

# AIL721: Deep Learning

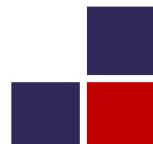
**Instructor:** James Arambam

Email: [jamesa@scai.iitd.ac.in](mailto:jamesa@scai.iitd.ac.in)



**ScAI**

Yardi School of Artificial Intelligence  
Indian Institute of Technology Delhi





# Course Logistics

## □ Class Schedule:

- Location: LH421, LHC
- Timing: Tue/Fri 5-6pm, Wed: 12-1pm

## □ Textbooks:

- Understanding Deep Learning by J.D Prince
- Deep Learning: Foundations & Concepts by Bishop

## □ Piazza or Moodle?:

- Signup Link: [https://piazza.com/iit\\_delhi/spring2025/ail721](https://piazza.com/iit_delhi/spring2025/ail721)
- Access code: ail721

## □ Course Website:

- <https://jamesarambam.me/dl>

## □ Office Hours:

- Thursday, 2-3 pm
- Or by appointment only

## □ Teaching Assistants:

- TBA
- TA office hours: TBA



# Course Logistics

## □ Attendance Policy:

- Institute default (<75% leads to the grade being lowered by one).

## □ Grading Schemes:

- Mid-term: **25%**
- End-term: **30%**
- Assignments: **20%**
- Projects: **25%**

## □ Audit pass Criteria:

- Marks equivalent to B- or higher
- Attendance more than 75%.



# Course Project - 25%

## ❑ Team:

- Team size: TBA
- Work load should be evenly distributed.
- Form team by **week 3**.

## ❑ Evaluation Criteria:

- Problem originality, modeling elegance.
- Appropriate use of DL tools and techniques.
- Clarity, completeness, and accuracy of report.
- Good writing skills and proper references.



# Course Project - 25%

## □ Project Grading Scheme:

### ■ Proposal Report: 8%

- Evaluation criteria: Based on the **novelty** of the problem selected.
- Due: **Week 6**.
- Report: Abstract, problem statement, datasets, proposed methodology.

### ■ Final Presentation: 7%

- Due: **Week 14**.

### ■ Final Report: 10%

- Report: Abstract, problem statement, datasets, methodology, results, discussion and analysis.
- Due: **Week 14**.

**Start Early!**



# Latex Softwares

The screenshot shows the Overleaf web-based LaTeX editor interface. On the left, there's a sidebar with navigation links like 'File outline', 'Introduction', and 'Some examples to get started'. The main area has tabs for 'Source' (selected), 'Source (legacy)', and 'Rich Text'. The code editor contains a LaTeX document with various packages and commands. To the right is a preview window showing a document titled 'Your Paper' with a green frog image and some text.

```

<-->
Menu Home Upgrade Project Review Share Submit History Layout Chat
Source Source (legacy) Rich Text Recompile
frog.jpg
main.tex
sample.bib
File outline
Introduction
Some examples to get started
How to create Sections
How to include Figures
How to add Tables
How to add Comments
How to add Lists
How to write Mathematics
How to change the ...
How to change the document
How to add Citations
Good luck!
1 \documentclass{article}
2
3 % Language setting
4 % Replace 'english' with e.g. 'spanish' to change the
document language
5 \usepackage[english]{babel}
6
7 % Set page size and margins
8 % Replace 'letterpaper' with 'a4paper' for UK/EU
standard size
9 \usepackage[letterpaper,top=2cm,bottom=2cm,left=3cm,right
=3cm,marginparwidth=1.75cm]{geometry}
10
11 % Useful packages
12 \usepackage{amsmath}
13 \usepackage{graphicx}
14 \usepackage[colorlinks=true, allcolors=blue]{hyperref}
15
16 \title{Your Paper}
17 \author{You}
18
19 \begin{document}
20 \maketitle
21
22 \begin{abstract}
23 Your abstract.
24 \end{abstract}
25
26 \section{Introduction}
27
28 Your introduction goes here! Simply start writing your
document and use the Recompile button to view the

```

**Overleaf:** [www.overleaf.com](http://www.overleaf.com)

The screenshot shows the LyX desktop application interface. The document title is 'UserGuide.lyx'. The content includes a section on 'Operators with Limits' with a formula  $\sum_{n=0}^{\infty} \frac{1}{n!} = e$ . It also shows how integral signs are placed. The interface has a toolbar, menu bar, and various tool buttons.

**5.1.6 Operators with Limits**

Sum ( $\sum$ ) and integral ( $\int$ ) operators are very often decorated with limits. These limits can be entered in LyX by entering them as you would enter a super- or subscript, directly after the symbol. The sum operator will automatically place its "limits" over and under the symbol in displayed formulas, and to the side in inline formulas, as in  $\sum_{n=0}^{\infty} \frac{1}{n!} = e$ , versus

$$\sum_{n=0}^{\infty} \frac{1}{n!} = e$$

Integral signs, however, will place the limits to the side in both formula types.

All operators with limits will be automatically re-sized when placed in display mode. The placement of the limits can be changed by placing the cursor directly behind the operator and using the menu **Edit > Math > Change Limits Type** or entering **Alt+M L**.

Certain other mathematical expressions also have this "moving limits" feature, such as **Math ! Limits**

$$\lim_{x \rightarrow \infty} f(x),$$

which will place the  $x \rightarrow \infty$  underneath the "lim" in display mode. In inline formulas it looks like this:  $\lim_{x \rightarrow \infty} f(x)$ .

Note that the lim-function was entered as the function macro **\lim**. Have a look at section **Ref. subsec:Functions** for an explanation of function macros.

**5.1.7 Math Symbols**

Font: Default

**LyX:** [www.lyx.org](http://www.lyx.org)



# Computing Resources

## ❑ IIT Delhi HPC:

- Working on providing compute credits for each student in the course.

## ❑ Google Colab

- Applied for academic compute credit, which should take around 1 week.

## ❑ Lightning.AI:

- <https://lightning.ai/train>

## ❑ Kaggle:

- <https://www.kaggle.com/code/dansbecker/running-kaggle-kernels-with-a-gpu>

## ❑ Amazon AWS Sagemaker:

- <https://studiolab.sagemaker.aws/>



# Credits

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- [1] Sumeet Agarwal & Parag Singla, IIT Delhi. **Deep Learning Course.**
- [2] Andrew Ng & Kian Katanforoosh, Stanford University. **Deep Learning Course.**
- [3] Alexander Amini, Ava Amini & Sadhana Lolla, MIT. **Deep Learning Course.**
- [4] Bhiksha Raj & Rita Singh, CMU. **Deep Learning Course.**
- [5] Simon J.D Prince. **Understanding Deep Learning Book.**
- [6] Chris Bishop & Hugh Bishop. **Deep Learning: Foundations & Concepts Book.**
- [7] Ian Goodfellow, Yoshua Bengio, and Aaron Courville. **Deep Learning Book.**

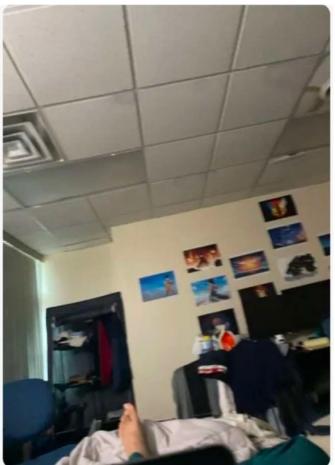
# Any Questions?



