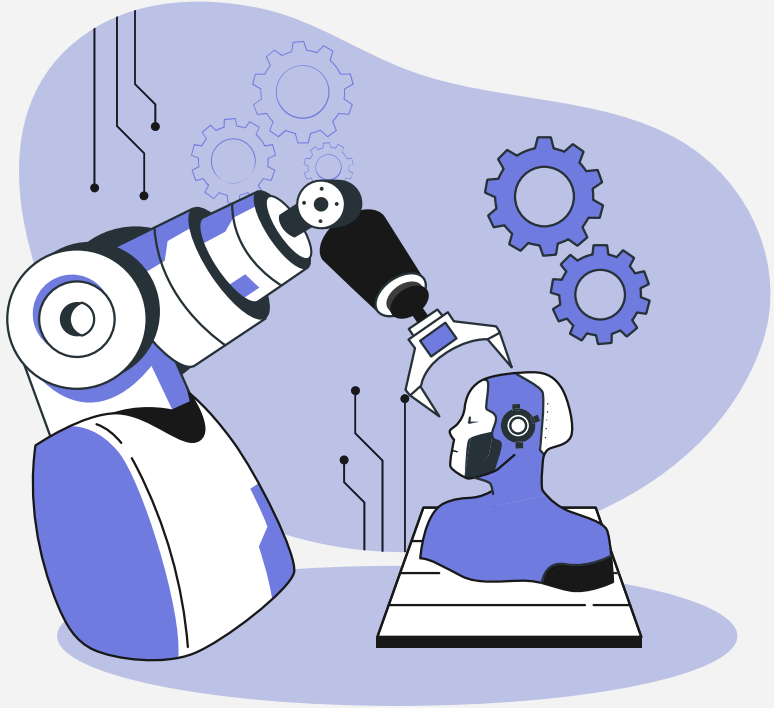
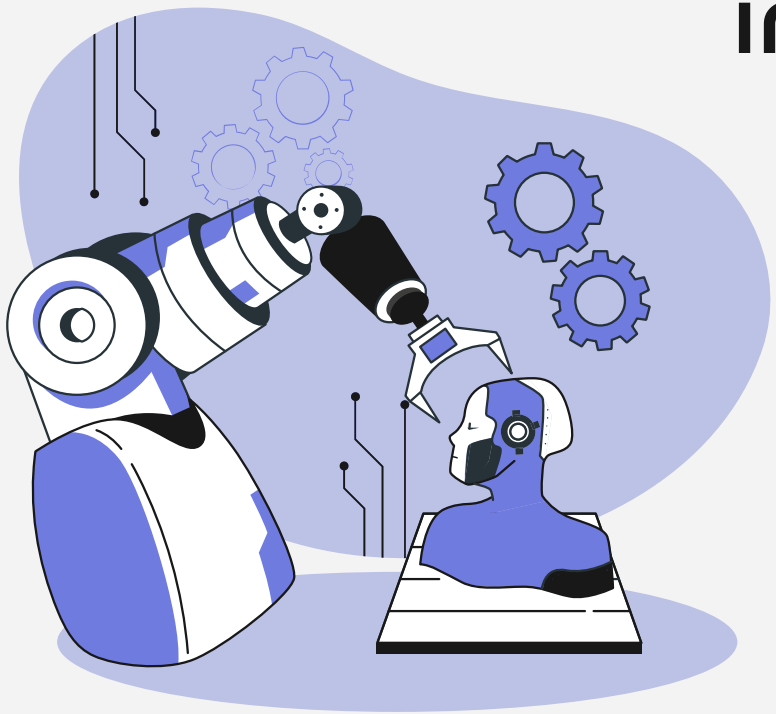
LLM Primer

Nikko Carlo Yabut, MEng AI

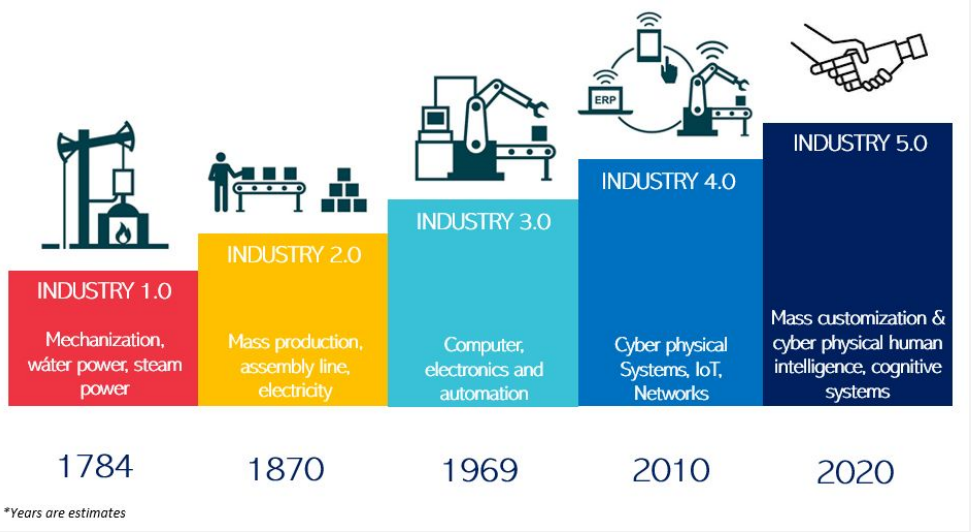


01 Intro

Where are we now in the Industrial Revolution?



Evolution of Industrial Revolution



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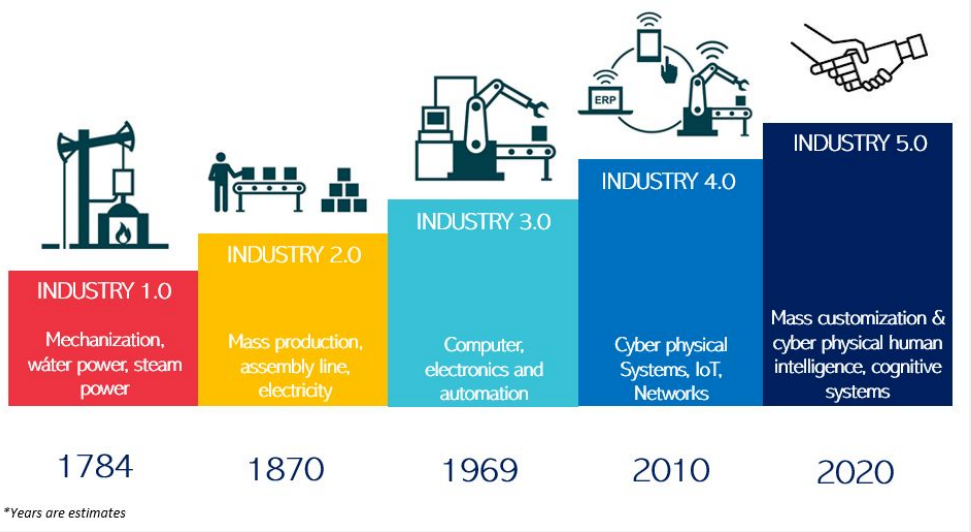
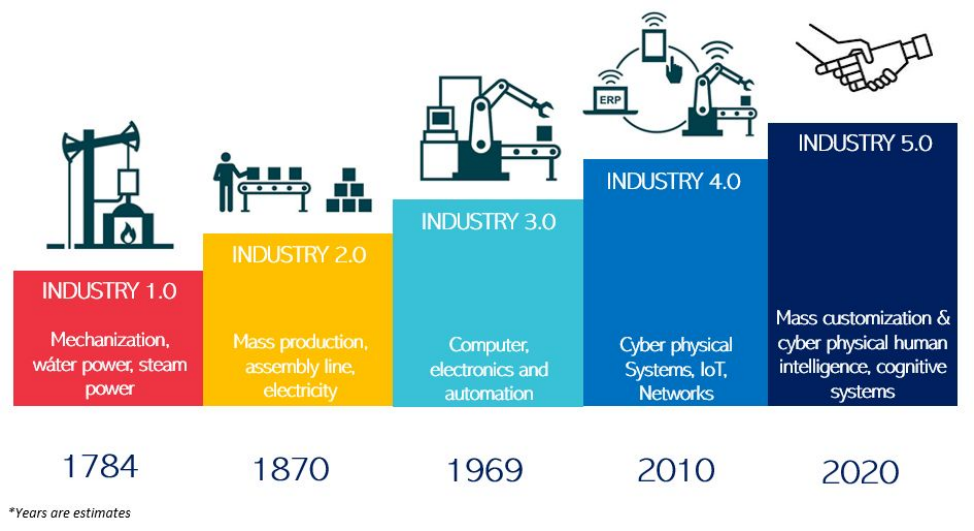
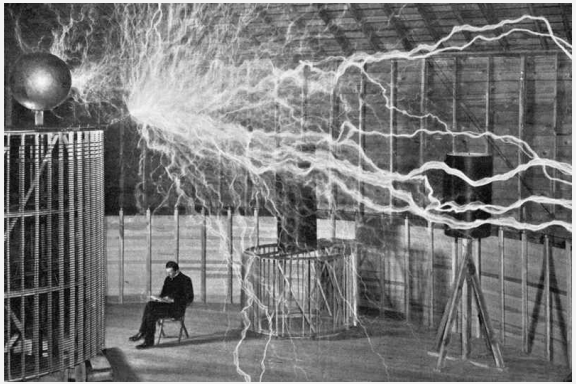


Industry 1.0: The First Industrial Revolution

- **From MANUAL labor to Machines**
- **Key Technology:** Water and steam power.
- **Impact:**
  - Machines transformed manufacturing, starting with textiles in Europe.
  - Fueled by coal, industrial growth expanded significantly.
  - The economy saw a massive boost, and large-scale production became possible.
- **Outcome:** Marked the beginning of large-scale industrialization.

