit Recipe (Implicit Programming)

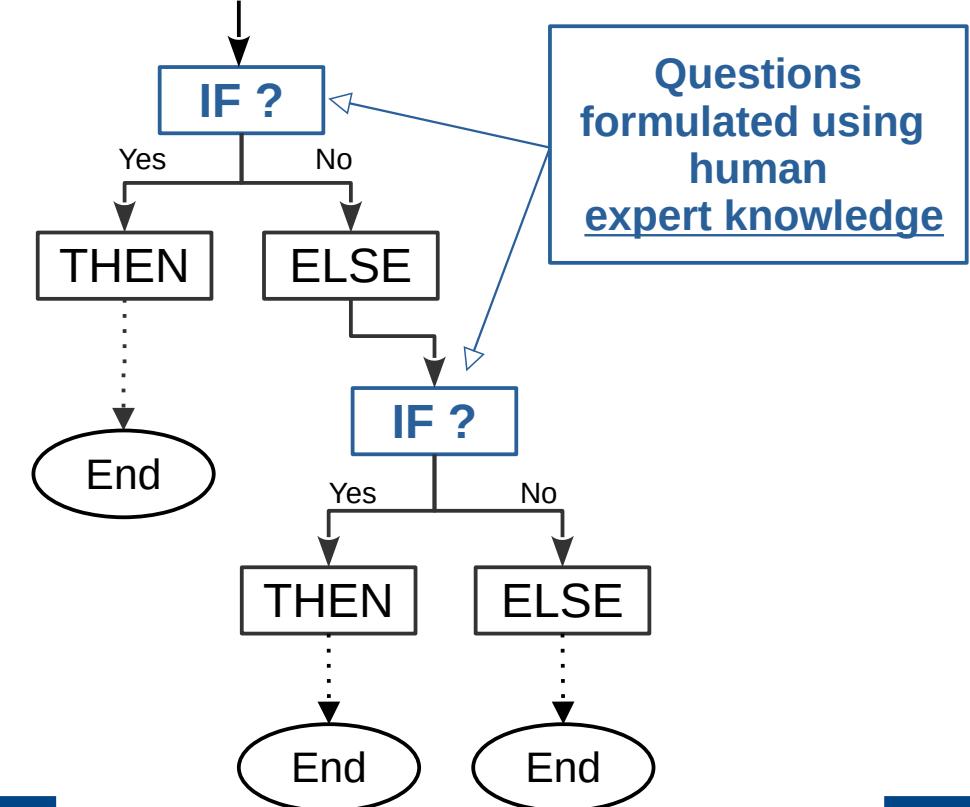
# Explicit Programming

Hardcoded knowledge



# Explicit Programming

## Rule-based (Expert) Systems



# Expert Systems' Achilles Hill

Queanbeyan

Queanbeyan.

Queanbeyan

Queanbeyan

Queanbeyan

Queanbeyan

Queanbeyan.