# Recent Breakthroughs in AI

# Recent Breakthroughs in AI

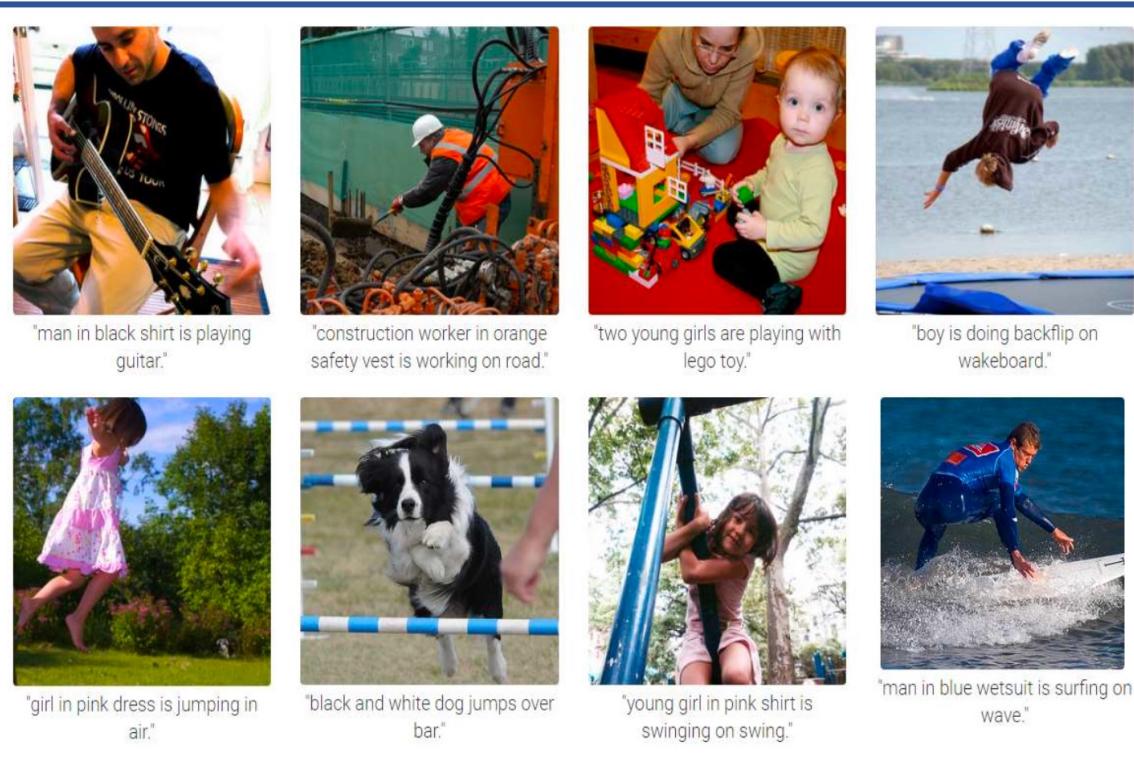
ChatGPT, tell me about this picture



7:12 PM The ceiling in the photo appears to have several noticeable water stains, which could indicate potential water damage. The stains seem to be spread across multiple tiles, suggesting there might be a leak from the roof or pipes above. It would be advisable to address this issue promptly to prevent any further damage or potential mold growth. Notifying building maintenance or the landlord to investigate and fix the source of the leak would be the best course of action.

Besides the water stains on the ceiling, the photo shows a few other details:

1. **Posters on the Wall:** There are several posters or prints on the wall featuring various images, likely of scenes from movies, video games, or other forms of media.
2. **Furniture and Clutter:** The room contains a few pieces of furniture, including a blue chair, a black wardrobe or storage unit, and a desk with two monitors. There are clothes and other items visible on the wardrobe and desk, indicating a typical lived-in space.
3. **Lighting and Ventilation:** The ceiling has a light fixture and an air vent, suggesting this is a standard room with typical building amenities.
4. **Bed and Bedding:** The lower part of the photo shows a bed with a person lying on it, with their foot visible in the foreground. The bed has a comforter and some clothing or linens on it.
5. **Overall Condition:** The room appears somewhat cluttered, with personal belongings spread out. The presence of water stains on the ceiling is the most concerning issue visible.



