INTRODUCTION.

NEURAL NETWORKS

An attempt to understand and recreate human brains!

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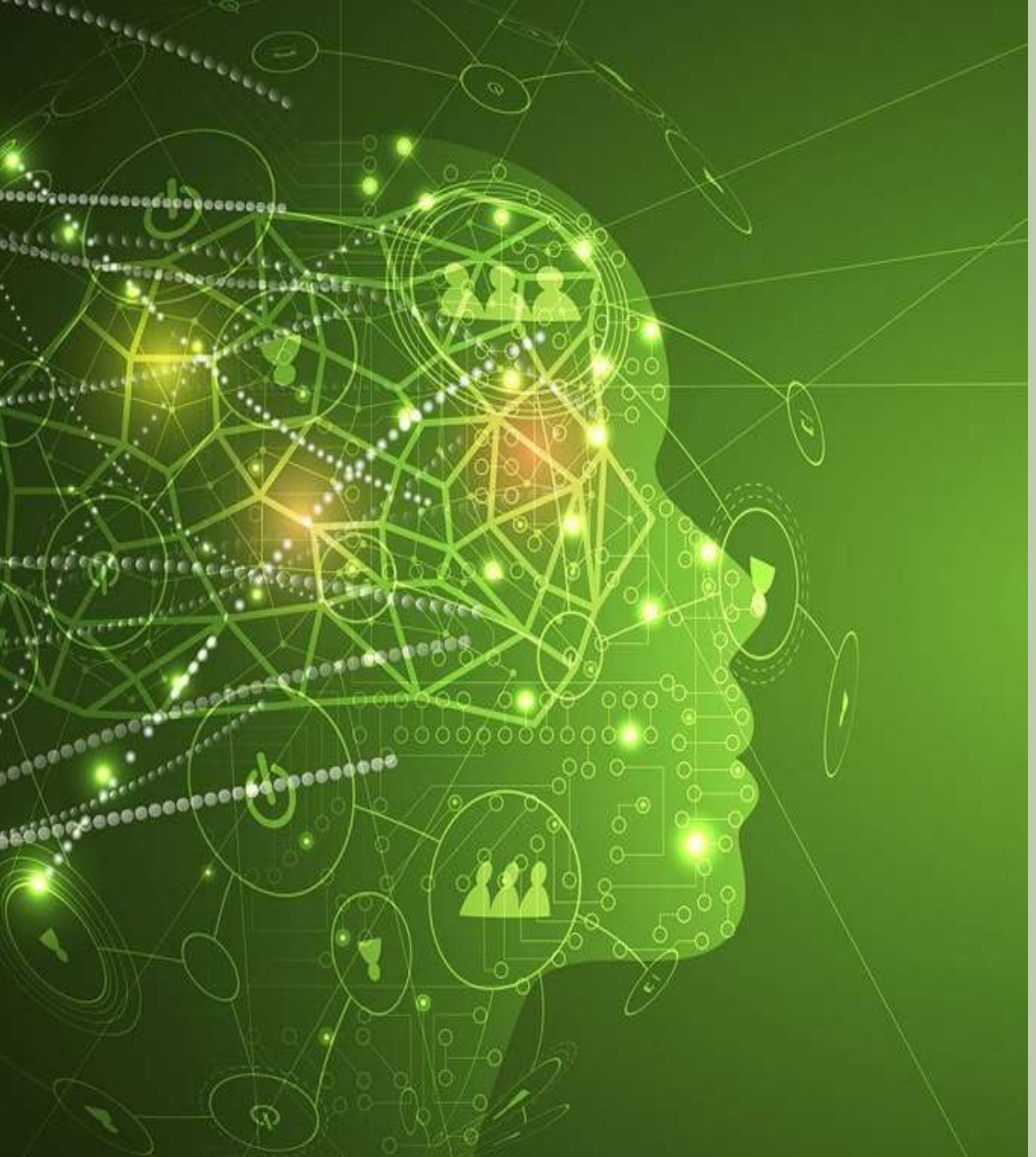