Evolution of Industrial Revolution

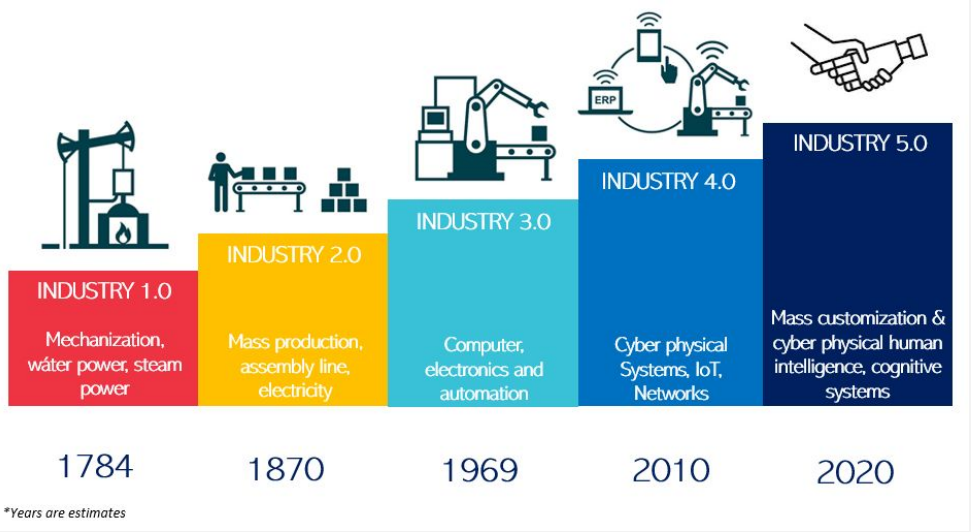




Industry 2.0: The Second Industrial Revolution

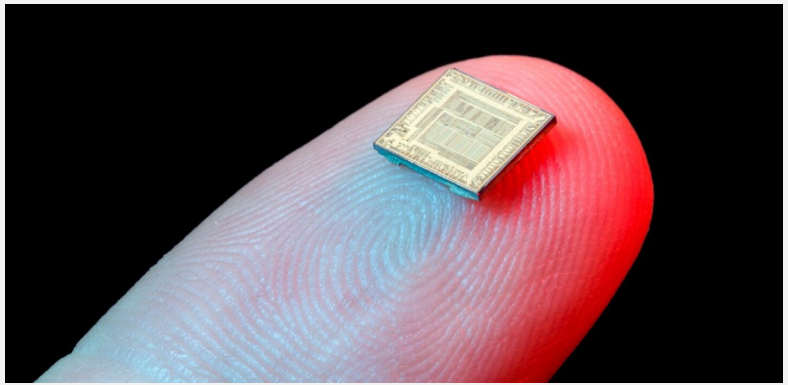
- **Key Technology:** Electrification.
- **Impact:**
  - **Electricity replaced steam** as the primary energy source for machines.
  - Mass distribution of **electricity enabled advanced manufacturing**.
  - Technological advancements included assembly lines, and publications like *The Principles of Scientific Management* emerged.
  - **Led to increased productivity**, meeting the needs of customers, employees, shareholders.
- **Outcome:** Often called the **Technology Revolution** due to the scale of innovation.

Evolution of Industrial Revolution

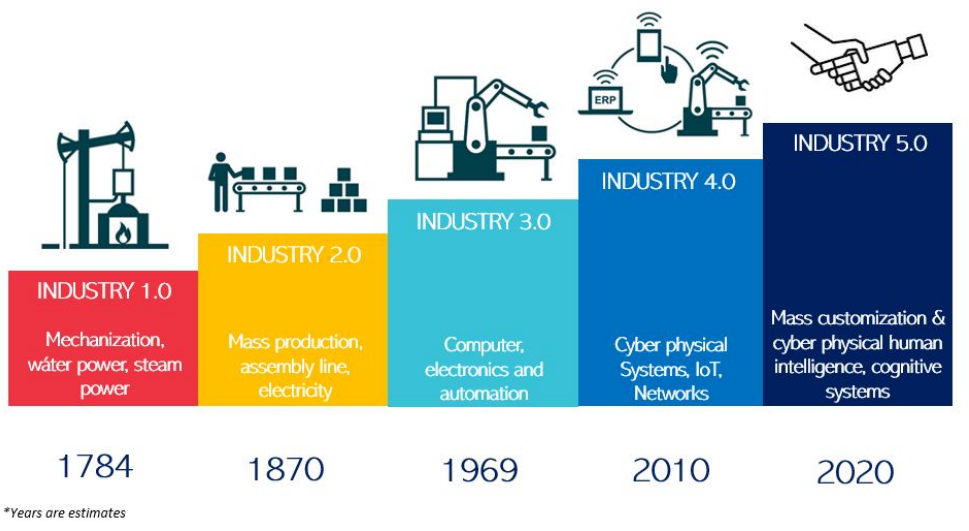


Industry 3.0: The Third Industrial Revolution

- **Key Technology:** Microchips, computers, and automation.
- **Impact:**
  - Introduction of computers facilitated **automation in production.**
  - **Programmable Logic Controllers (PLC)** replaced human workers in assembly lines.
- **Outcome:** Known as the **Information Revolution** or **IT Revolution**, due to the rise of computing and digital technologies.



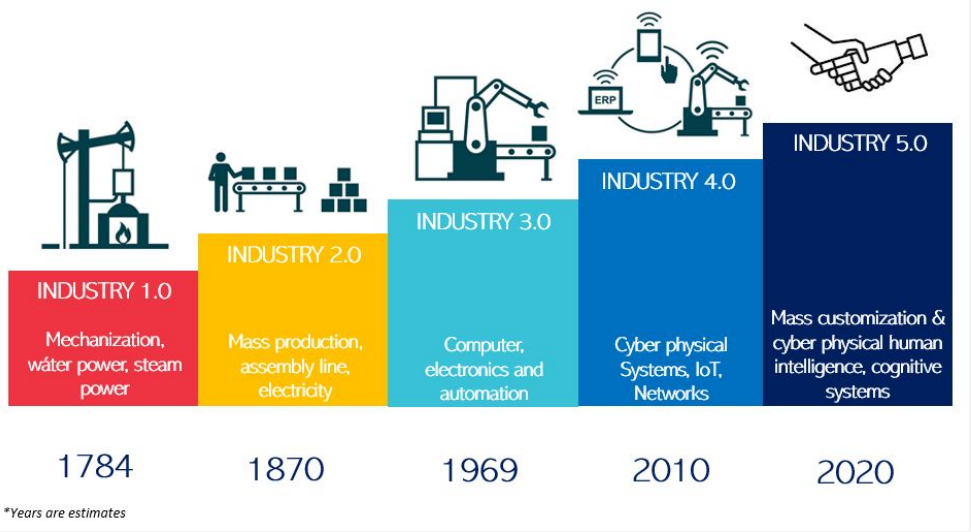
Evolution of Industrial Revolution



Industry 4.0: The Fourth Industrial Revolution

- **Key Technologies:**
  - **Telecommunications (Wireless Comms)**
  - **Internet**
  - **Internet of Things (IoT)**
  - **Cloud Computing**
  - **Big Data**
  - **Robotics**
  - **AI**
- **Impact:**
  - Fully automated production systems where machines communicate, control, and make decisions **without human intervention.**
- **Outcome:** Known as the **Digital Revolution**, reshaping industries and leading to higher levels of efficiency.

Evolution of Industrial Revolution



Industry 5.0: The Fifth Industrial Revolution

- **Time Period:** Emerging (futuristic vision).
- **Key Focus:** Collaboration between human and AI.
- **Impact:**
  - Emphasizes **co-bots** (collaborative robots) working alongside humans.
  - Enhanced efficiency through **human-robot collaboration on the factory floor.**
  - Inspired by Japan's **Society 5.0** concept, where humans and AI deliver business value together.
- **Outcome:** A more human-centric approach.

Evolution of Industrial Revolution

Where are we now in the Industrial Revolution?

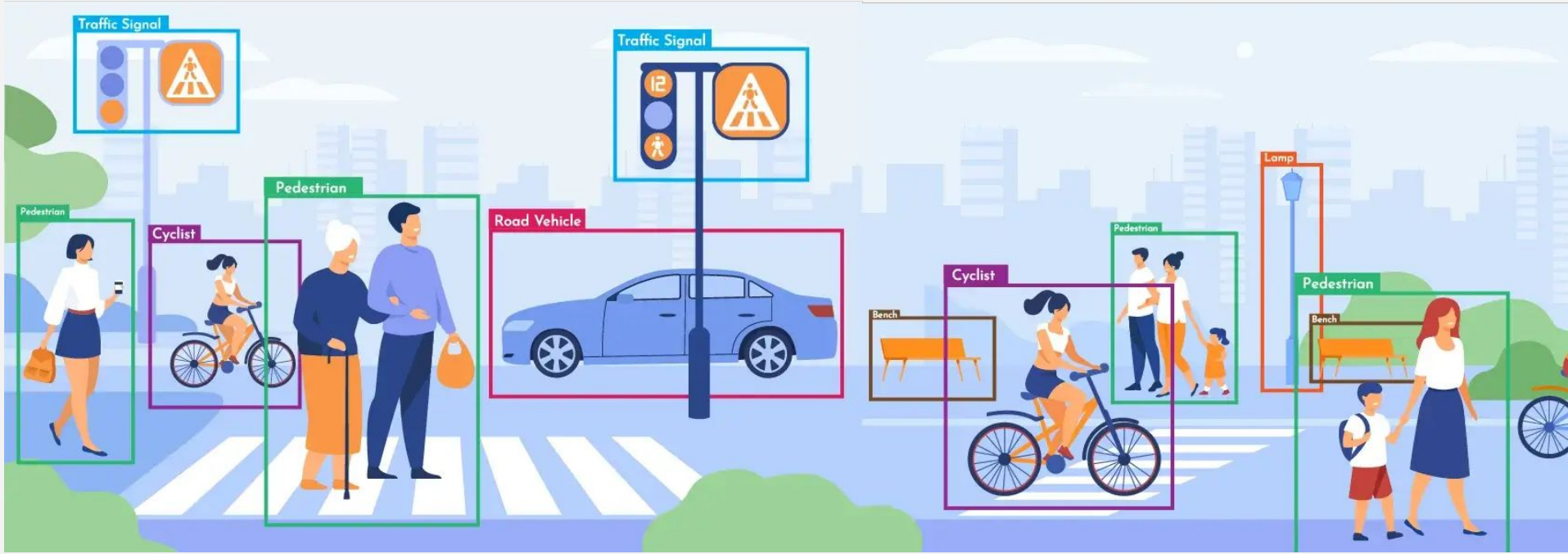
Industry 4.0
(Digital Revolution)

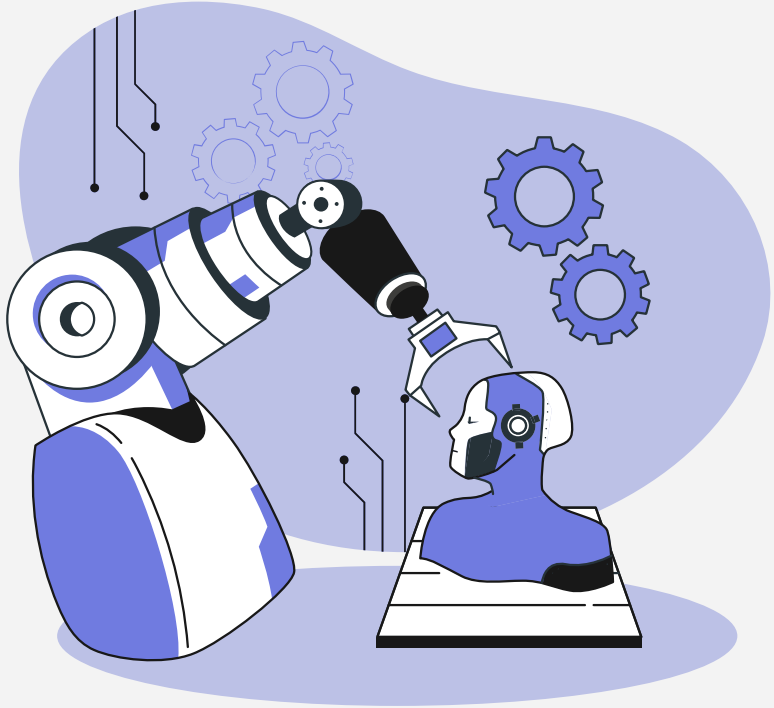
&

Industry 5.0
(Human-AI Collaboration)

Evolution of Industrial Revolution

In this discussion, we will focus on a specific use case of Industry 5.0: LLMs





02
AI, ML, DL, GenAI

Intelligence

A very general mental capability that among other things involves the ability to:

- Reason
- Plan
- Solve problems
- Think abstractly
- Comprehend complex ideas
- Learn from experience

Journal of Intelligence 1997 Vol 24 No 1

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Artificial Intelligence (AI)

A machine has AI capabilities
IF it exhibits **animal** or **human** intelligence

Ants bridging algo

AI, ML, DL, GenAI

Artificial Intelligence

Is the field of study that deals with creation of machine that exhibits animal or human intelligence.