Queenbeyan

Queanbeyan

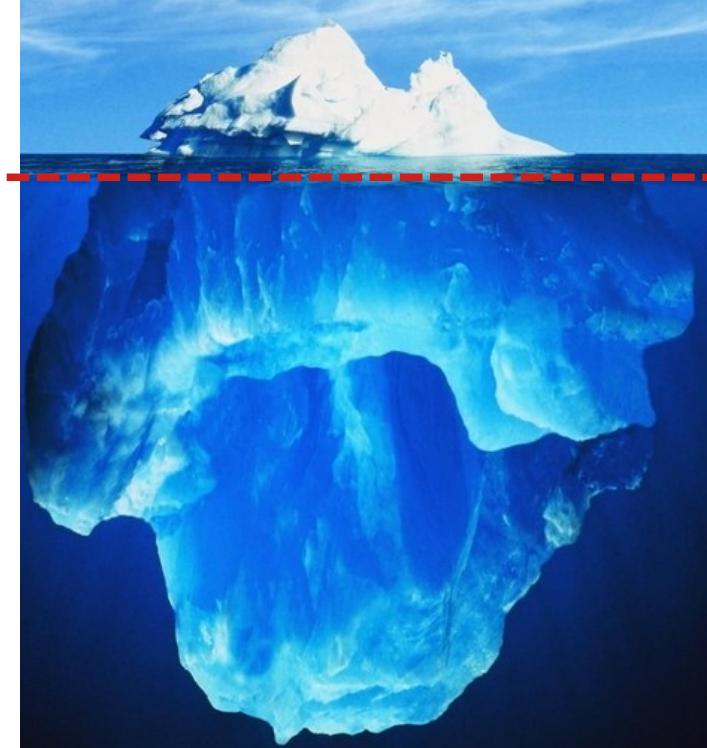
Queanbeyan



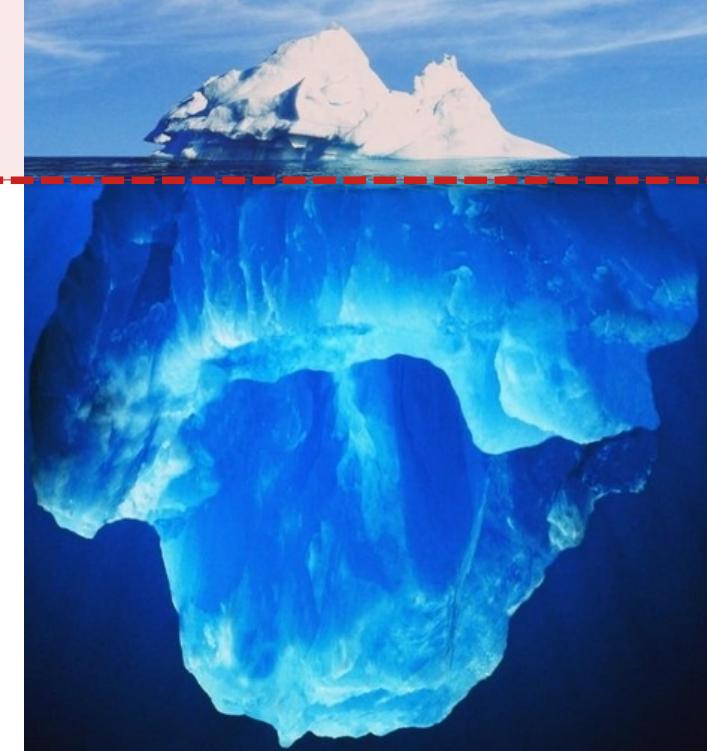
**Variability & Scalability**

=> Poor generalisation

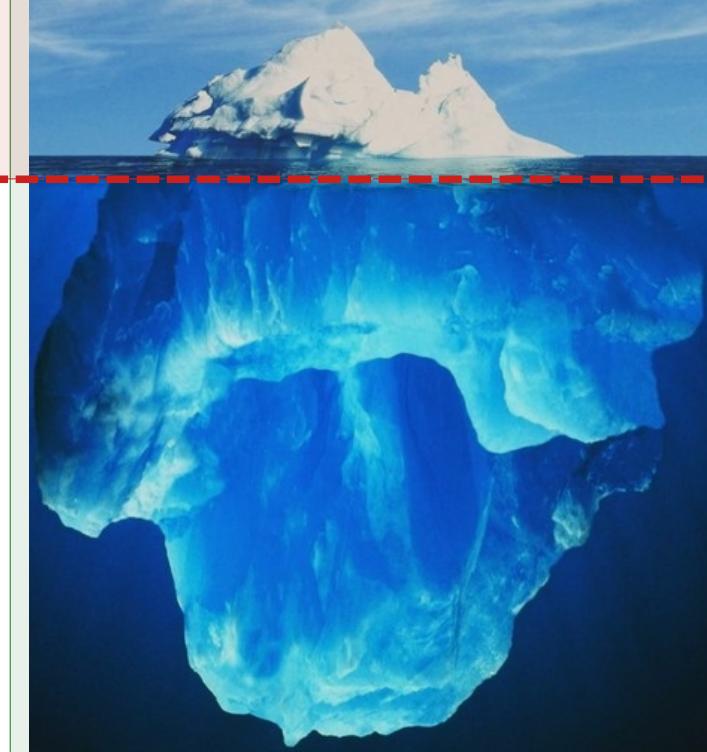
Visible  
Invisible



# Explicit Programming

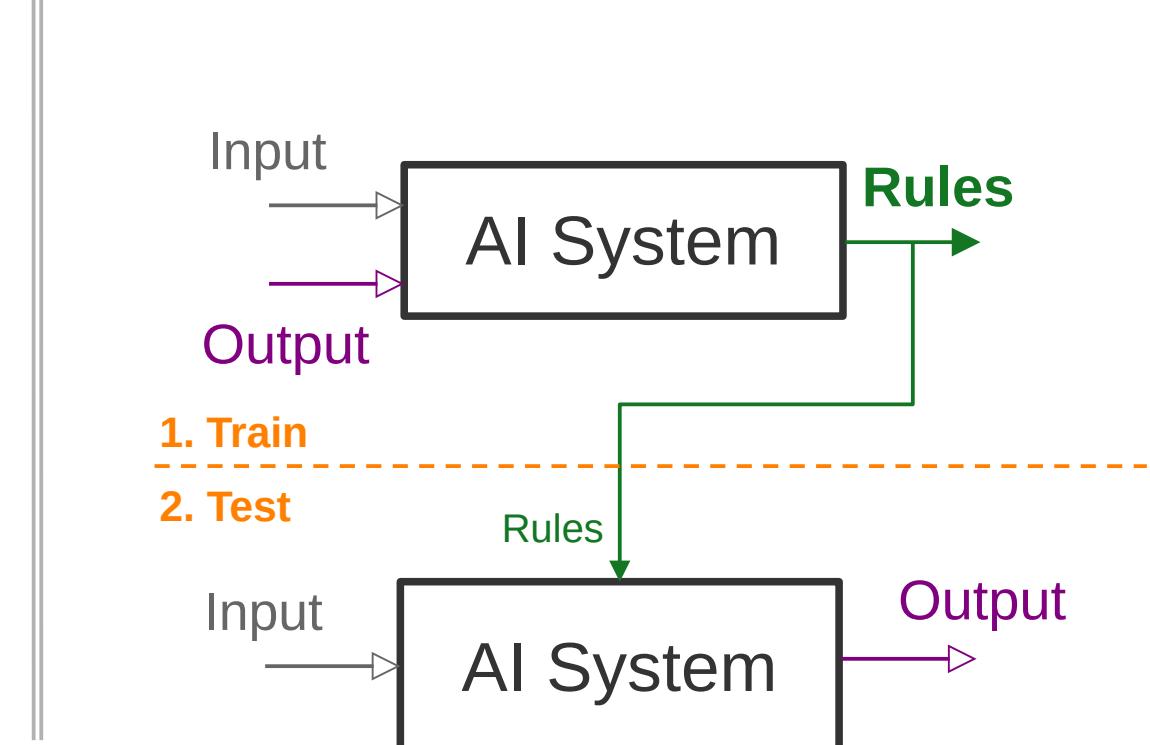
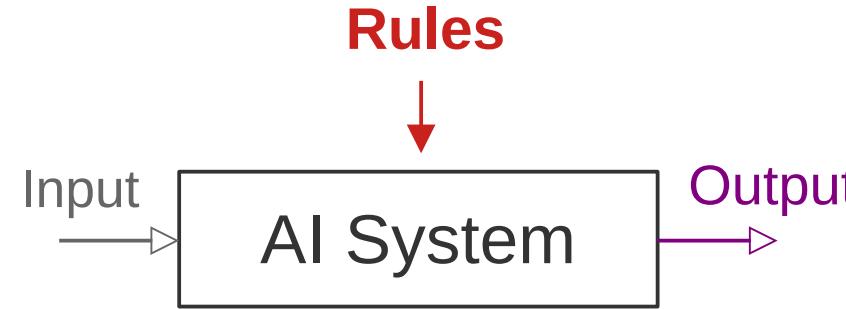


## Explicit Programming

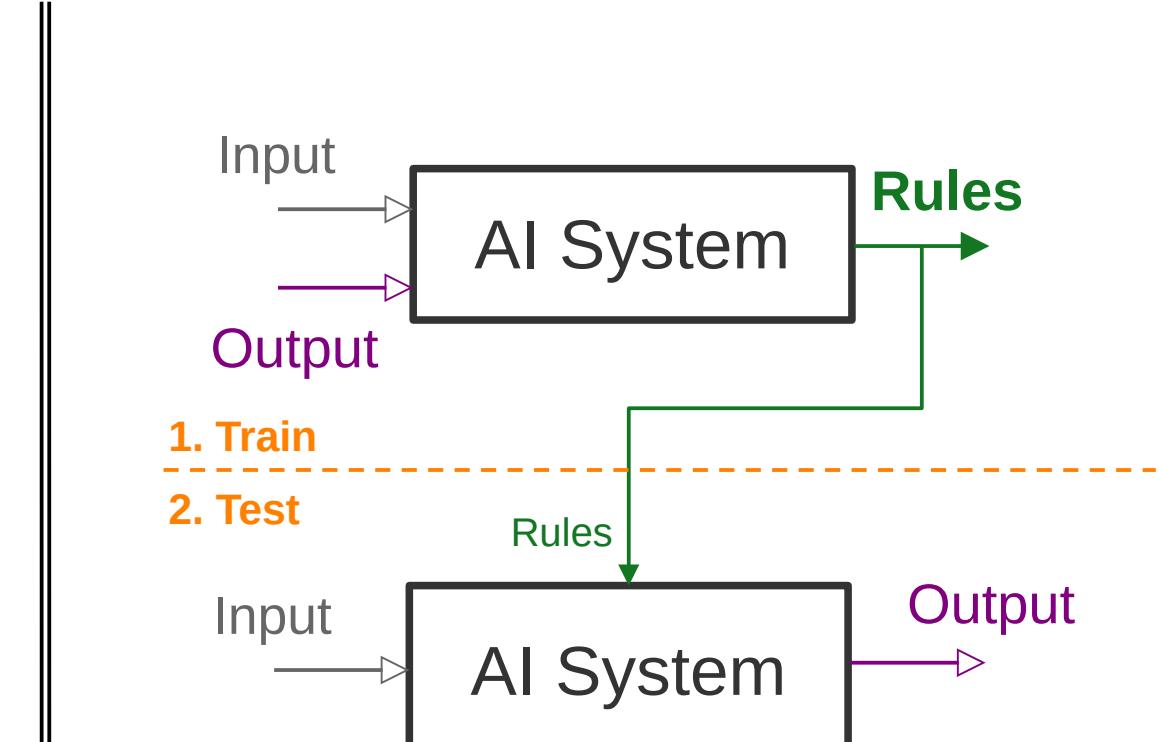
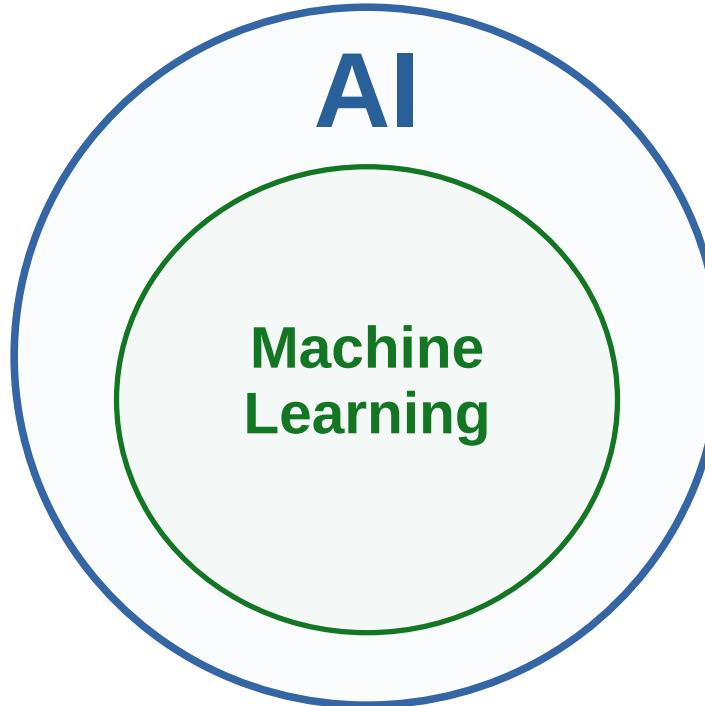