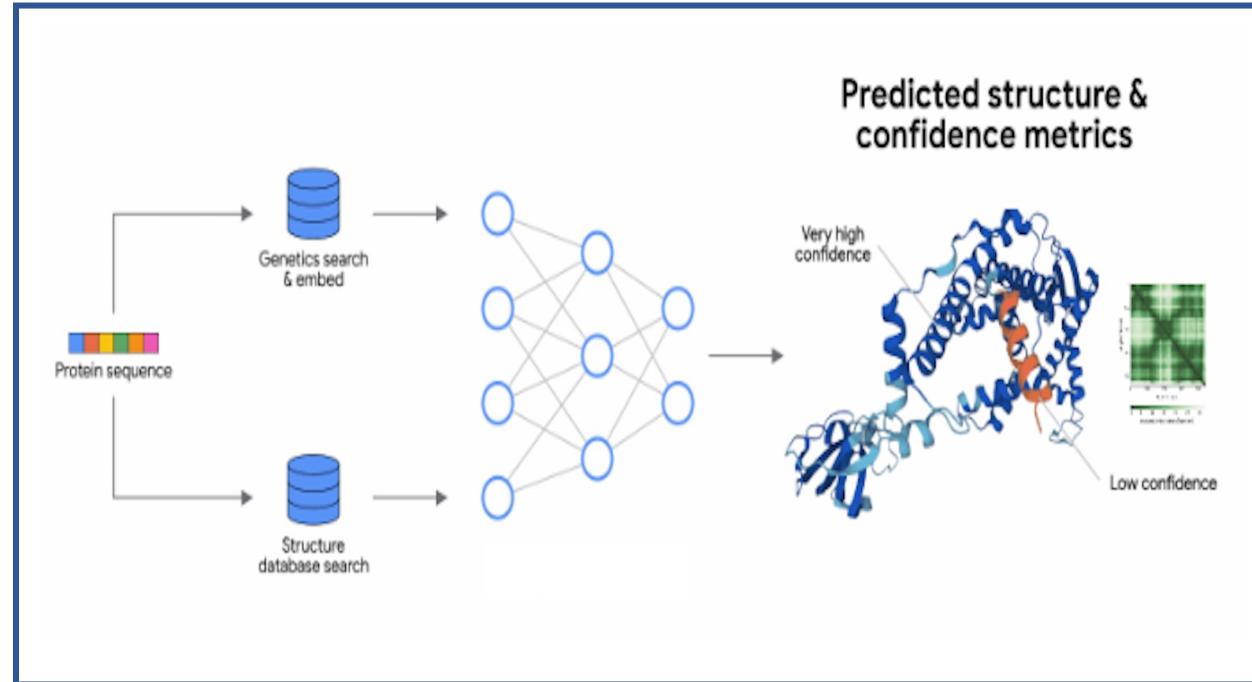
ChatGPT

Image Captioning

# Recent Breakthroughs in AI



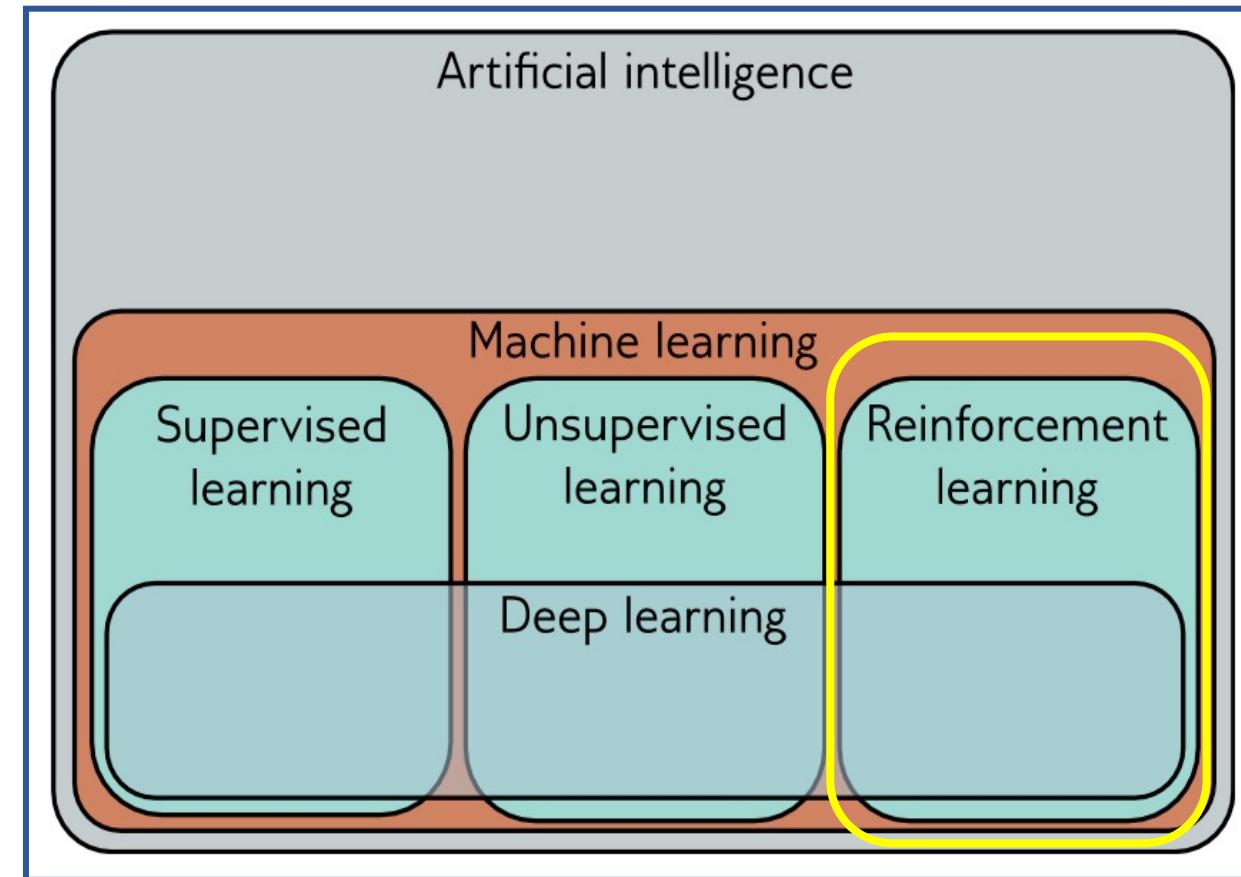
AlphaGo



A machine learning approach called **deep learning** is the key technique underlying many recent **major breakthroughs** in AI.

# What is Deep Learning?

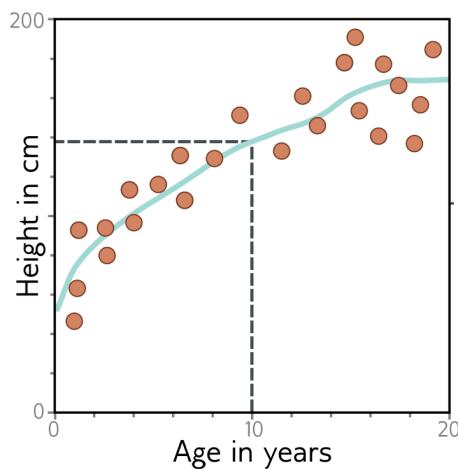
- Deep learning is a type of **machine learning** technique.



# What is Deep Learning?

- A general-purpose framework for **learning from data**.

$$y = f(x; \mathbf{w}) \quad f(x; \mathbf{w}) = w_0 + w_1 \cdot x + w_2 \cdot x^2$$

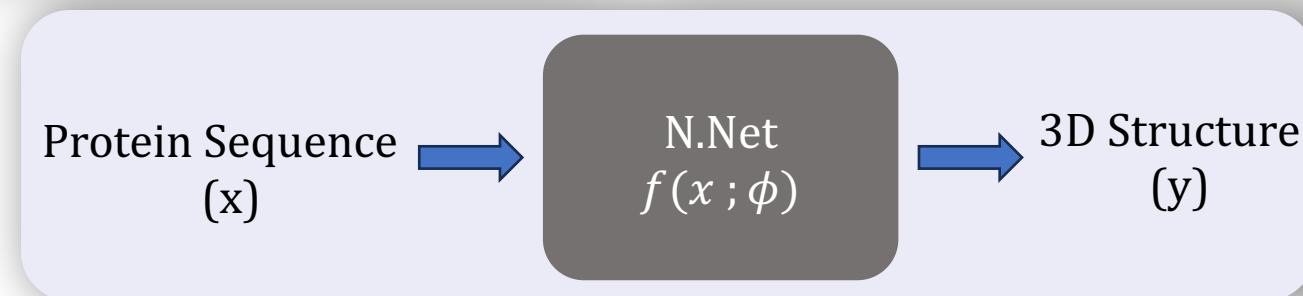
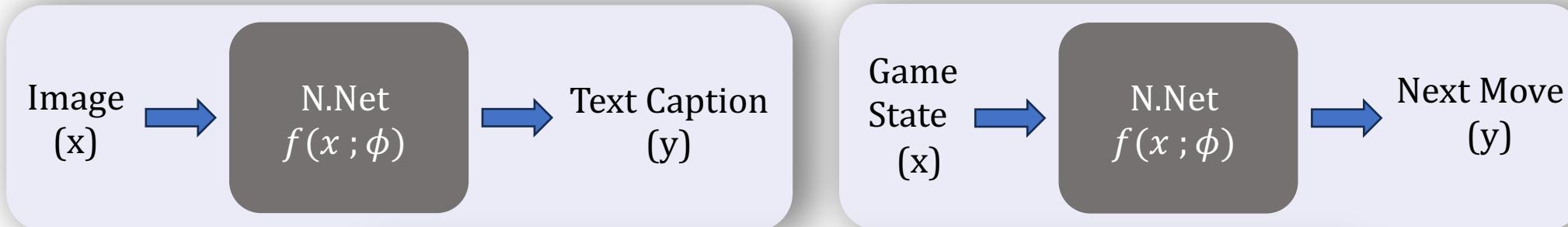


Data regarding a child's age and height.

	x	y
Data ID	Age (in years)	Heights (in cm)
1	2	57
2	5	87
3	18	165

# What is Deep Learning?

- Based on computational models called **neural networks**.



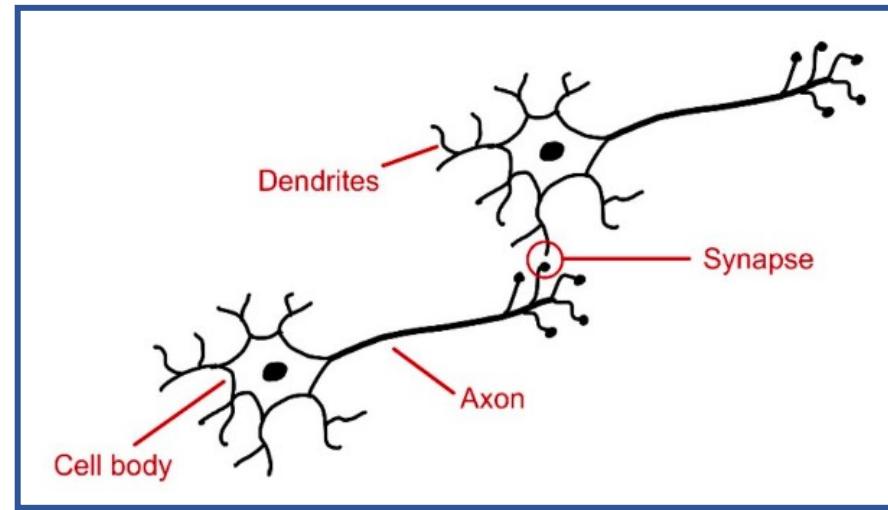
What's inside these boxes?