Machine Learning

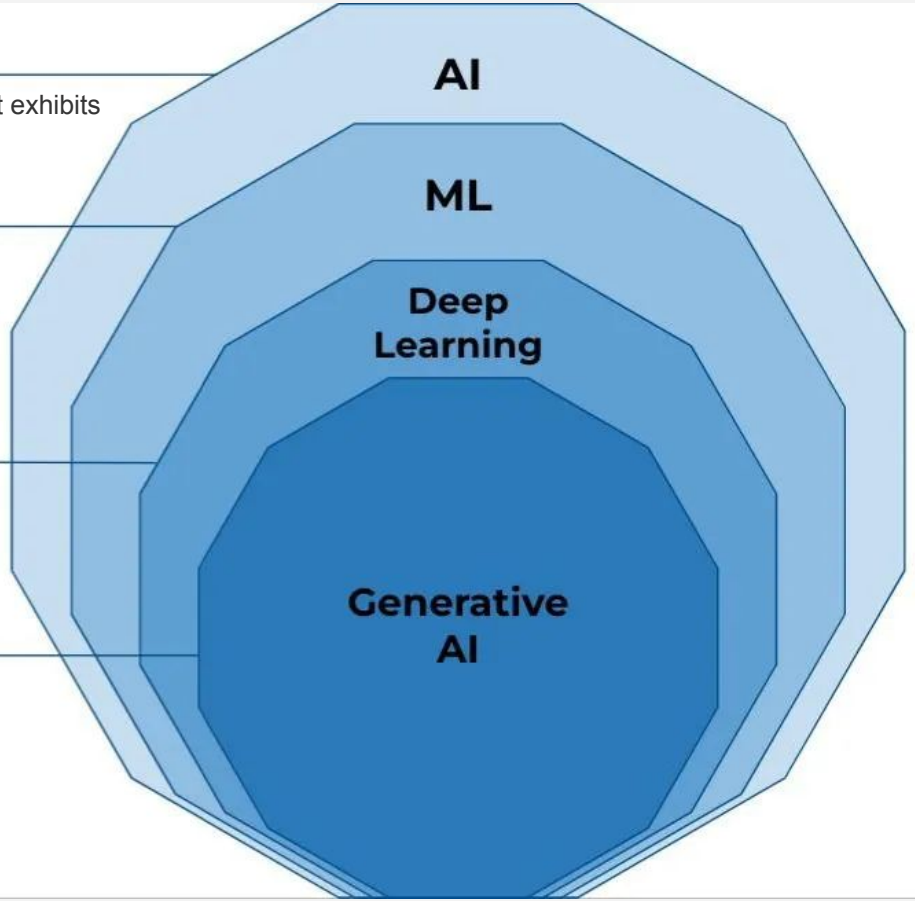
Is a branch of AI that focus on the creation of intelligent machines that learn from data. Another very well know branch inside AI is **Optimization**.

Deep Learning

Is a subset of Machine Learning methods, based on **Artificial Neural Networks.**
Examples: CNNs, RNNs

Generative AI

A type of ANNs that generate data that is similar to the data it was trained on.
Examples: GANs, LLMs



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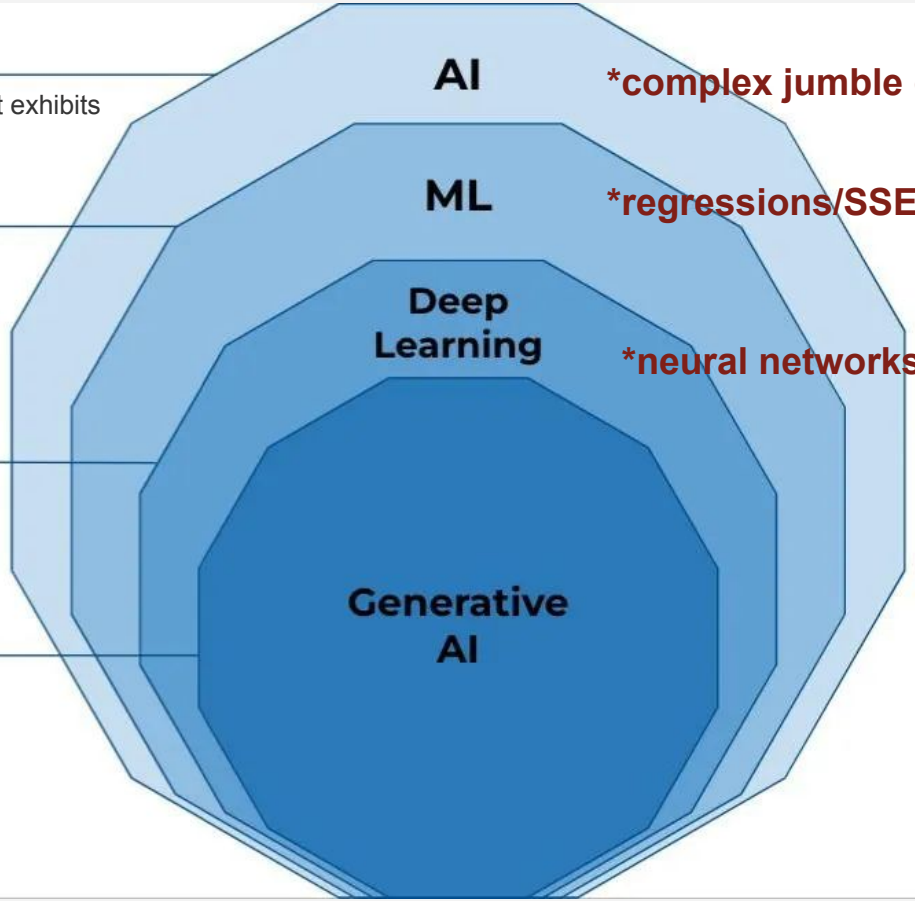


*complex jumble of if/else

*regressions/SSE (linear/log)