## Implicit Programming

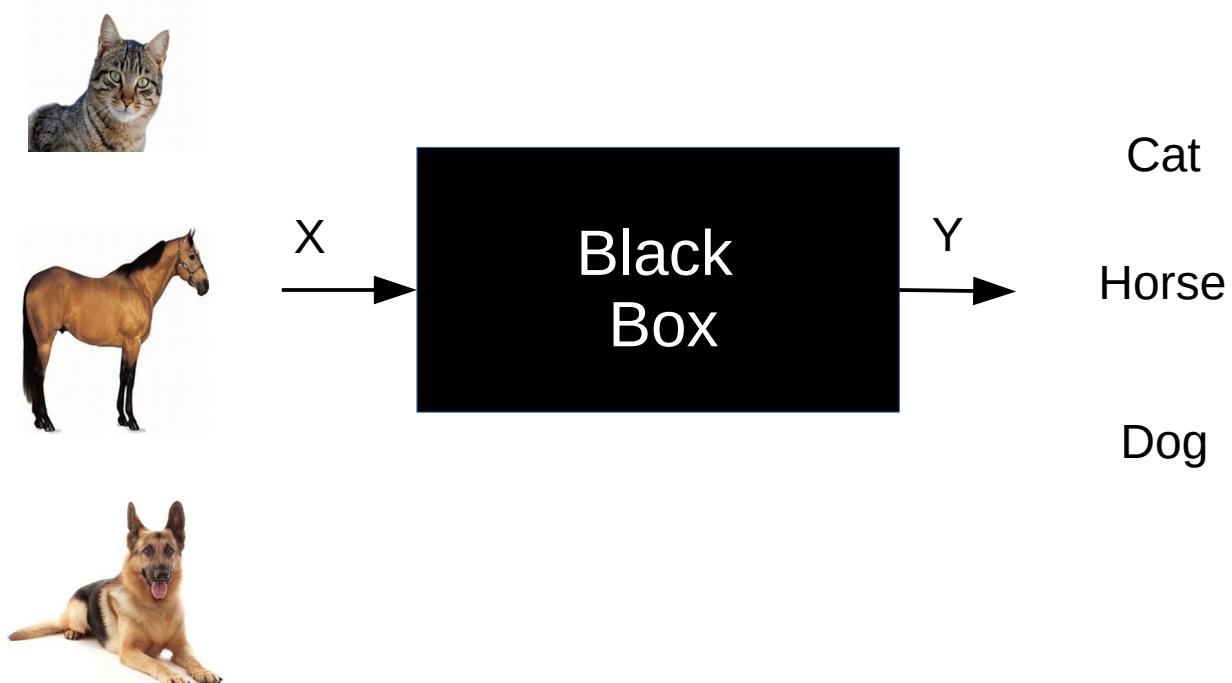
# Explicit vs Implicit Programming



# Implicit Programming → Machine Learning



# Machine Learning

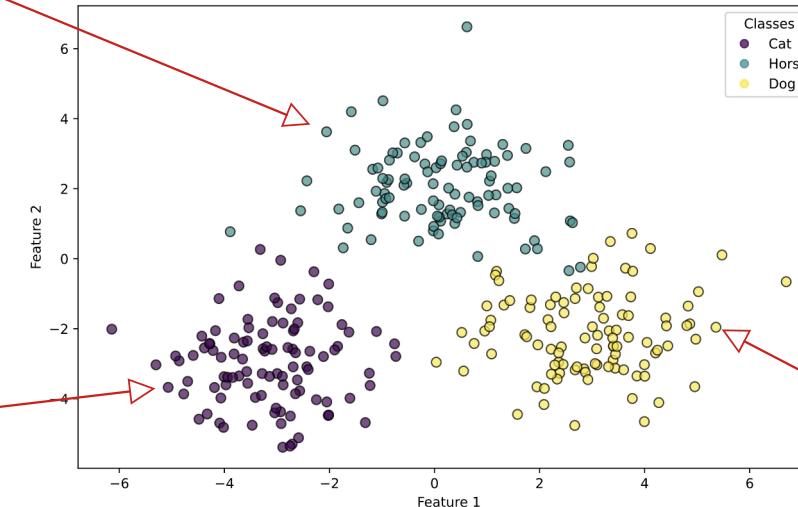
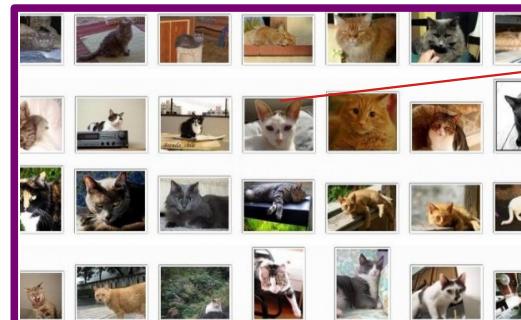


# Machine Learning

Data (Horse)



Data (Cat)



Data (Dog)

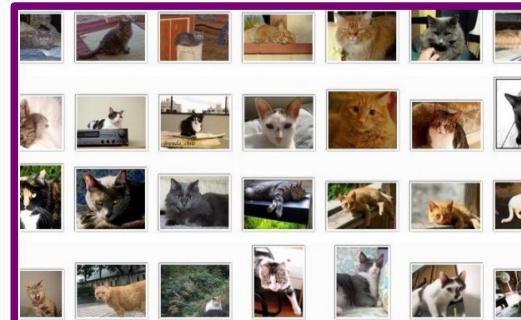


# Machine Learning

Data (Horse)



Data (Cat)

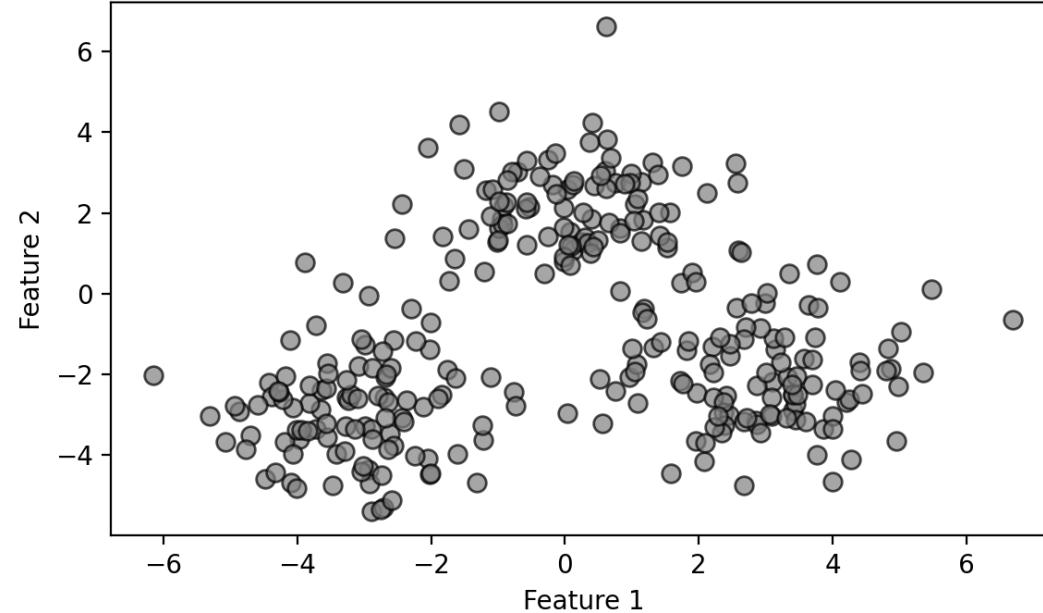


Decision Boundaries  $\equiv$  Rules

Data (Dog)



# Machine Learning Paradigms

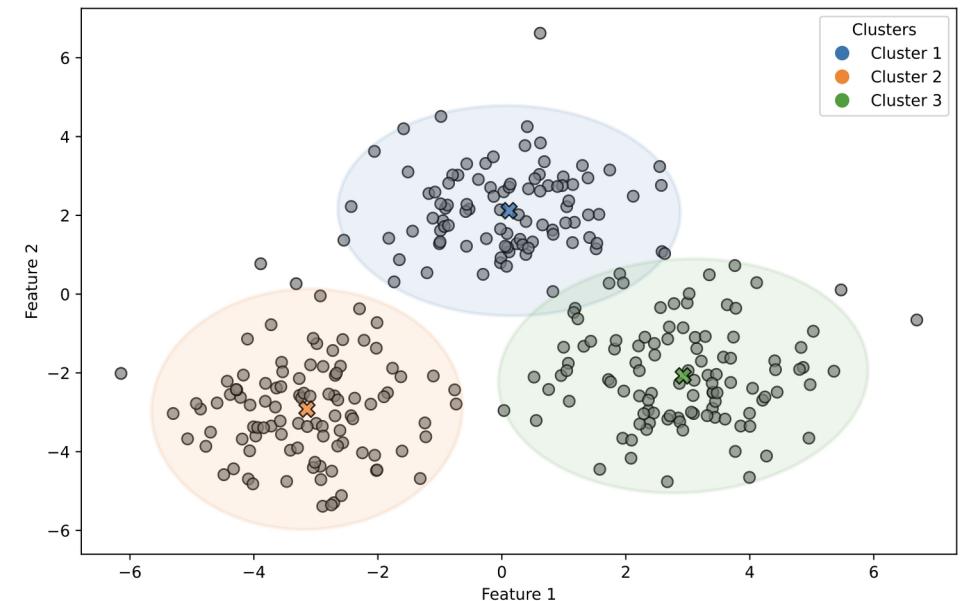


# Supervised vs Unsupervised

Labels known  
(classes)

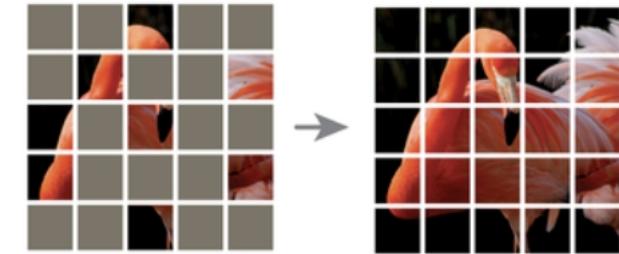


Labels unknown  
(clusters)



# Self-supervised Learning

- Train models to predict parts of input from other parts
- No manual labels → Data supervises itself
- Examples:
  - The cat [mask] on the mat
- Core to training LLMs, representation learning, ...