# A Brief History of Neural Networks Research

# What are Neural Networks?

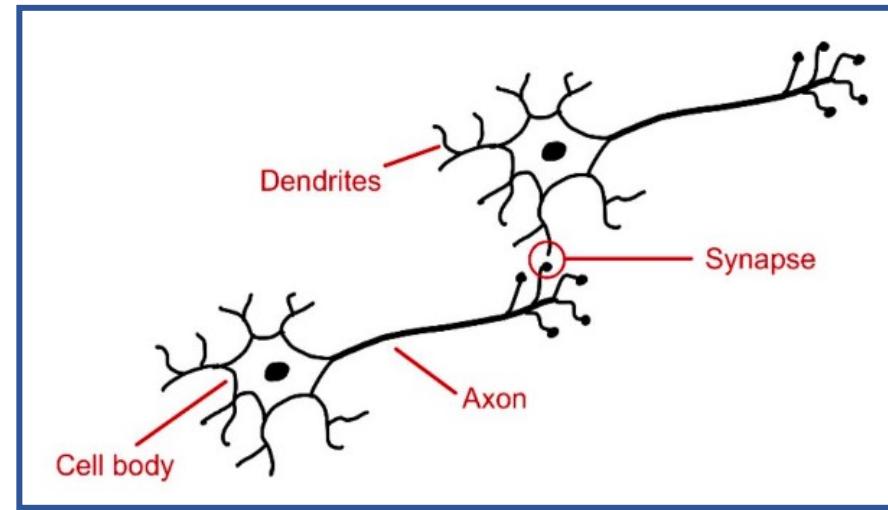
- Inspired by studies of information processing in the **brains**.
- Basic processing unit is called a **neuron**.
- Human brains contain **~90 billion** neurons.
- Each neuron has **several thousand synapses**.



A schematic illustration of two neurons from the human brain.

# What are Neural Networks?

- A complex network of **~100 trillion** synapses.



A schematic illustration of two neurons from the human brain.

- Firing of neurons depends on the **strength of the synapses**.
- The **changes in strength** are the key mechanisms for **storing information** and **learning from experience**.

# What are Neural Networks?



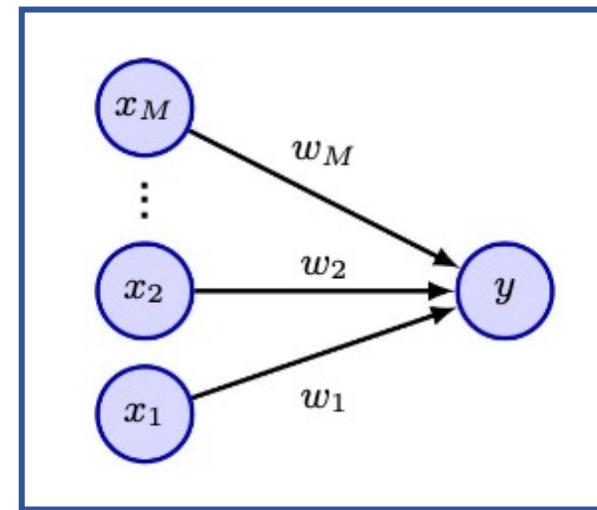
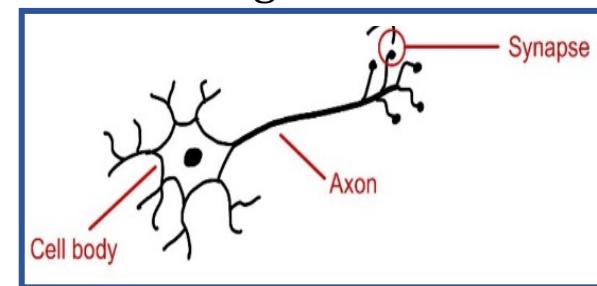
- These properties are captured by a simple mathematical model called **artificial neural networks**.

- Mathematically:

$$h = \sum_{i=1}^M w_i \cdot x_i \quad (1)$$

$$y = a[h] \quad (2)$$

A biological neuron.

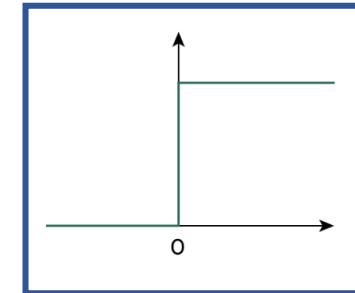


A simple artificial neural network.

# A Brief History of Neural Networks



□ McCulloch and Pitts, 1943



□ Rosenblatt's Perceptron, 1962

**Multi-layer Perceptron (MLP)**

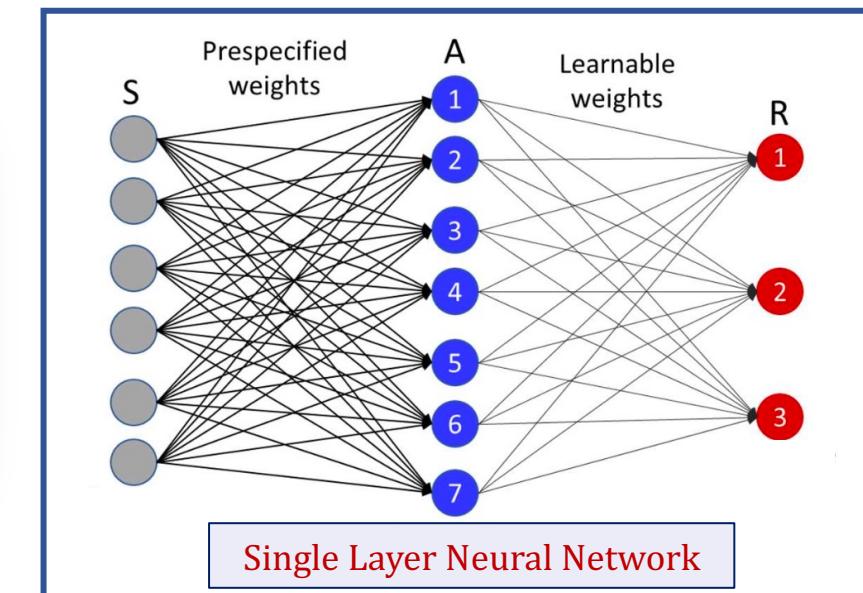
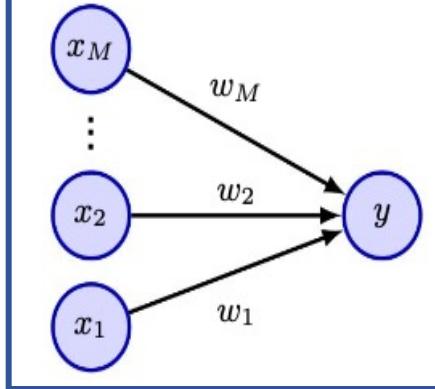
Mathematically:

$$h = \sum_{i=1}^M w_i \cdot x_i \quad (1)$$

$$y = a[h] \quad (2)$$

Activation function is a step function:

$$a[h] = \begin{cases} 0, & \text{if } h \leq 0, \\ 1, & \text{if } h > 0 \end{cases}$$



1943

1962

[McCulloch and Pitts]

[Rosenblatt]

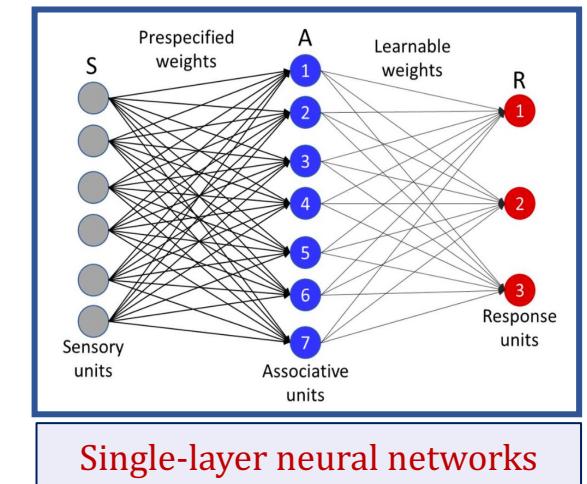
# A Brief History of Neural Networks



## □ Minsky and Papert 1969

- Gave **formal proofs** about the **limited capabilities** of single-layer neural networks.
- Speculated that limitations would extend to **multiple layers of learnable parameters**.