*neural networks

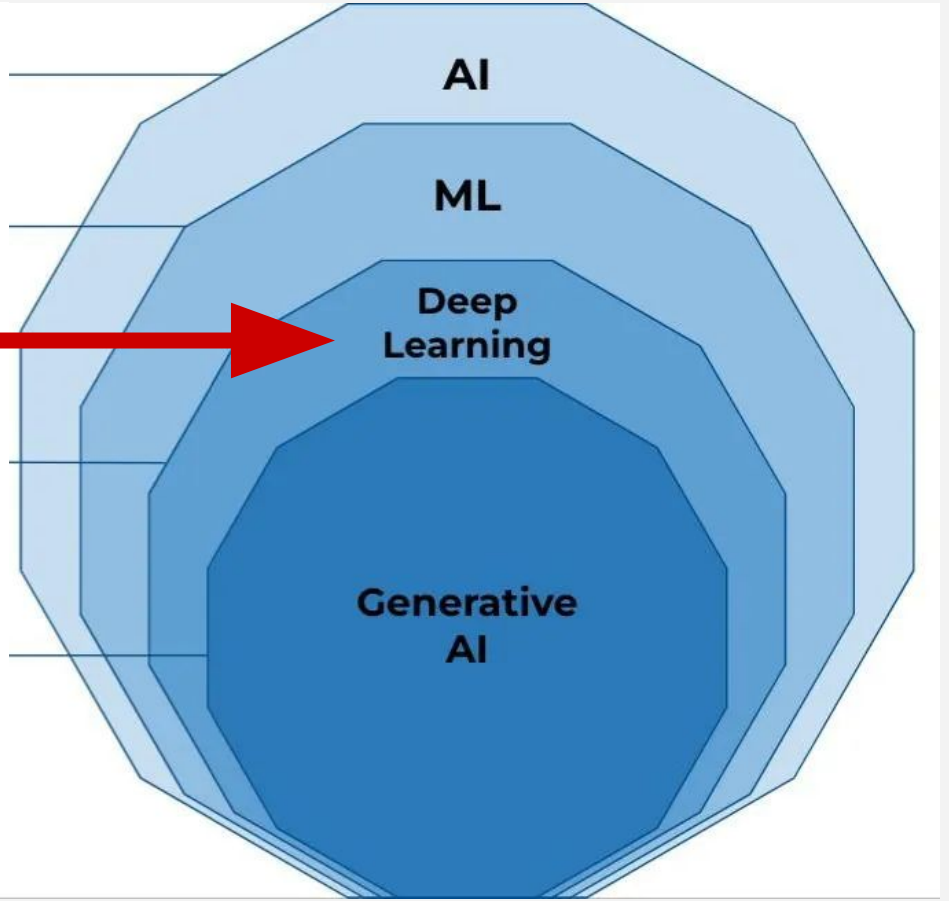
AI, ML, DL, GenAI

The Nobel Prize in Physics 2024

Ill. Niklas Elmehed © Nobel Prize Outreach
John J. Hopfield
Prize share: 1/2

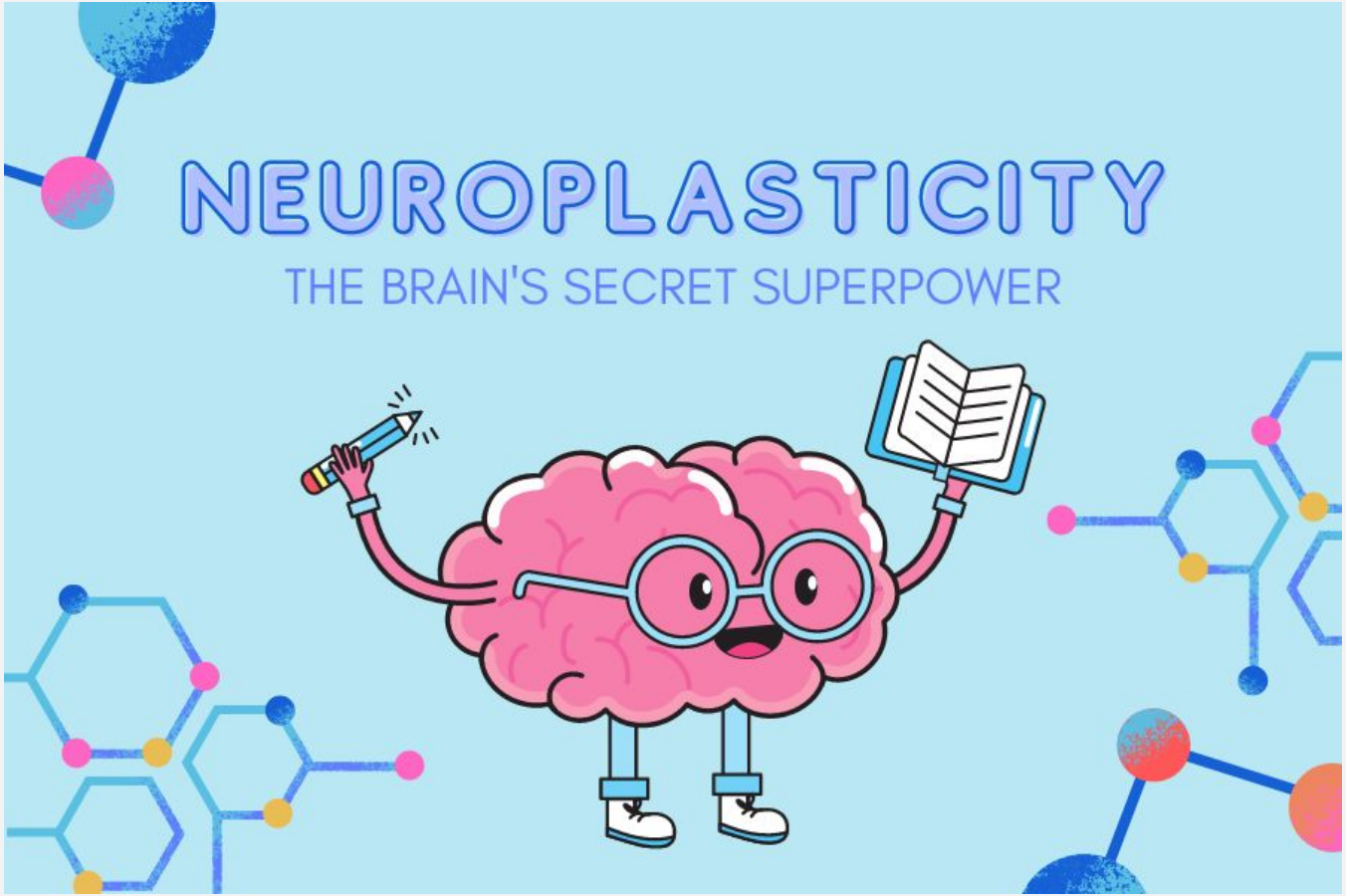
Ill. Niklas Elmehed © Nobel Prize Outreach
Geoffrey Hinton
Prize share: 1/2

The Nobel Prize in Physics 2024 was awarded jointly to John J. Hopfield and Geoffrey E. Hinton "for foundational discoveries and inventions that enable machine learning with artificial neural networks"

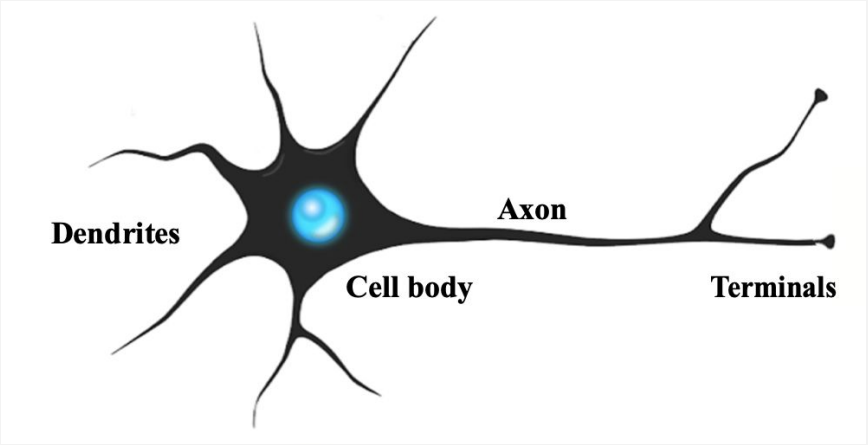


How do machines ‘learn’?

From biological neuron to Neural Network neuron



From biological neuron to Neural Network neuron



Biological Neurons: Structure and Function

Dendrites

Receive signals from other neurons, starting the communication process.

Soma (Cell Body)

Processes incoming signals to decide the neuron's response.

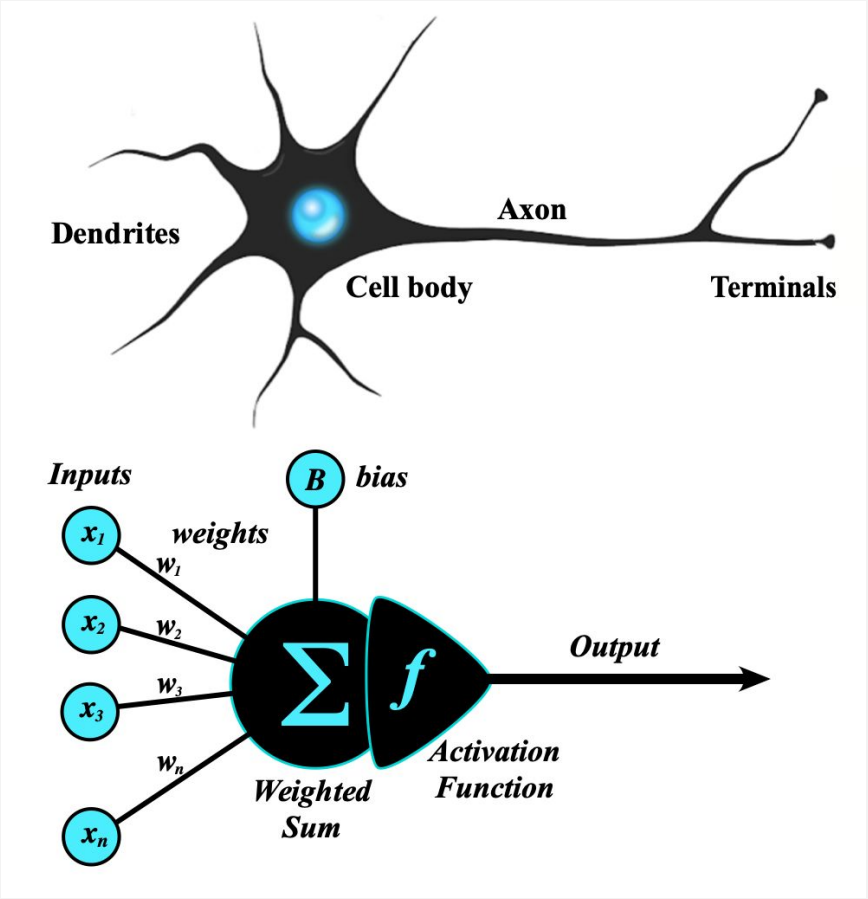
Axon

Transmits the processed signal outward to connected neurons.

Synapses

Junction points where signals pass to neighboring neurons.

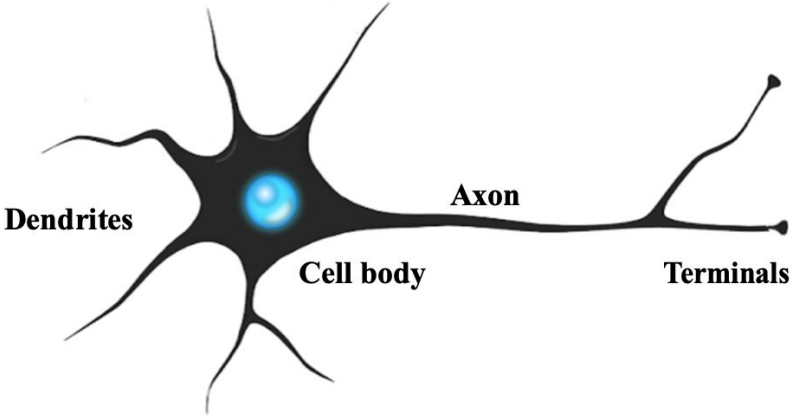
From biological neuron to Neural Network neuron

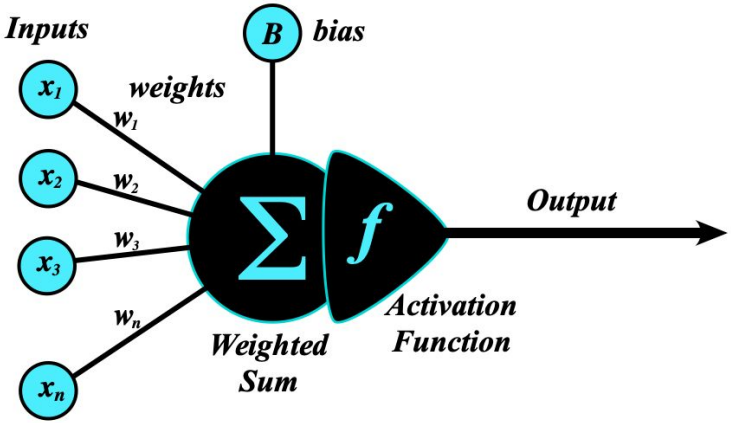


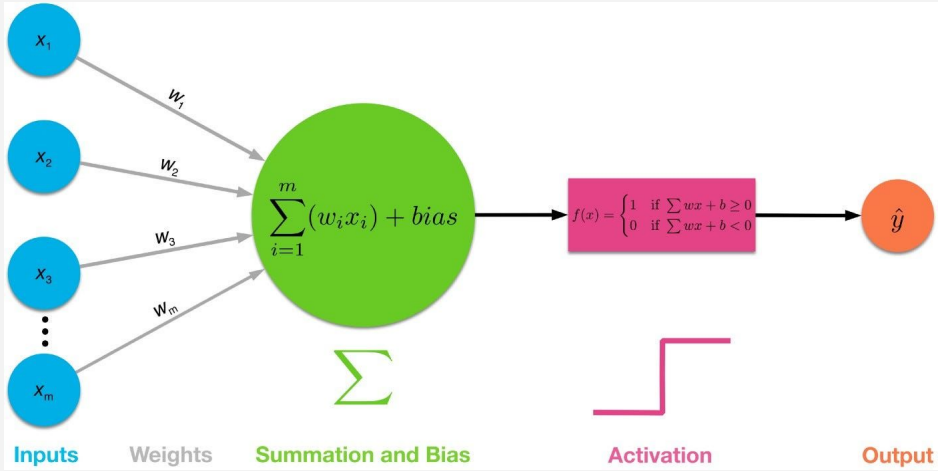
Comparison of Biological Neurons and AI Neurons

- **Structure:**
  - **Biological Neuron:**
    - Composed of dendrites, a cell body (soma), and an axon.
    - Complex connections and synapses with other neurons.
  - **AI Neuron:**
    - Simplified mathematical model or node in a neural network.
    - Represents inputs, weights, activation functions, and outputs.
- **Learning Mechanism:**
  - **Biological Neuron:**
    - Learns through neuroplasticity / synaptic plasticity (strengthening/weakening of connections).
    - Involves complex biological processes like long-term potentiation.
  - **AI Neuron:**
    - Learns through adjustments of weights via algorithms (e.g., backpropagation).
    - Utilizes large datasets to optimize performance during training.