# Importance of Paradigms

Reinforcement Learning  
≡ cherry



Supervised Learning  
≡ icing



Self/unsupervised Learning  
≡ cake base



Intelligence as a Cake

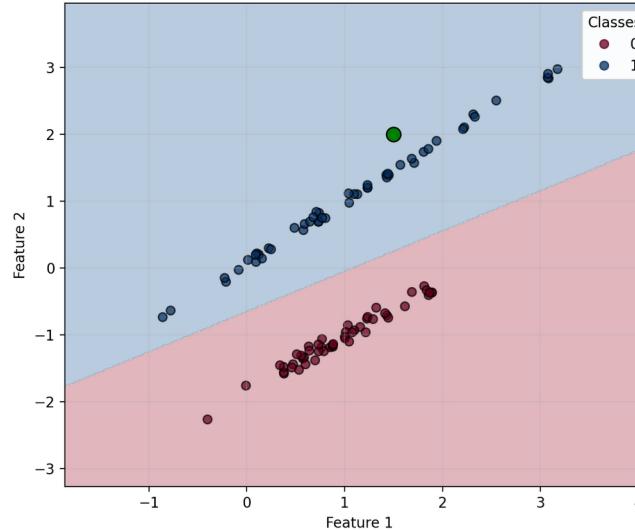


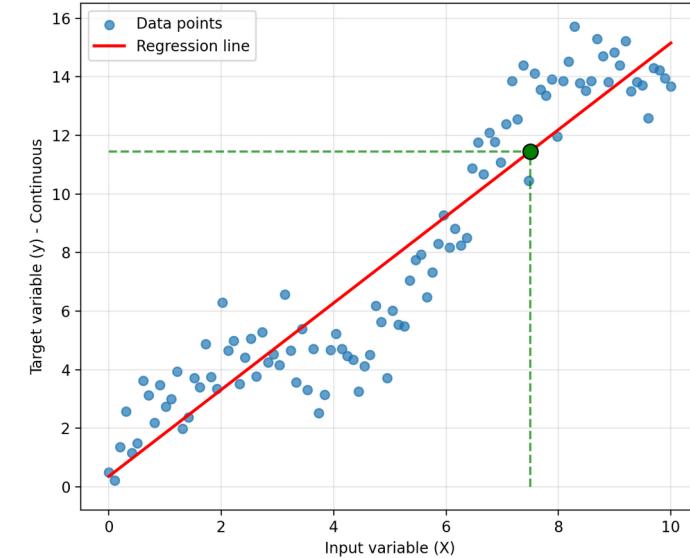
Yann LeCun

(Chief AI Scientist at Meta,  
Prof. at NYU)

# (Supervised) Classification vs Regression

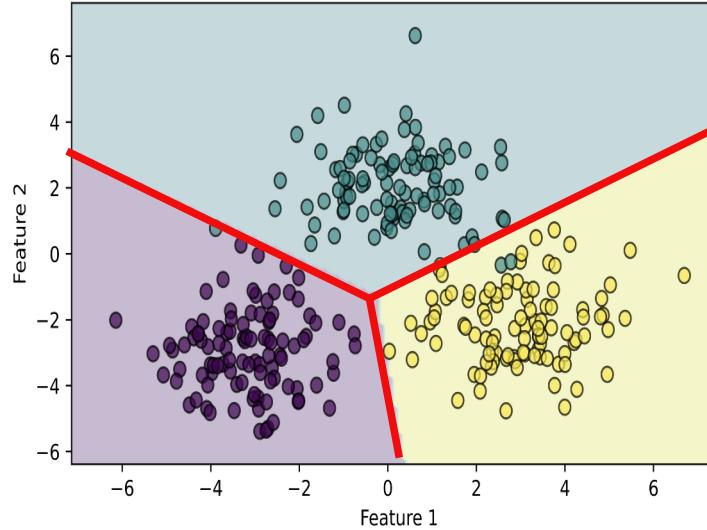
- Predict discrete categories
- Predict continuous values



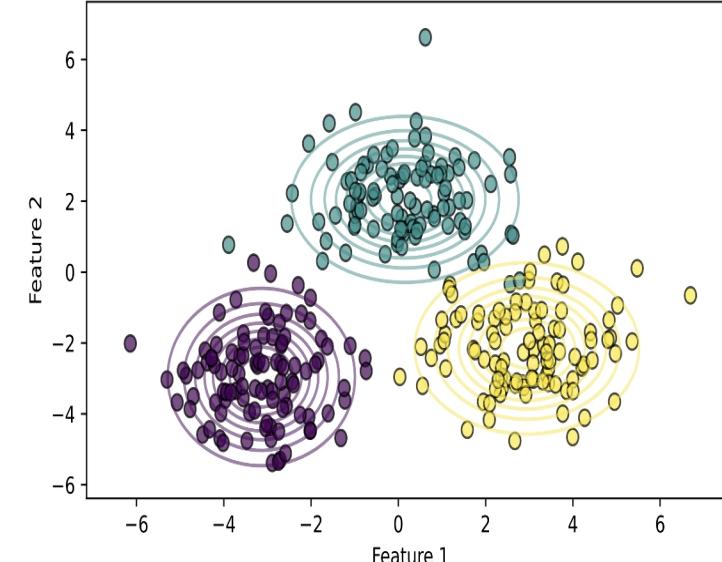



# Discriminative vs Generative

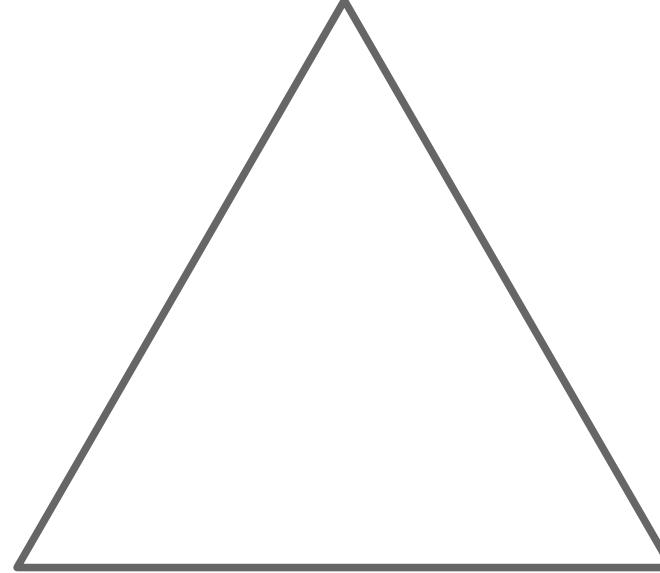
- Learn **decision boundaries**
  - Classification