[Incorrect!]



# A Brief History of Neural Networks

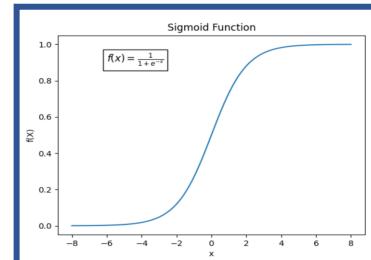
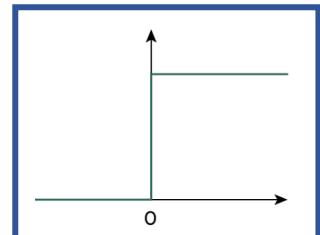


□ Rumelhart, **Hinton** and Williams, 1986



- Invented a **Backpropagation learning algorithm** for multiple layers of learnable parameters.

- Replaced step function.



Continuous Differentiable Activation Function

1943

1962

1969

1986

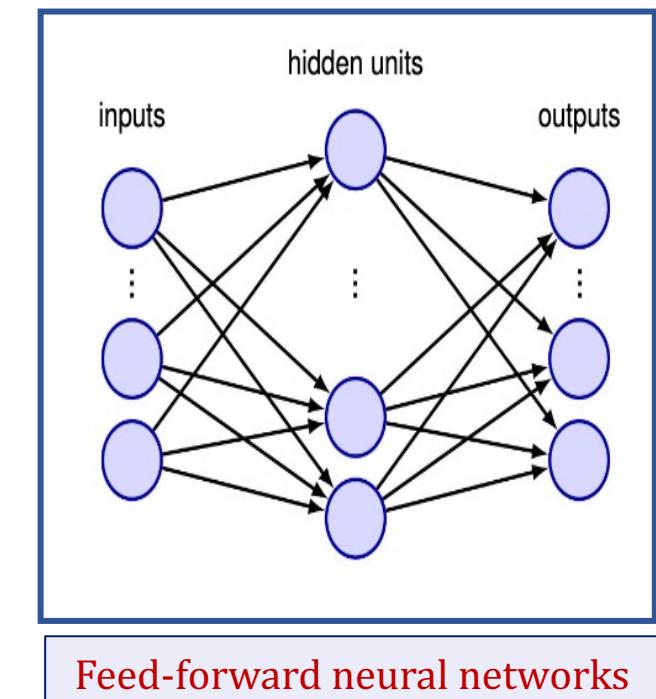
First NN Winter

[McCulloch and Pitts]

[Rosenblatt]

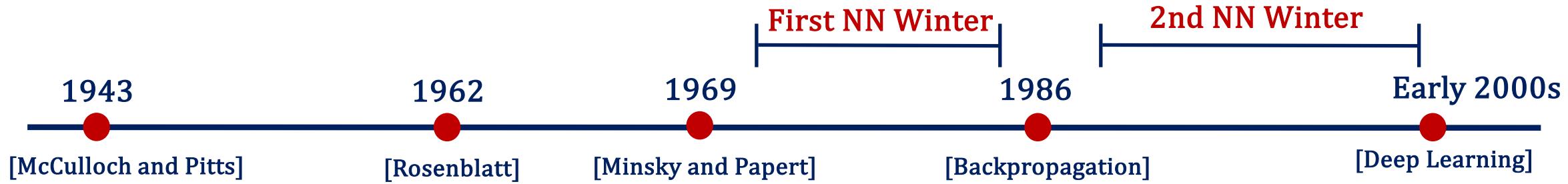
[Minsky and Papert]

[Backpropagation]



Hit the wall again!

- Only a **few final layers** were able to **learn** useful values for networks with many layers.
- Required a lot of hand-crafted pre-processing called **feature engineering**.

 Deep Neural Networks (or Deep Learning), Early 2000s

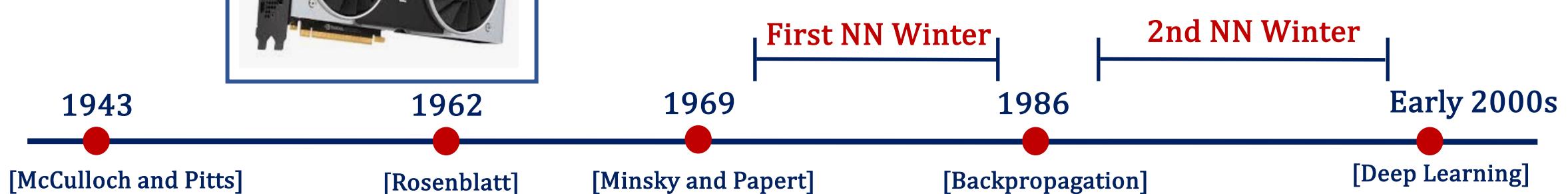
# A Brief History of Neural Networks

## □ Deep Neural Networks (or Deep Learning), Early 2000s

- Abundant data: Lots of **data** from the internet.

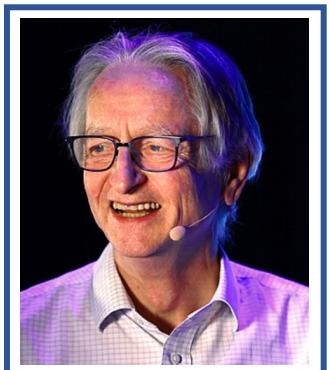


- Better compute power: Graphical processing units (**GPUs**)



## □ Deep Neural Networks (or Deep Learning), Early 2000s

- Many research groups started working **actively** on neural networks.
- Some of the prominent research groups at the time:



Geoffrey Hinton's group  
at University of Toronto



Yann LeCun's group at  
New York University



Yoshua Bengio's group at  
University of Montreal



Jürgen Schmidhuber's  
group at IDSIA



Andrew Ng at Stanford  
University & Google

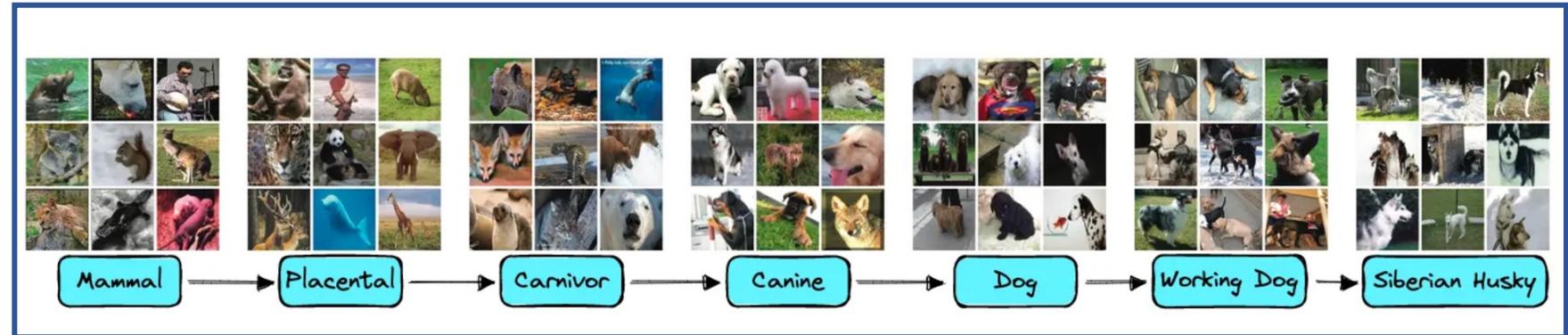


# A Brief History of Neural Networks

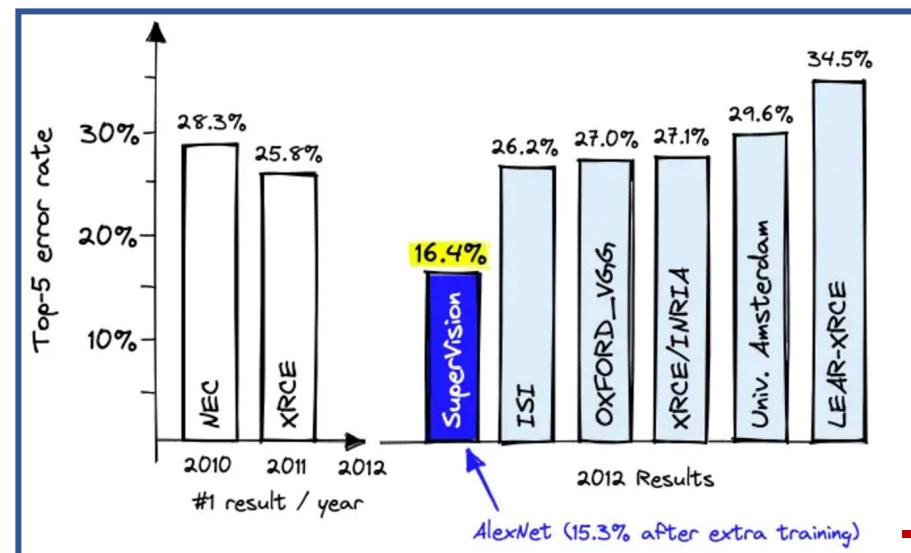
- **ImageNet Competition:** created a database of more than 14 million hand-annotated images.



Fei-Fei Li's group at  
Stanford University



- **AlexNet, 2012:** A convolutional neural network (CNN) based approach by Alex Krizhevsky, Ilya Sutskever and Geoffrey Hinton.



# A Brief History of Neural Networks

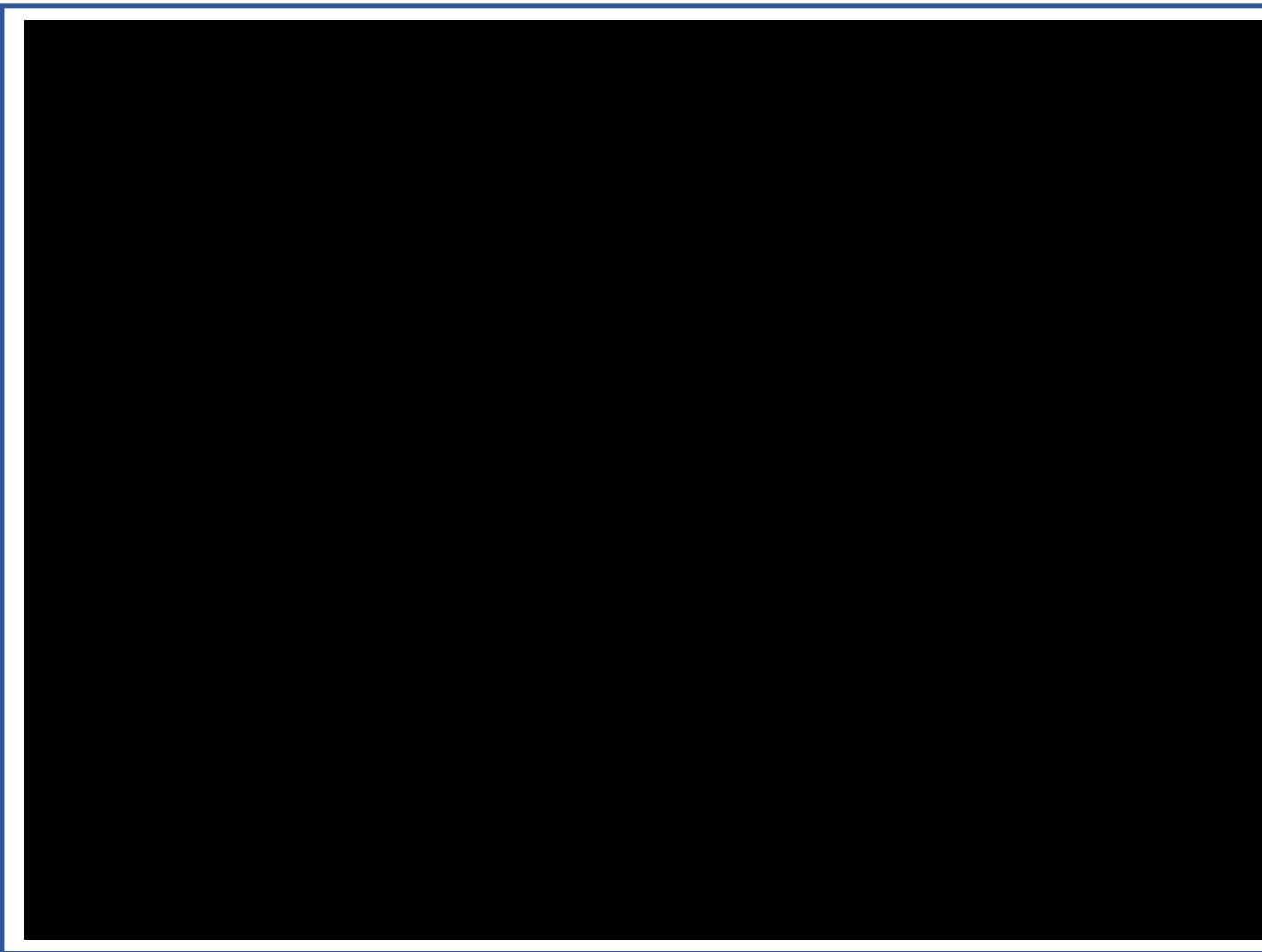
- 2013 Deep Q-Network (DQN): AI agent playing Atari video games by DeepMind.



# A Brief History of Neural Networks



- 2013 Deep Q-Network (DQN): AI agent playing Atari video games by DeepMind.