From biological neuron to Neural Network neuron







Linear regression is essentially a special case of a **one-neuron network.**

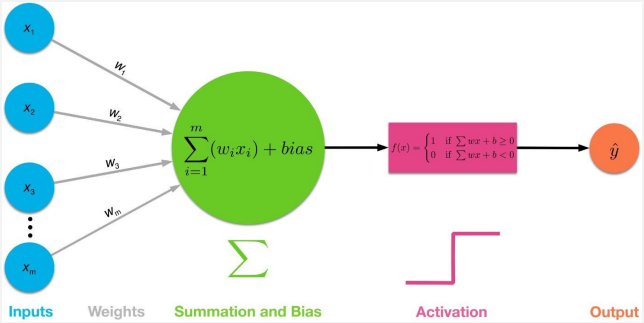
Why One Neuron Isn't Enough

Single neuron limits

Can only solve simple, linear problems.

Complex patterns need more

One neuron can't recognize intricate shapes or boundaries.



Aspect	Linear Regression	One-Neuron Network
Formula	$\hat{y} = \mathbf{w}^\top \mathbf{x} + b$	$y = \phi(\mathbf{w}^\top \mathbf{x} + b)$
Activation Function	None (or identity)	Typically nonlinear (e.g. ReLU, sigmoid)
Training Loss	MSE	Depends (MSE, cross-entropy, etc.)
Use Case	Regression	Regression or classification

✅ 1. Formula for Linear Regression

The **linear regression** model predicts a continuous outcome based on one or more input features:

$$\hat{y} = w_1 x_1 + w_2 x_2 + \cdots + w_n x_n + b$$

Or more compactly using vector notation:

$$\hat{y} = \mathbf{w}^\top \mathbf{x} + b$$

Where:

- $\hat{y}$ is the predicted output,
- $\mathbf{x} = [x_1, x_2, \ldots, x_n]^\top$ is the input vector,
- $\mathbf{w} = [w_1, w_2, \ldots, w_n]^\top$ is the weight vector,
- b is the bias term (intercept).

✅ 2. Formula for a One-Neuron Network (Perceptron without activation)

A **single neuron** in a neural network (without activation) also computes a weighted sum of its inputs:

$$y = \mathbf{w}^\top \mathbf{x} + b$$

If it includes a **nonlinear activation function** ϕ, the formula becomes:

$$y = \phi(\mathbf{w}^\top \mathbf{x} + b)$$

🔗 3. Relationship Between the Two

Linear regression is essentially a **special case** of a one-neuron network:

- It uses **no activation function** (or a linear activation: $\phi(x) = x$).
- It's trained using **least squares** loss.
- The goal is to minimize the **mean squared error** (MSE) between predictions and actual values.

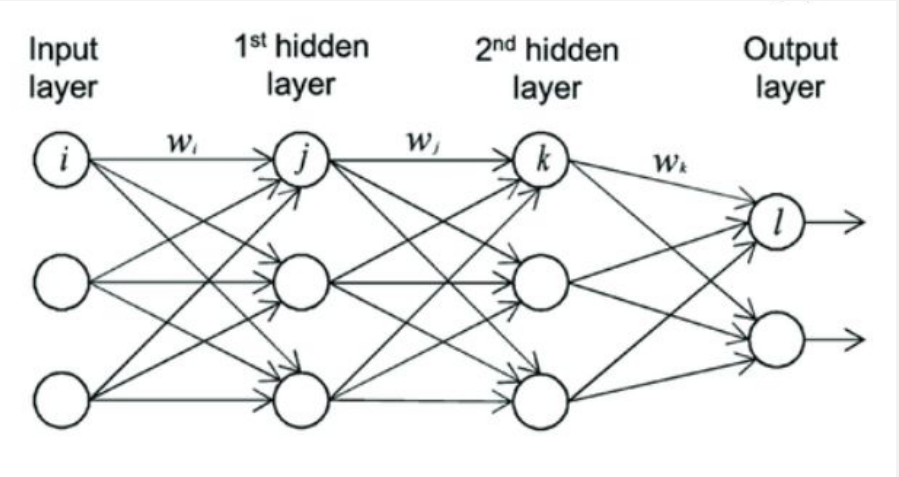
Introducing MLPs

MLP (Multi-Layer Perceptron)?

A **Multi-Layer Perceptron (MLP)** is a type of neural network that **combines many neurons** arranged in **layers** to solve more complex problems than a single neuron can handle.

Just like people working together can solve bigger problems than one person alone, **MLPs stack neurons** into:

- **Input Layer** – receives the data
- **Hidden Layers** – extract patterns and features
- **Output Layer** – produces the final decision or prediction



Each neuron in a layer is connected to **all** neurons in the next layer — this is called a **fully connected network**.

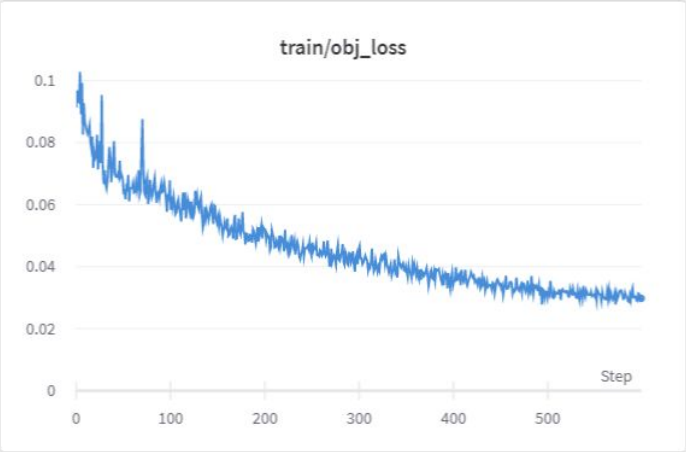
An MLP allows us to go from **simple decisions (single neuron)** to **complex pattern recognition**, by letting multiple neurons **collaborate** and **refine** their outputs through layers.

We’ve built the brain.
Now the big question is…

can it learn?

How do machines ‘learn’?

“Learning from mistakes…”



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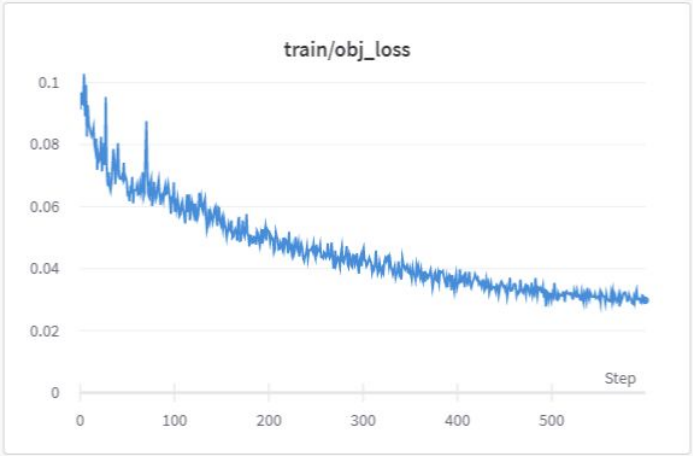
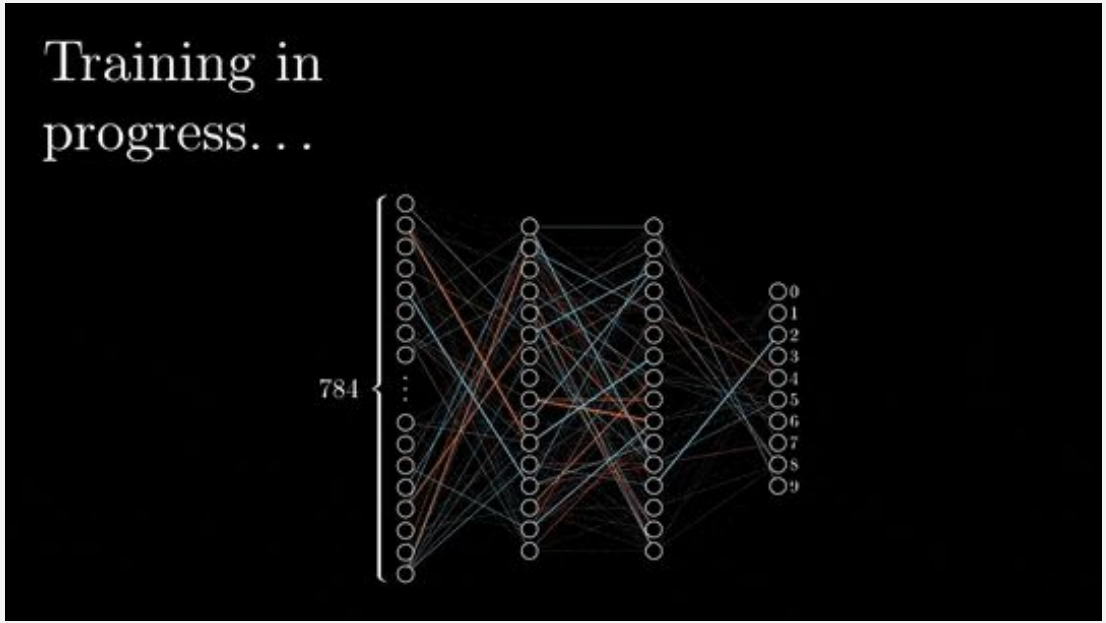


A computer program is said to **learn** from **experience E** with respect to some class of **tasks T**, and **performance measure P**, if its performance at tasks in T, as measured by P, improves with experience E. – Tom Mitchell

How does machines ‘learn’? BACKPROPAGATION



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What is Backpropagation?