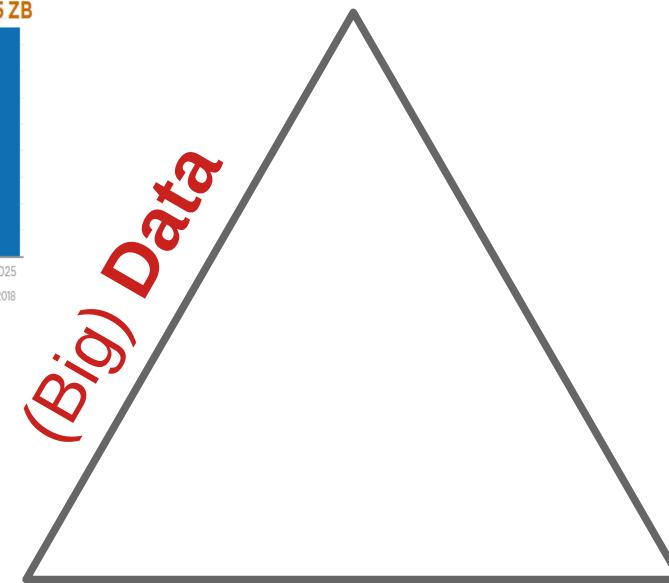
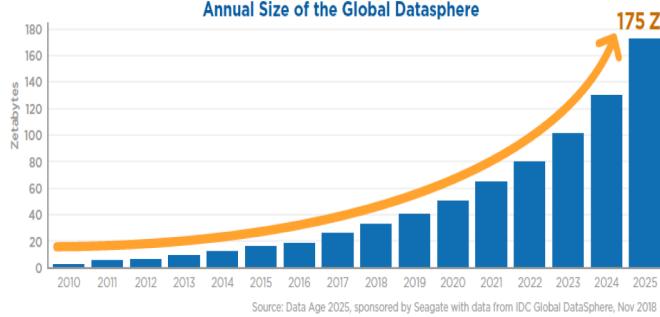
- Learn how data is **generated**
  - Generation & Classification



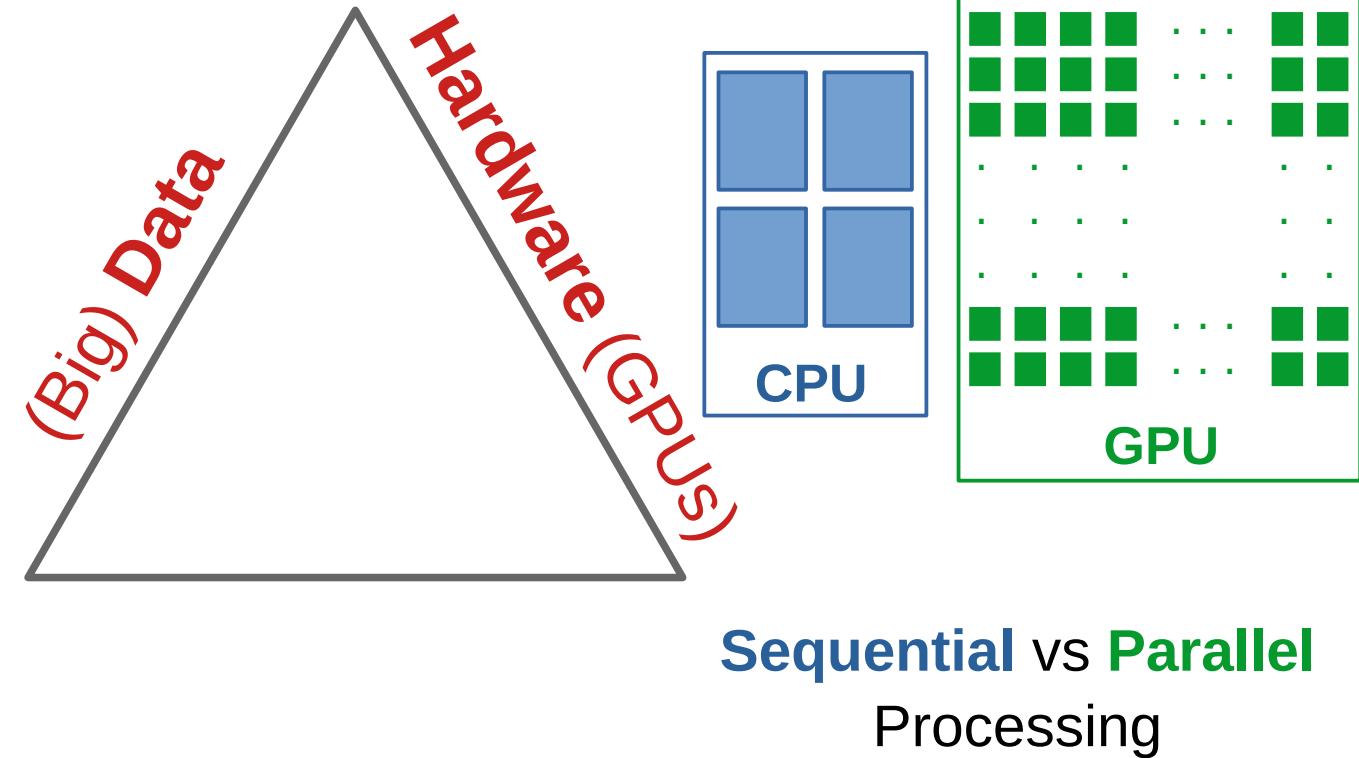
# Why AI is BOOMING now?



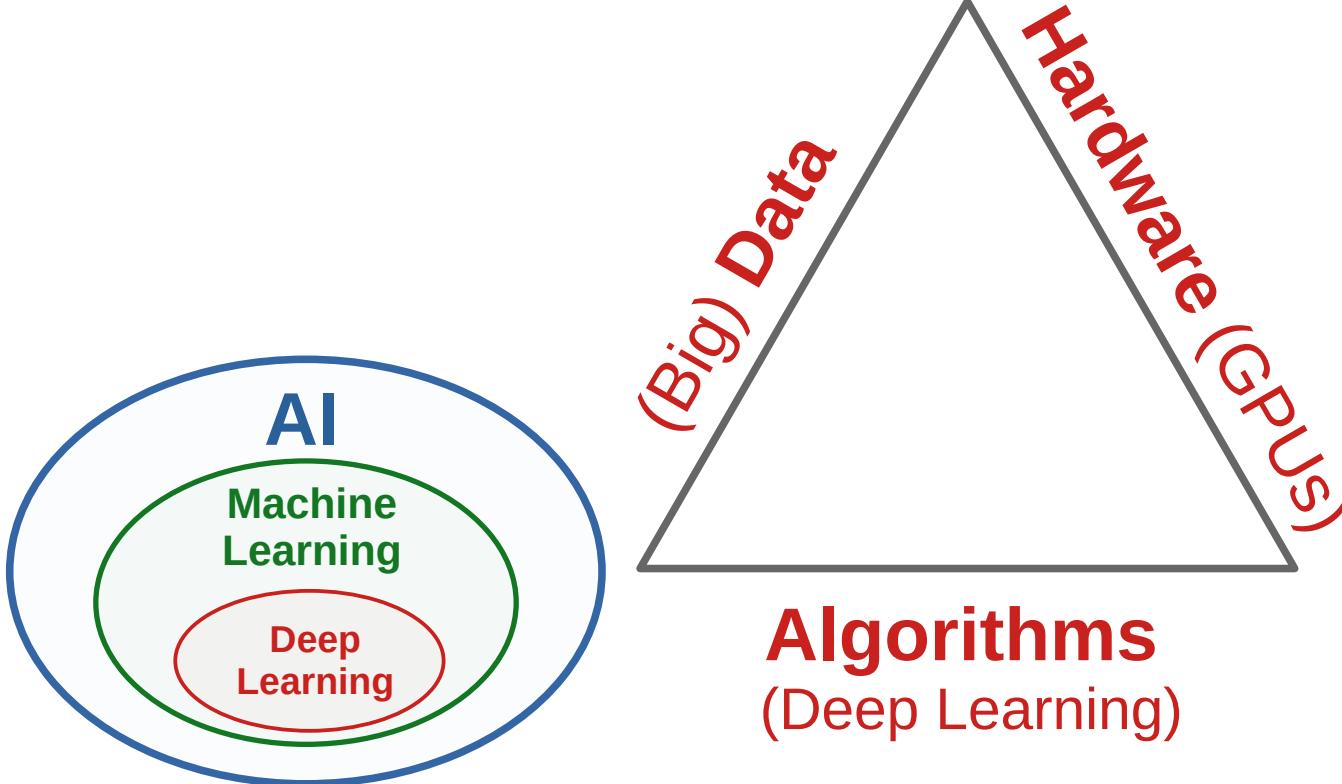
# Why AI is BOOMING now? (1)