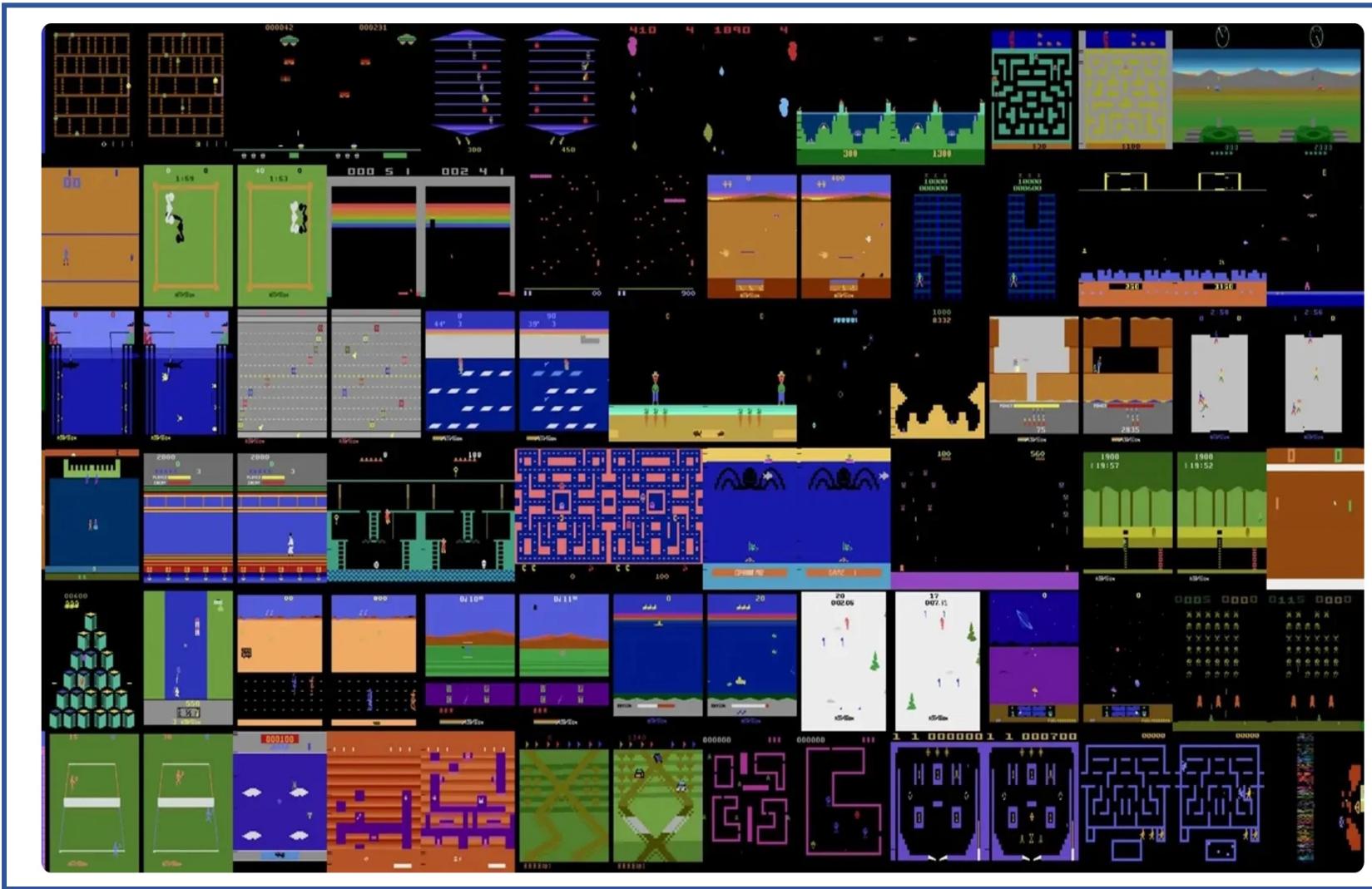


Computer Vision  
(Deep Learning)

Reinforcement Learning

# A Brief History of Neural Networks

- 2013 Deep Q-Network (DQN): AI agent playing Atari video games by DeepMind.



Computer Vision  
(Deep Learning)

Reinforcement Learning

# A Brief History of Neural Networks



- 2016 AlphaGo: AI agent beat Human player in the Game of Go by DeepMind.



Computer Vision  
(Deep Learning)

Reinforcement Learning

AI Planning (Monte-Carlo Tree Search)

AlphaGo - The Movie | Full award-winning documentary

Google DeepMind 530K subscribers

Subscribe

297K Share Download

36M views 4 years ago

# A Brief History of Neural Networks

- 2019 OpenAI Five: Open AI Five defeats Dota2 world champions.

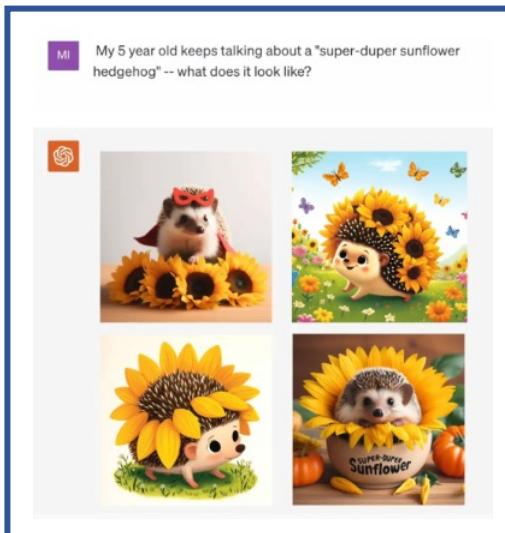
Dota2: Multiplayer Video Game



Computer Vision  
(Deep Learning)

Reinforcement Learning (Multi-Agent)

- 2021 DALL-E: Text-to-image generation model by OpenAI.



Natural Language Processing  
(Deep Learning)

Computer Vision  
(Deep Learning)

# A Brief History of Neural Networks

- **2021 AlphaFold:** AI agent predicting highly accurate protein structure by Google DeepMind.

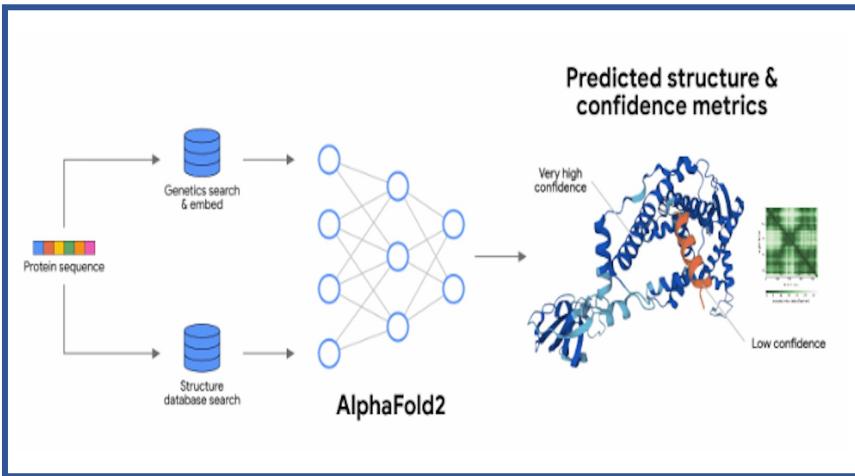
**nature**

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nature > articles > article

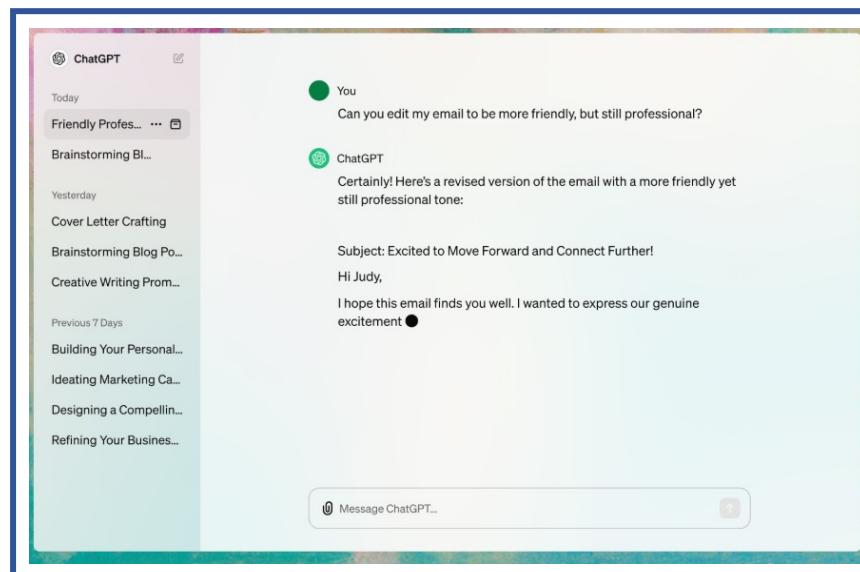
Article | Open access | Published: 22 July 2021

**Highly accurate protein structure prediction for the human proteome**



Deep Learning

- **2022 ChatGPT:** AI chatbot based on a large language model (LLM) by OpenAI.