Backpropagation is how a neural network **learns from its mistakes**.

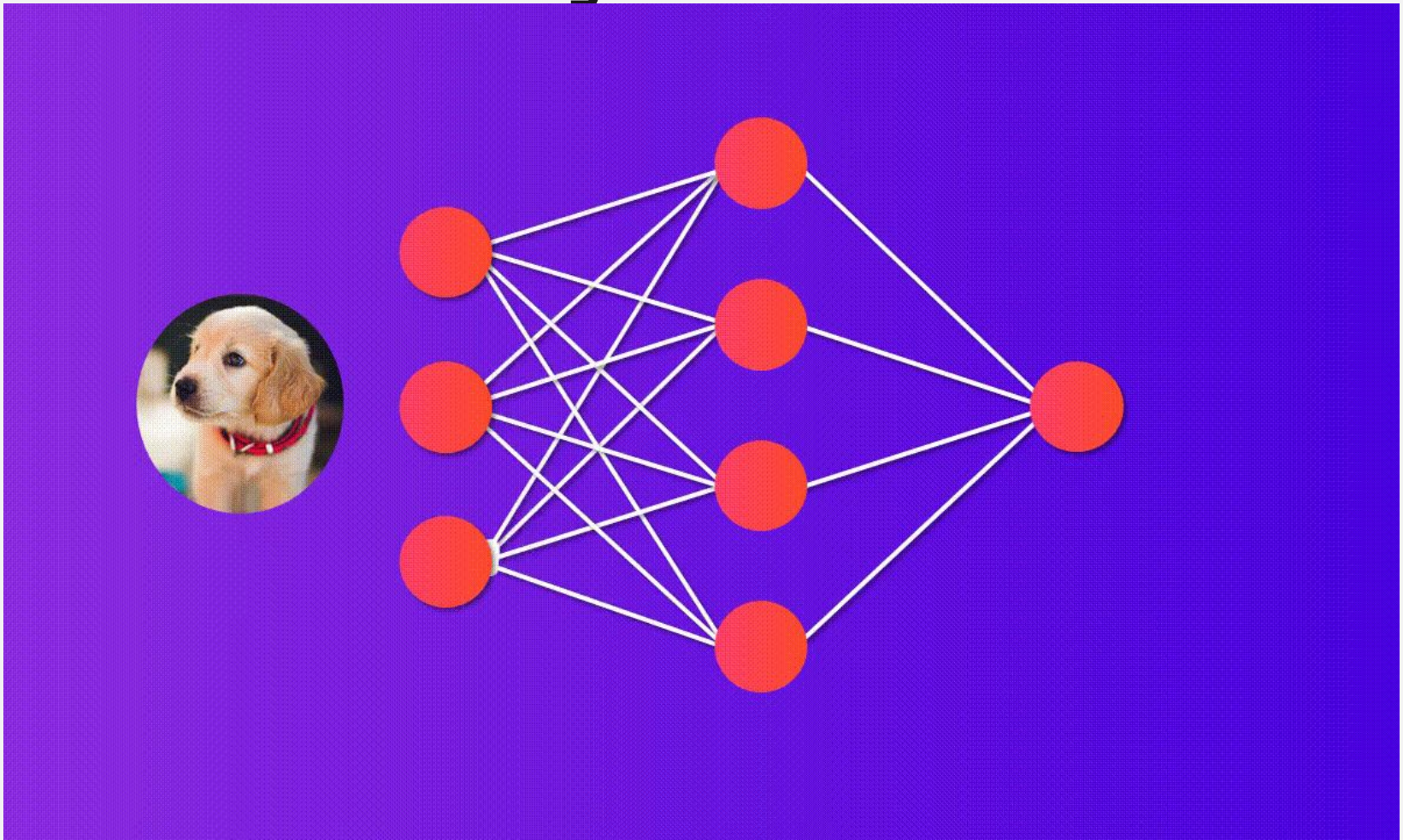
It works by:

1. **Comparing** the model’s prediction to the correct answer (using a **loss function**).
2. **Measuring the error**, then

Sending that error backward through the network to **adjust the weights**—so it does better next time.

💡 **Analogy:**
Like a student reviewing a wrong answer, figuring out *why* it was wrong, and correcting their approach.

Neural Network doing Prediction



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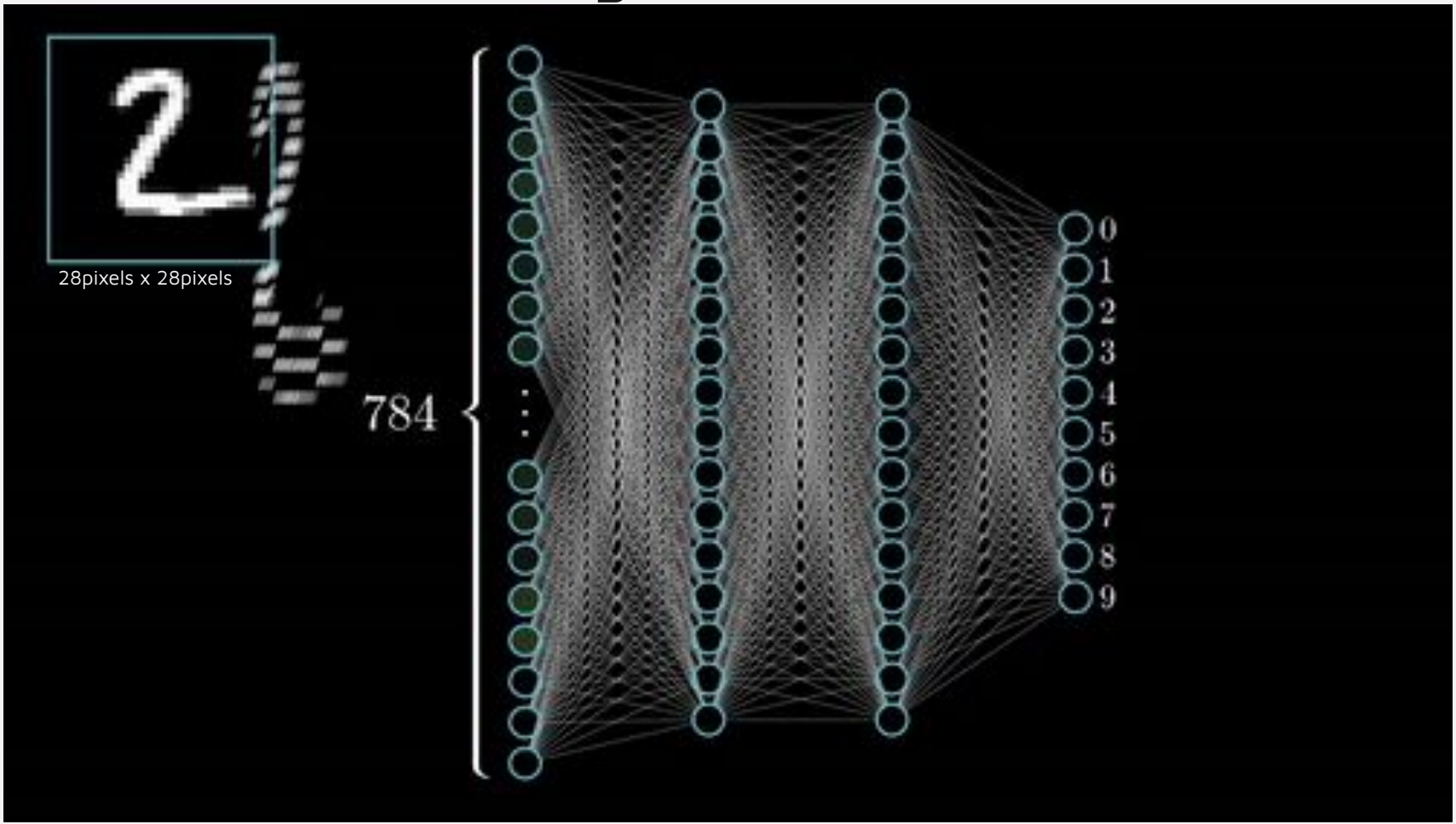
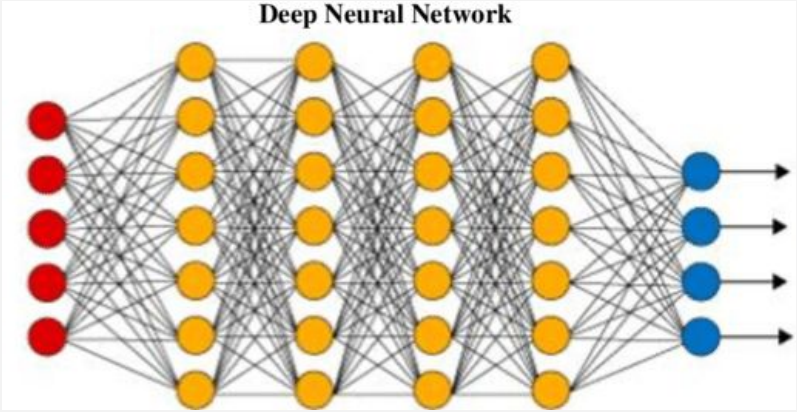


How many Neurons is in ChatGPT 3.5?

ChatGPT

ChatGPT 3.5 was based on the GPT 3.5 engine, which received training on over 175 billion training parameters. ChatGPT 4 took this training one step further, and is purportedly trained on over a trillion parameters.