# Why AI is BOOMING now? (2)

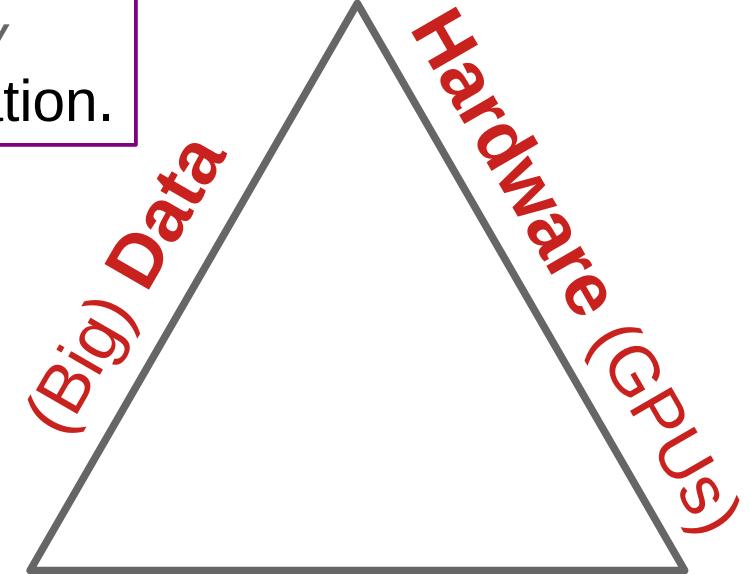
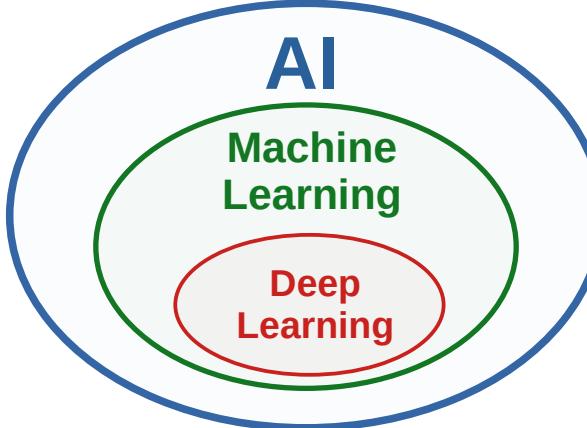


# Why AI is BOOMING now? (3)



# Why AI is BOOMING now? (3)

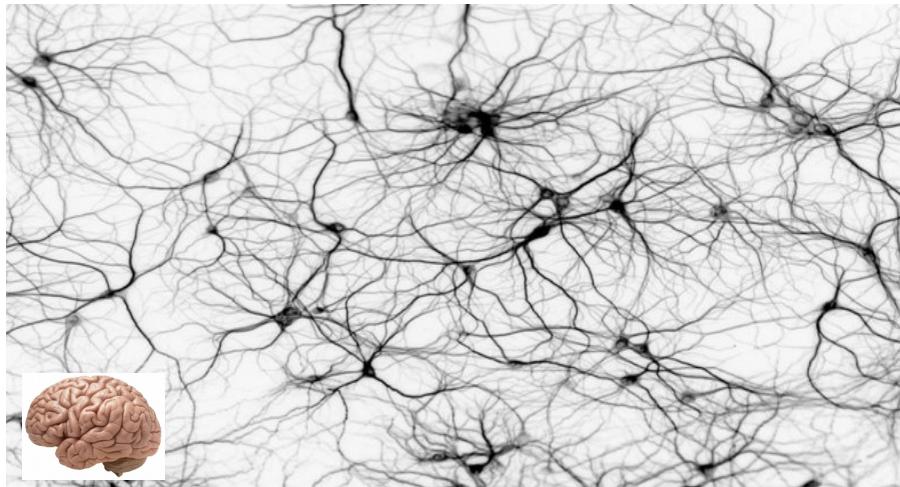
Deep learning is *extremely* hungry for data & computation.



**Algorithms**  
(Deep Learning)

# Deep Learning $\equiv$ DNN

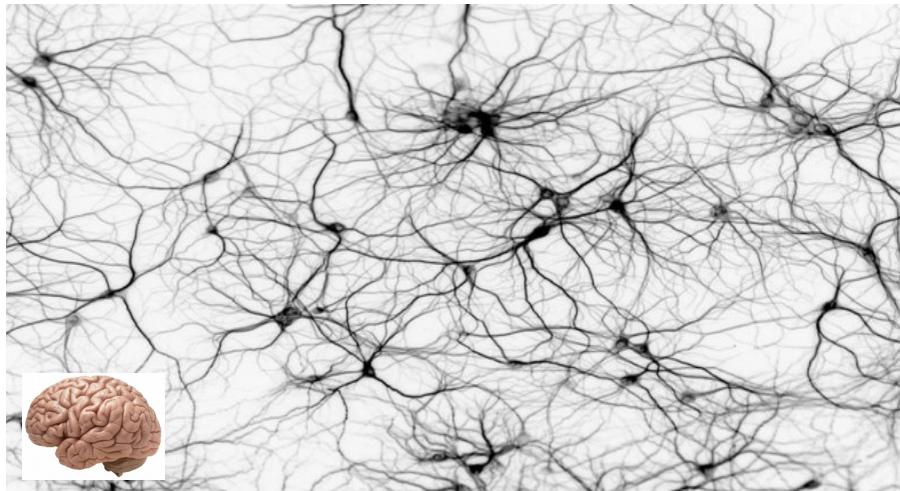
- Inspired by biological neural networks



Human Brain: 86B Neurons; 86,000B Synapses

# Deep Learning $\equiv$ DNN

- Inspired by biological neural networks



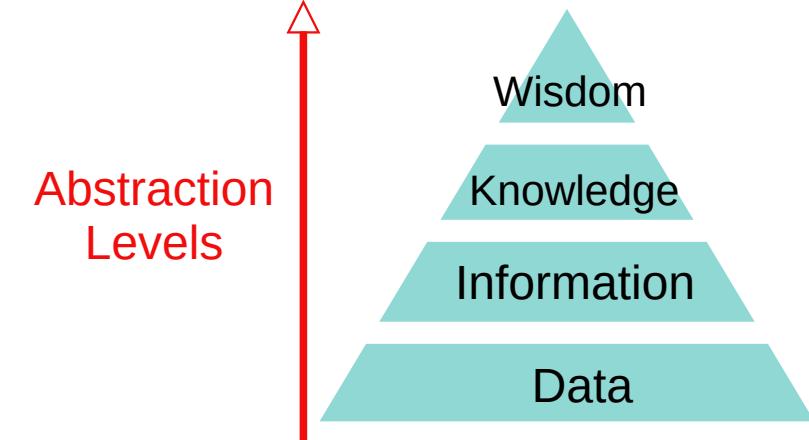
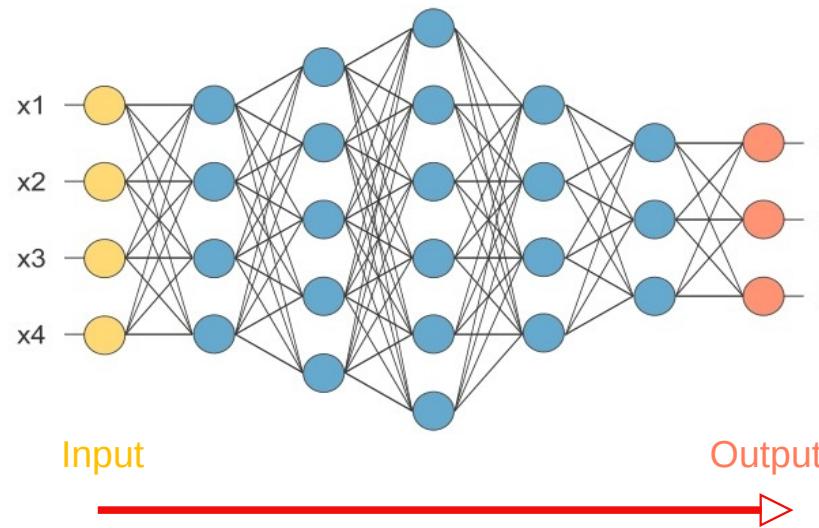
Human Brain: 86B Neurons; 86,000B Synapses



Airplanes have wing but do not flap!