The screenshot shows a conversation in the ChatGPT interface. A user asks: "Can you edit my email to be more friendly, but still professional?". ChatGPT responds with a revised version of the email:

Certainly! Here's a revised version of the email with a more friendly yet still professional tone:

Subject: Excited to Move Forward and Connect Further!

Hi Judy,

I hope this email finds you well. I wanted to express our genuine excitement ●

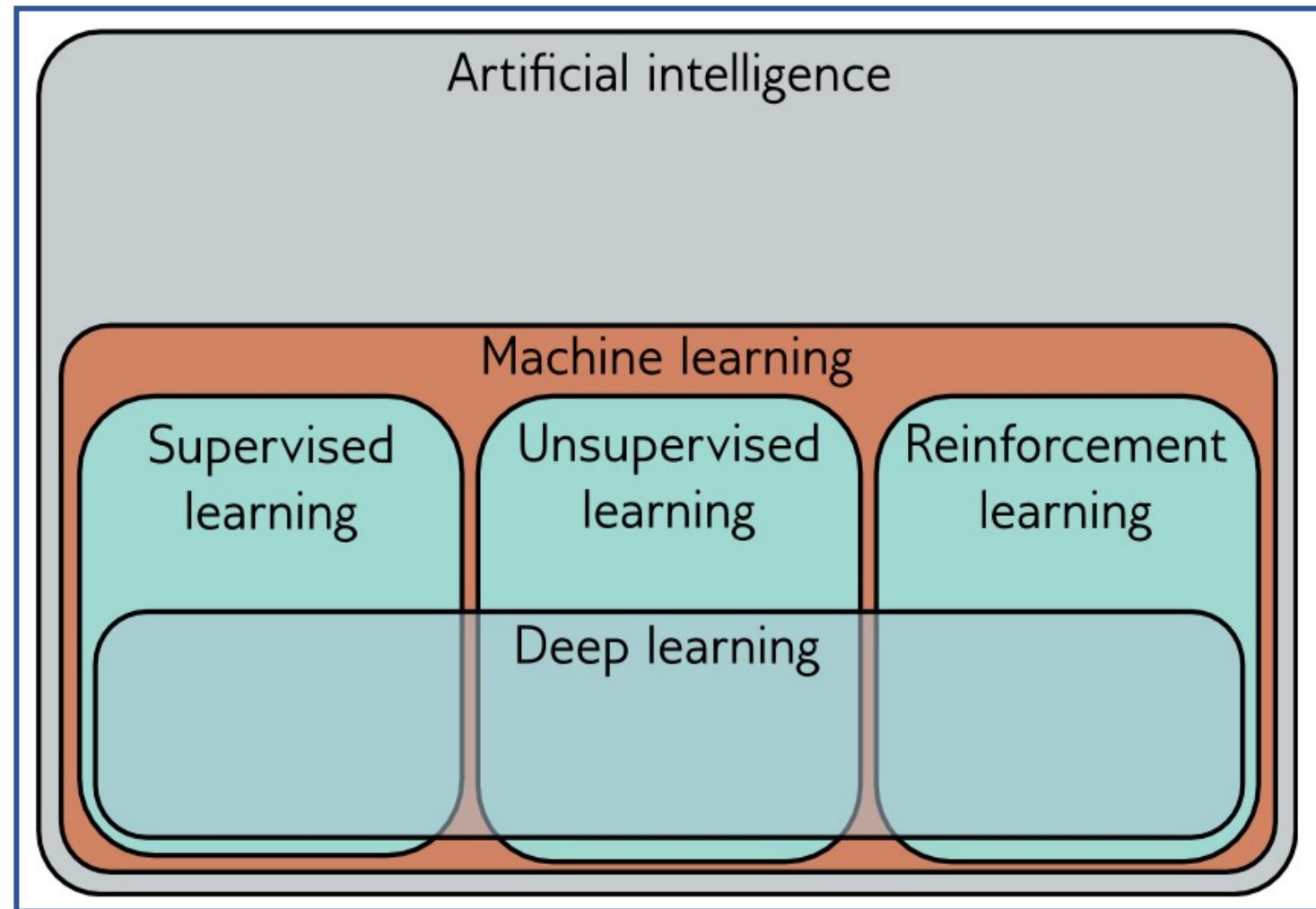
Natural Language Processing  
(Deep Learning)

# What do we learn?



- Given enough data and computing power.
- Neural networks (or Deep Learning) are powerful in learning **certain tasks**.

# What are we going to learn in this course?



- **Supervised learning:** Multilayer perceptron, basic neural network model (shallow network), Deep neural network
- **How we train them:**
  - Loss functions, optimization, backpropagation learning algorithm.
  - Overfitting, regularization.
- **Computer vision:** CNNs, pre-trained models, other architectures.
- **Natural language processing:** RNNs, LSTM, attention mechanism, transformers, LLMs,  
**guest lecture on training LLMs (by an industry expert).**
- **Learning on graphs:** Graph Neural Networks (GNNs).
- **Deep reinforcement learning,** reinforcement learning with human feedback (RLHF).
- **Unsupervised learning:** Generative models, GANs, variational autoencoders, diffusion models.



# Course Outline

## □ Detailed Syllabus:

Course website:

<https://jamesarambam.me/dl>

Week No.	Lecture Dates	Topic	Reference Materials
1	03 Jan	Introduction — Brief history and motivation	-
2	07 Jan - 10 Jan	Supervised learning: multilayer perceptron (shallow neural nets); why deep?	-
3	15 Jan - 21 Jan	Loss functions, optimisation, backpropagation	-
4	22 Jan - 24 Jan	Overfitting, regularisation	-
5	28 Jan - 31 Jan	Deep learning for Computer Vision - Basic models (CNNs)	-
6	04 Feb - 07 Feb	Deep learning for Computer Vision - Other architectures, pre-trained models	-
7	11 Feb - 14 Feb	Deep learning for NLP - Basic models (RNNs, LSTM, GRU)	-
8	18 Feb - 19 Feb	Deep learning for NLP - Attention mechanism, Transformers	-
-	21 Feb - 27 Feb	Mid Term Exam	-
9	28 Feb - 07 Mar	Deep learning for NLP - Transformers continued, Guest Lecture on training LLMs (tentative)	-
-	10 Mar - 16 Mar	Semester Break	-
10	18 Mar - 21 Mar	Graph Neural Networks (GNN)	-
11	25 Mar - 28 Mar	Generative Adversarial Network (GAN)	-
12	01 Apr - 04 Apr	Deep Reinforcement Learning, Reinforcement Learning With Human Feedback (RLHF)	-
13	08 Apr - 11 Apr	Variational Auto-encoders, Diffusion Models	-
14	15 Apr - 18 Apr	Advanced Topics	-
15	22 Apr - 25 Apr	Course Project Presentation	-



**End**