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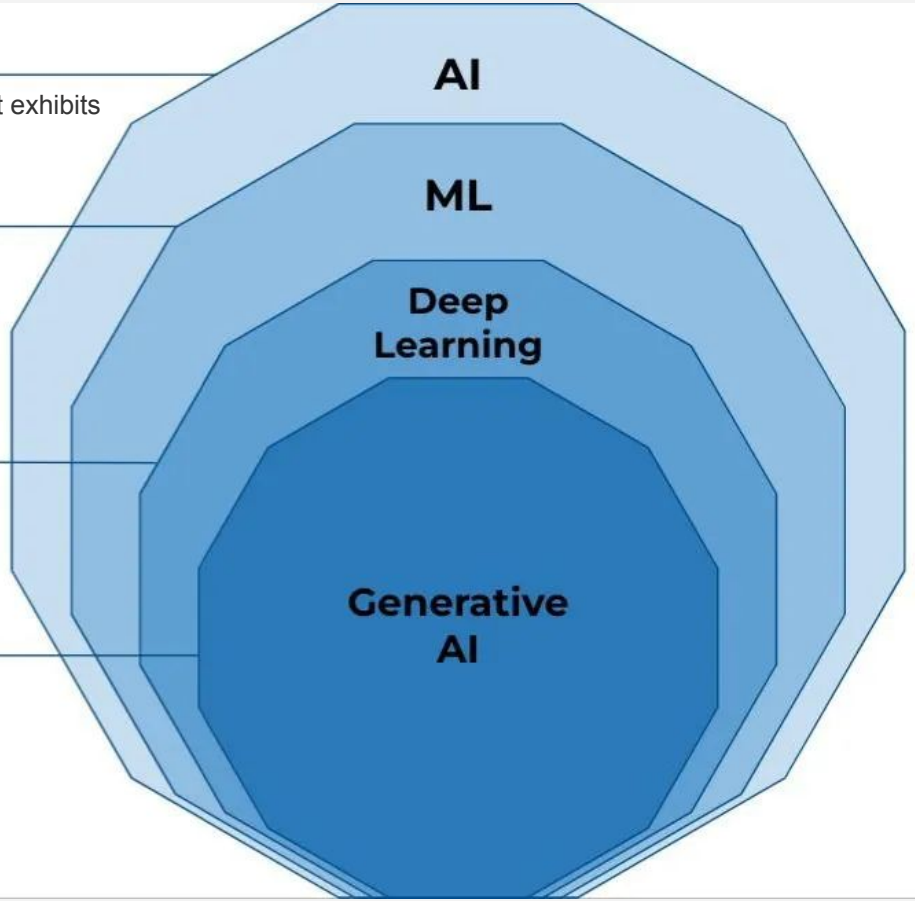
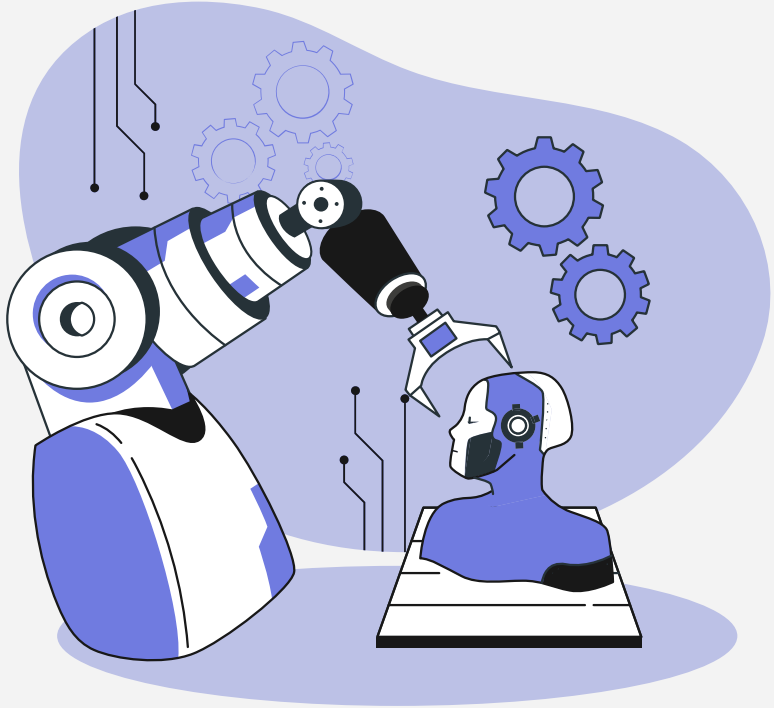
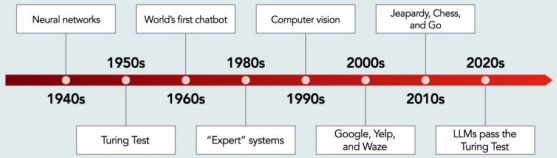


03
LLM



AI took 80+ years to become an overnight sensation



planview.

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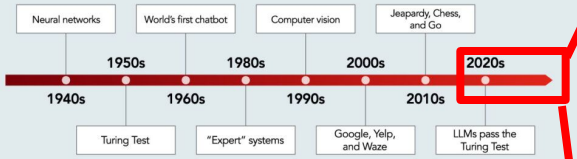

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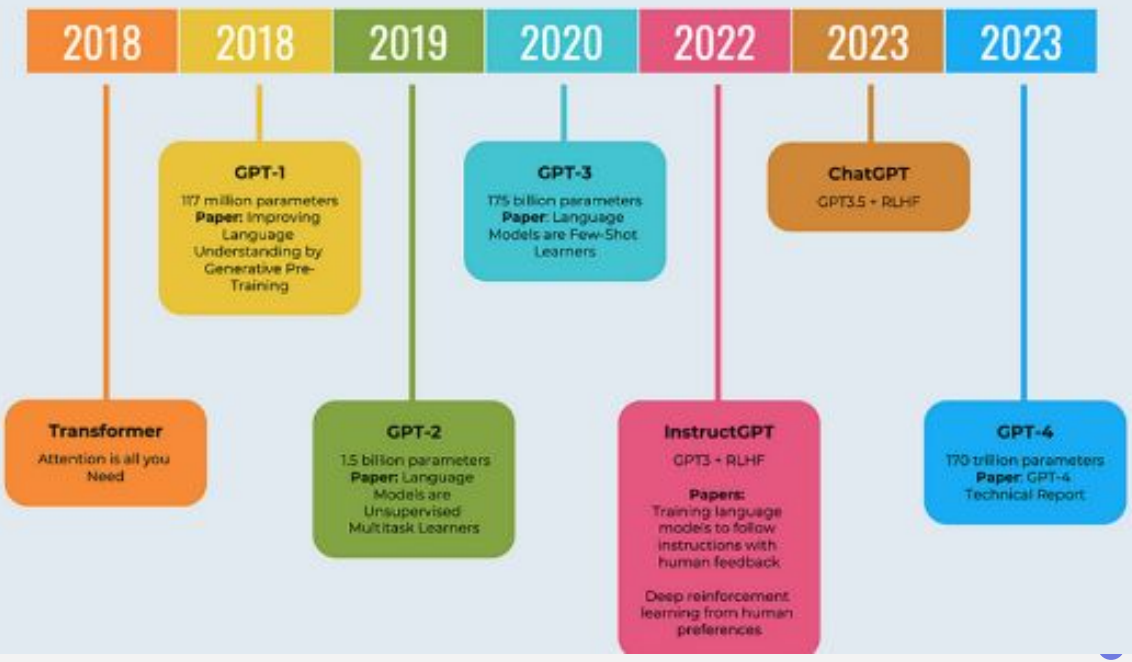
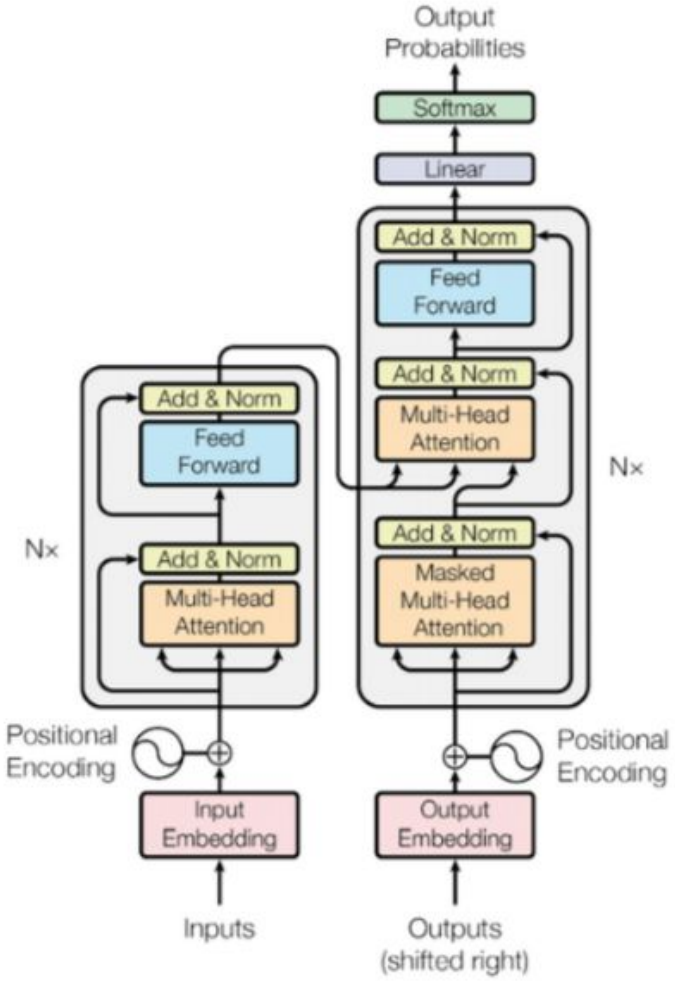
History of ChatGPT



Transformer

Attention Is All You Need



Why are LLMs an overnight sensation?

- **Language is a representation of human knowledge**
- Products of language is easy to generate (e.g. Internet, books, publications, messages, etc)
- Language is the best modality to train AI models to mimic human intelligence
- In the past year, LLMs have been successful in solving real-world problems
- **Best to think of LLMs as the compression with context of the digital human knowledge**

Large Language Models

Definition: LLMs are advanced AI models trained on vast amounts of text data to understand and generate human language.

Scale and Complexity: LLMs consist of billions to trillions of parameters, allowing them to handle complex language tasks like translation, summarization, and conversation.

Learning Process: They learn patterns, context, and semantics from large datasets to generate coherent responses.

Real-World Applications: LLMs power chatbots, virtual assistants, content generation tools, code-writing systems, and more across industries.

Challenges: Despite their capabilities, LLMs face challenges like bias in training data, high computational costs, and sometimes generating inaccurate or nonsensical responses.

How does LLM work?