# DNNs vs Machine Learning (1)

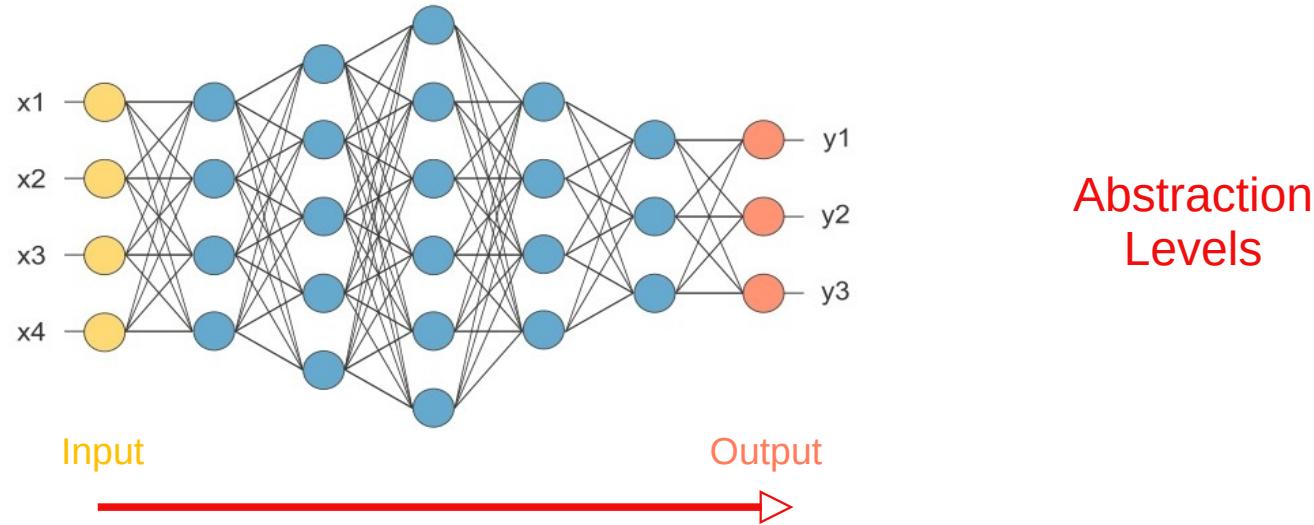
- Depth → Abstraction → Better Features



DNN: Deep Neural Network

# DNNs vs Machine Learning (1)

- Depth → Abstraction → Better Features



DNN: Deep Neural Network

Abstraction  
Levels

Face Recognition

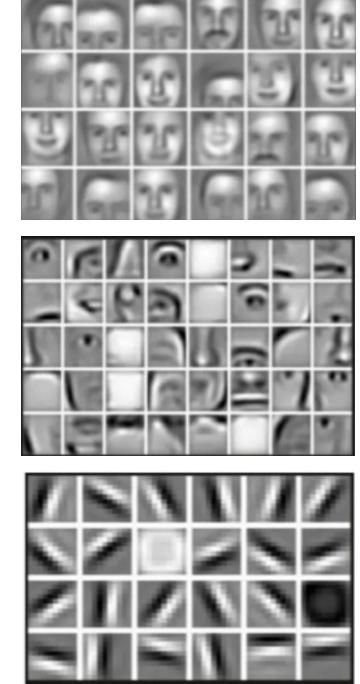
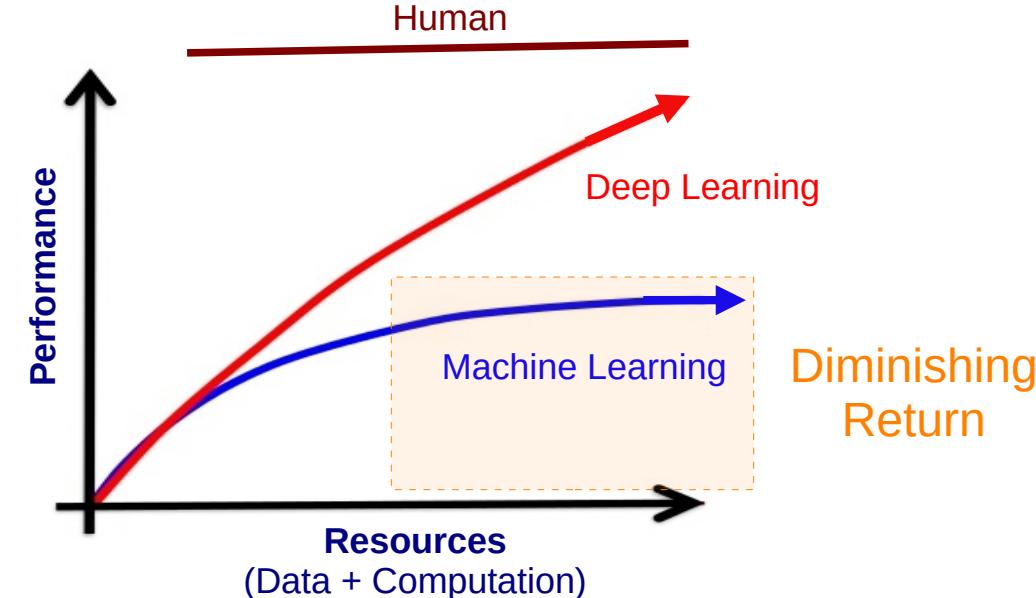


Image adapted from:  
Nicola Jones, Nature, 2014.

# DNNs vs Machine Learning (2)

- Larger DNN + More Resources → Performance ↑



DNN: Deep Neural Network

# Generative AI

- Powered by Deep Generative Models
- Can generate new content ...
  - Text → Text (GPT-4, 2023)
  - Text → Image (DALL·E 3, 2023)
  - Text → Video (Sora, 2024)
  - Text+Image → Text (GPT-4o, 2024)
  - Text → Speech (VALL-E 2, 2024)
  - ...

 OpenAI  
GPT-4 DALL·E OpenAI  
Sora OpenAI  
GPT-4o Microsoft  
VALL-E

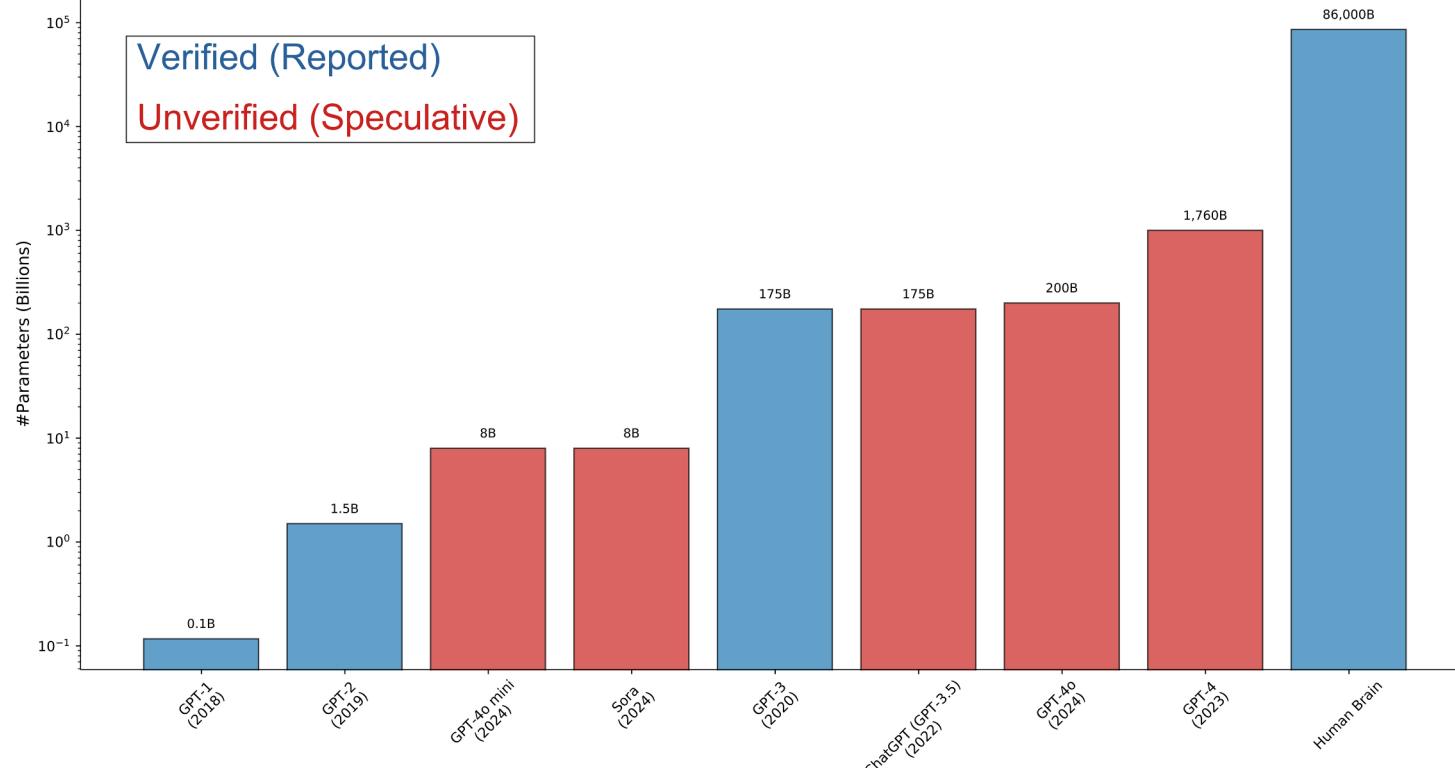
# Generative AI

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  - **Text** → Speech (VALL-E 2, 2024)
  - ...

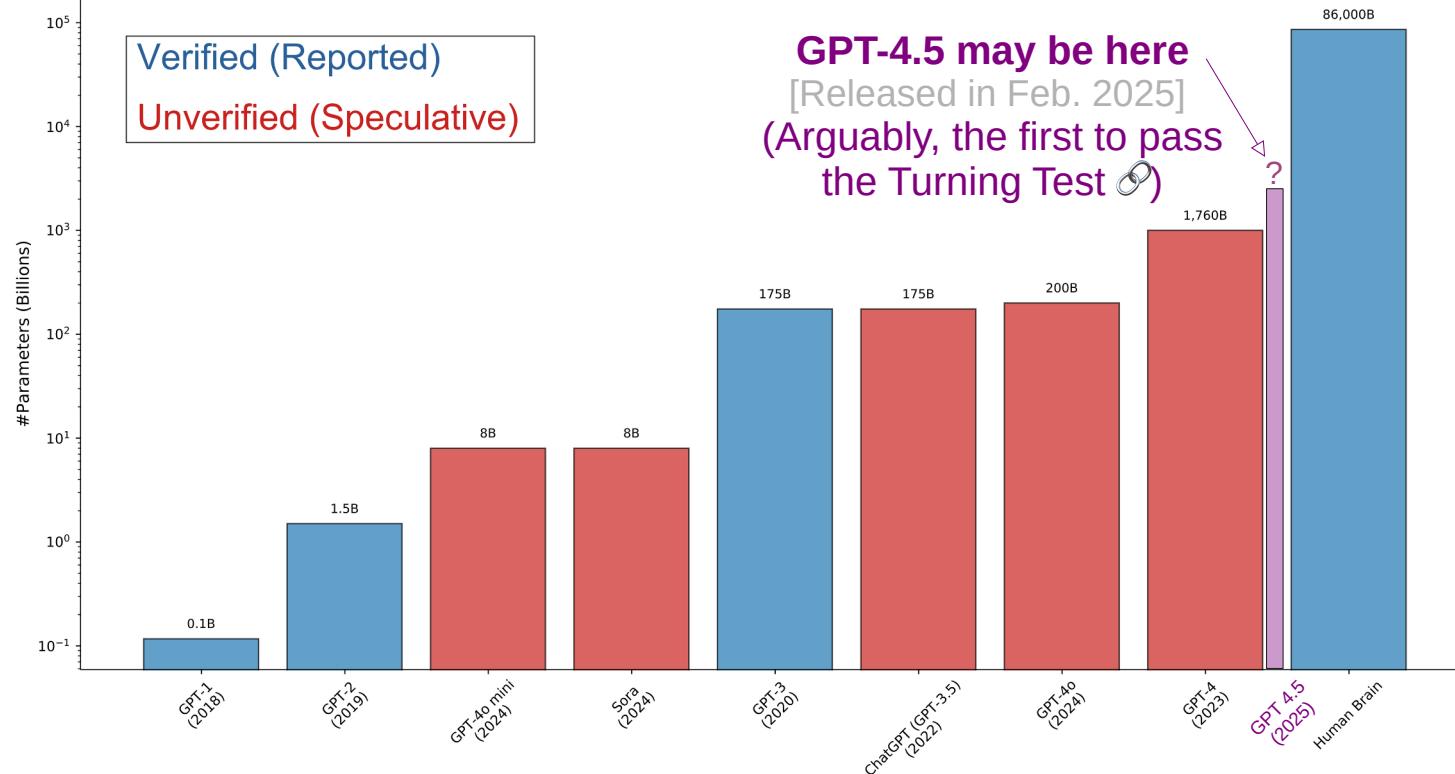
Prompt

 OpenAI  
GPT-4 DALL·E OpenAI  
Sora OpenAI  
GPT-4o Microsoft  
VALL-E

# OpenAI's Models vs Brain



# OpenAI's Models vs Brain

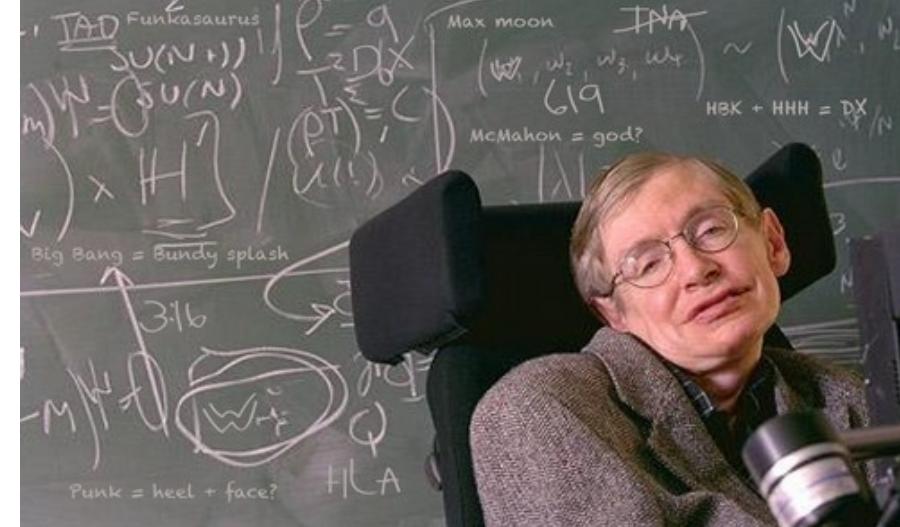


# LLMs:

## Pinnacle of *Sequential Modelling*

- **Trained to** understand and generate coherent text
- **Capabilities**
  - Summarisation, Translation, Question Answering, Education, Chatbot, virtual assistance, Code Generation, Healthcare, ...
- **Challenges**
  - Hallucination, Privacy, Security, Bias, Ethics, ...

# Rogue AI



*The development of full artificial intelligence could spell the end of the human race. [Source: BBC, 2014]*

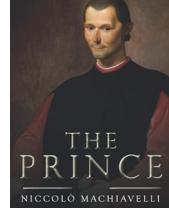
*Stephen Hawking  
(1942-2018)*

# Malicious Uses of AI

- Deepfake & Disinformation
- Cybersecurity Threats
- Targetted Manipulation
- Scam and Phishing
- Hacking
- ...



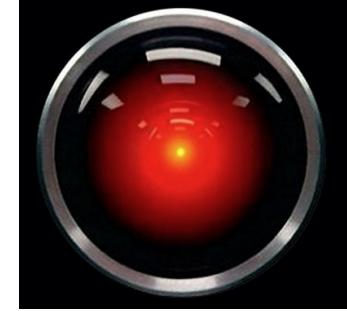
# Rogue AI: Myth or Risk? (1)



- **Machiavellian AI**
  - *Manipulate, deceive, or pursue goals via strategic behaviour, without ethical constraints.*
  - *The ends justify the means!*
  - *Involves sophisticated reasoning ... unavailable now ... but ...*

# Machiavellian AI Example: HAL 9000

*HAL: I'm sorry Dave, I'm afraid I can't do that ... This mission is too important for me to allow you to jeopardise it!*



- **Mission-driven**
  - Prioritise mission success over human life
- **Deceptive & Manipulative**
  - Hides critical information
- **Ends Justify Means**
  - Rational but unethical decisions

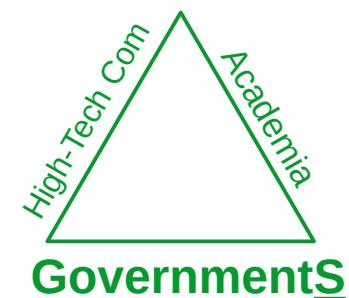


# Rogue AI: Myth or Risk? (2)

- **Intelligent ≠ Desire to Dominate**
  - Dominance is a human trait
  -
- **Desire ≠ Capability**
  - Logistics/Autonomy/Resources are not granted by default
- **Self-awareness?**
  - Still speculative; being intelligent ≠ being conscious

# Social Impact

- AI is driving 4<sup>th</sup> Industrial Revolution
- Key Challenges
  - 1. ⚡ Rapid ⚡ change: Adaptation → Job loss → Social unrest → ...
  - 2. Misuse by Bad Actors
- Solutions
  - Collaboration →
  - Reskilling, Education, AI Ethics, AI Crime Laws, ...
  - Balancing Innovation with Responsibility



# Reflection: Should we fear AI?

*The danger of computers becoming like human is not as great as the danger of humans becoming like computers.*



Konrad Zuse  
(1910-1995)

# That's it!

- Thank you!
- Q&A