- Use of autoregression to predict the next word (token)

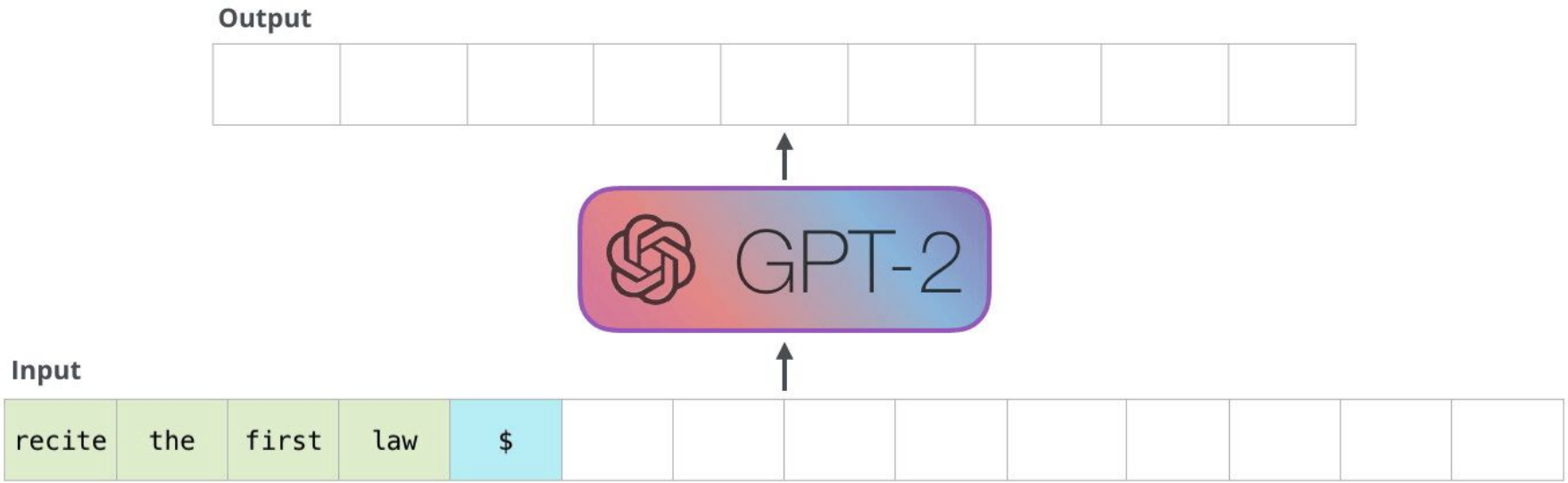
$$p(x_1, x_2, \dots, x_L) = p(x_1)p(x_2|x_1)\cdots p(x_L|x_1, x_2 \cdots x_{L-1}) = \prod_{i=1}^{L} p(x_i|x_{1:i-1})$$

$$p(the, cat, sat, on, the, mat) =$$
$$p(the) \cdot$$
$$p(cat|the) \cdot$$
$$p(sat|the, cat) \cdot$$
$$p(on|the, cat, sat) \cdot$$
$$p(the|the, cat, sat, on) \cdot$$
$$p(mat|the, cat, sat, on, the)$$

How does LLM work?

- Use of autoregression

$$p(x_1, x_2, \ldots, x_L) = p(x_1)p(x_2|x_1)\cdots p(x_L|x_1, x_2 \cdots x_{L-1}) = \prod_{i=1}^{L} p(x_i|x_{1:i-1})$$



Capabilities

- **Question Answering**
- Word Analogies
- Summarization
- Language Translation
- In-Context Learning

The capital of Malaysia is _____

Capabilities

- Question Answering
- **Word Analogies**
- Summarization
- Language Translation
- In-Context Learning

Capabilities

- Question Answering
- Word Analogies
- **Summarization**
- Language Translation
- In-Context Learning

The Olympic Games is a major international multi-sport event. During its history, both the Summer and Winter Games were a subject of many scandals, controversies, and boycotts. Some Olympic Games were not conducted due to major wars - such as World War I and World War II. The Games originated in Ancient Greece, and now are conducted every four years by the International Olympic Committee. Athletes from more than 200 nations participate in these games. The symbol of the Olympic Games - five interlocking colored rings, representing the continents of the world united by Olympism. The goal of the Olympic Movement is to contribute to building a peaceful and better world by educating youth through sport practiced without discrimination of any kind and in the Olympic spirit.

Summary

The Olympic Games, originating in Ancient Greece, are a major international event occurring every four years, involving over 200 nations. The event, overseen by the International Olympic Committee, has faced scandals, controversies, and were cancelled due to world wars. The five interlocked rings symbolize the unity among continents, promoting peace and youth education through non-discriminatory sport.

Capabilities

- Question Answering
- Word Analogies
- Summarization
- **Language Translation**
- In-Context Learning

Once upon a time, a quick rabbit named Ralph lived in a lush forest alongside a wise old turtle, Thomas. Ralph, full of energy and spirit, often teased the slow-moving Thomas, eventually challenging him to a race. Confident of his victory, Ralph sped ahead from the starting line, swiftly leaving Thomas far behind. Deciding to take a quick nap under a shady tree, Ralph thought, "Even with my rest, I'll surely win."

On the other hand, Thomas consistently trudged forward, maintaining his slow, steady pace. As the afternoon transitioned into evening, Ralph woke, alarmed to see that the sun was setting. Quickly, Ralph raced towards the finish line, but as he rounded the bend, he saw Thomas already there, smiling wisely.

Baffled and humbled, Ralph approached the finish line, comprehending the invaluable lesson of Thomas's victory: consistency over speed. The race brought newfound respect in Ralph's heart for Thomas, embedding a lifelong friendship between the two. The quick rabbit learned the wisdom embedded in Thomas's slow and steady philosophy that day.

Noong isang panahon, may mabilis na kuneho na nagngangalang Ralph na nakatira sa isang saganang gubat kasama ng isang marunong na matandang pagong, na si Thomas. Madalas asarin ni Ralph, na puno ng enerhiya at sigla, ang mabagal na si Thomas, at sa wakas ay hinamon nya ito sa isang karera. Sigurado sa kanyang tagumpay, si Ralph ay agad na umarangkada mula sa simula, mabilis na iniwanan si Thomas sa malayo.

Nagpasya siyang magpahinga at matulog sa ilalim ng isang puno, iniisip na "Kahit na magpahinga pa ako, sigurado akong ako ang mananalo."

Sa kabilang banda, si Thomas ay tuloy-tuloy na nagpatuloy, sinusunod ang kanyang mabagal ngunit walang patid na tulin. Nang maghapon na naglipat sa gabi, si Ralph ay nagising, nababahala sa paglubog ng araw. Mabilis, dumaloy si Ralph patungo sa finish line, ngunit nang siya ay nag-ikot, nakita niya na si Thomas ay nandoon na, ngumiti ng marunong.

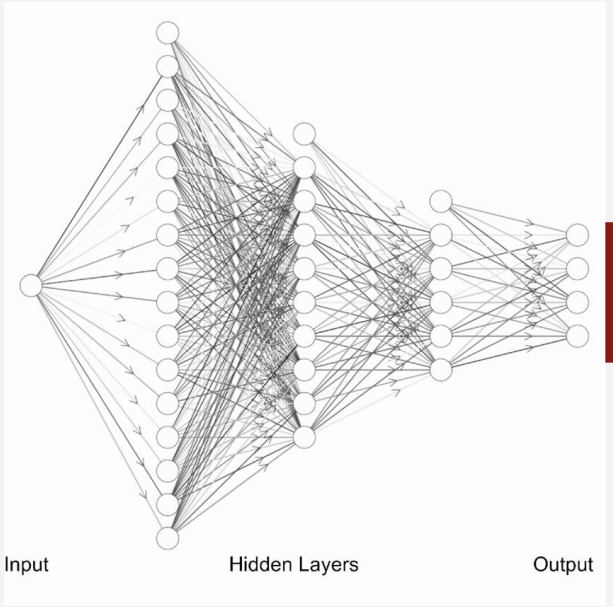
Nalilito at nababaon, lumapit si Ralph sa finish line, nauunawaan ang mahalagang aral ng tagumpay ni Thomas: ang konsistensya ay higit pa sa bilis. Ang karera ay nagdala ng bagong pag-galang sa puso ni Ralph para kay Thomas, nagtatanim ng dalisay na pagkakaibigan sa pagitan ng dalawa. Natutunan ng mabilis na kuneho ang karunungan na nakabaon sa mabagal at patuloy na pilosopiya ni Thomas noong araw na iyon.

Capabilities

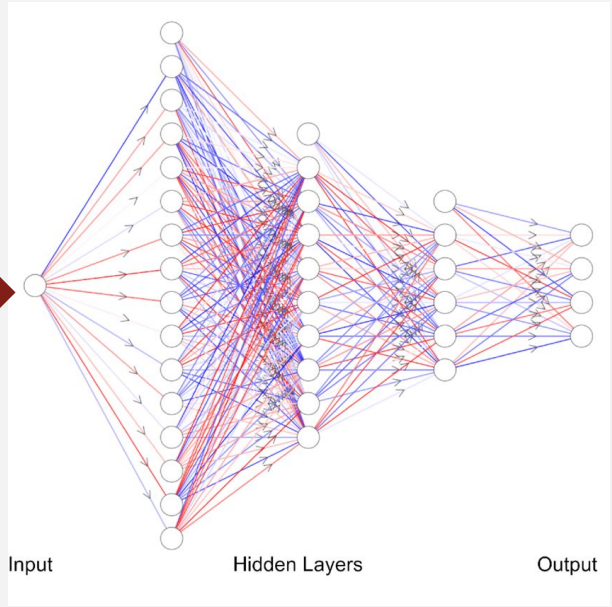
- Question Answering
- Word Analogies
- Summarization
- Language Translation
- **In-Context Learning**

```
# Chatbot - GPT-3 model

chatbot = GPT3() # User initiates a conversation

user_says = "Hello. I want to talk about cars."

chatbot_response = chatbot.respond(user_says)

print(chatbot_response) # "Sure, what would you like to know about cars?"

user_says = "What's the fastest car in the world?"

chatbot_response = chatbot.respond(user_says)

print(chatbot_response) # "As of my training data up until September 2021, the fastest car in the world is the Bugatti Chiron Super Sport 300+ with a top speed of 304.77 mph."

user_says = "What's its engine power?"

chatbot_response = chatbot.respond(user_says) print(chatbot_response) # "The Bugatti Chiron Super Sport 300+ has a quad-turbocharged 8.0 litre W16 engine that produces 1578 horsepower."
```

Training the LLM...



MODEL TRAINING



Training the LLM...

Pre-Training

Pre-Training Data

- **Publicly Available Data**: Books, encyclopedias (e.g., Wikipedia), open-access articles, forums, and websites.
- **Licensed Content**: Data acquired through proper agreements for enhanced quality.
- **Code Repositories**: Publicly accessible coding examples from platforms like GitHub and Stack Overflow.

BASE MODEL

Training the LLM...

Pre-Training

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BASE MODEL

Trivia:

GPT in ChatGPT stands for **G**enerative **P**re-trained **T**ransformer.

Training the LLM...

Pre-Training → Fine-Tuning

Pre-Training Data

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Fine-Tuning Data

- Can we further train the base model (aka pre-trained model)?

  s

BASE MODEL → FINE-TUNED MODEL

Training the LLM...

Pre-Training → Fine-Tuning → Instruction-Tuning

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Fine-Tuning Data

- Can we further train the base model (aka pre-trained model)?

Instruction-Tuning Data

- **Instructional Fine-Tuning**: Curated datasets to improve response relevance and alignment to user instructions.

sample:

System prompts: “You are a helpful assistant for an ERP System. Answer queries related to infor system only. ”

BASE MODEL → FINE-TUNED MODEL → ALIGNED MODEL

THANK YOU!

LLM Primer

Nikko Carlo Yabut, MEng AI