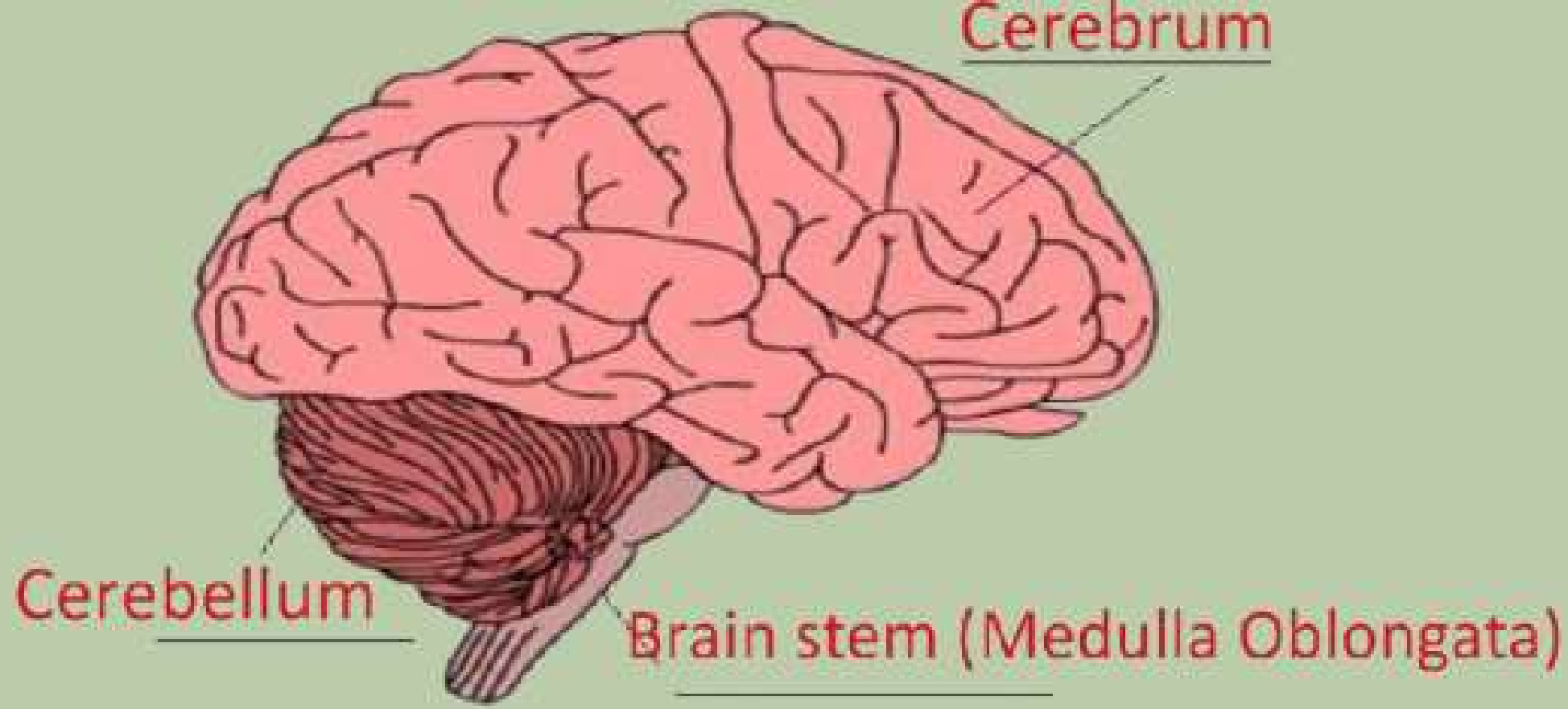
What Will You Learn Today?

1. Human Brain and its structure.
2. Understand the process of thinking.
3. Neurons
4. Bio Mimicry – Process
5. Artificial Neuron (Nodes)
6. Artificial Brain (Neural Network)
7. Types of Neural Networks
8. Quick Study of Neural Networks
9. Neuromorphic Chips
10. Live Usage
11. Conclusion & Question Round

Human Brain

- Human Brain is the most valuable creation of God. Humans can be discriminated from other species solely based on intelligence, Where do you think does this **intelligence** come from?
- The human brain is the most complex adaptive organ in our body.
- This jelly-like mass of tissue, weighing in at around 3 pounds, contains a staggering **one hundred billion** nerve cells, or neurons and the data is transferred at a speed of **120 *m/s***.
- The brain is divided into 3 parts i.e. – **cerebrum**, **cerebellum** and the **brainstem** (Medulla Oblongata), this classification can be seen in the next slide while explaining functions of each part briefly.

Source: ninds.nih.gov



Cerebellum

- Balance and Coordination
- Posture

Cerebrum

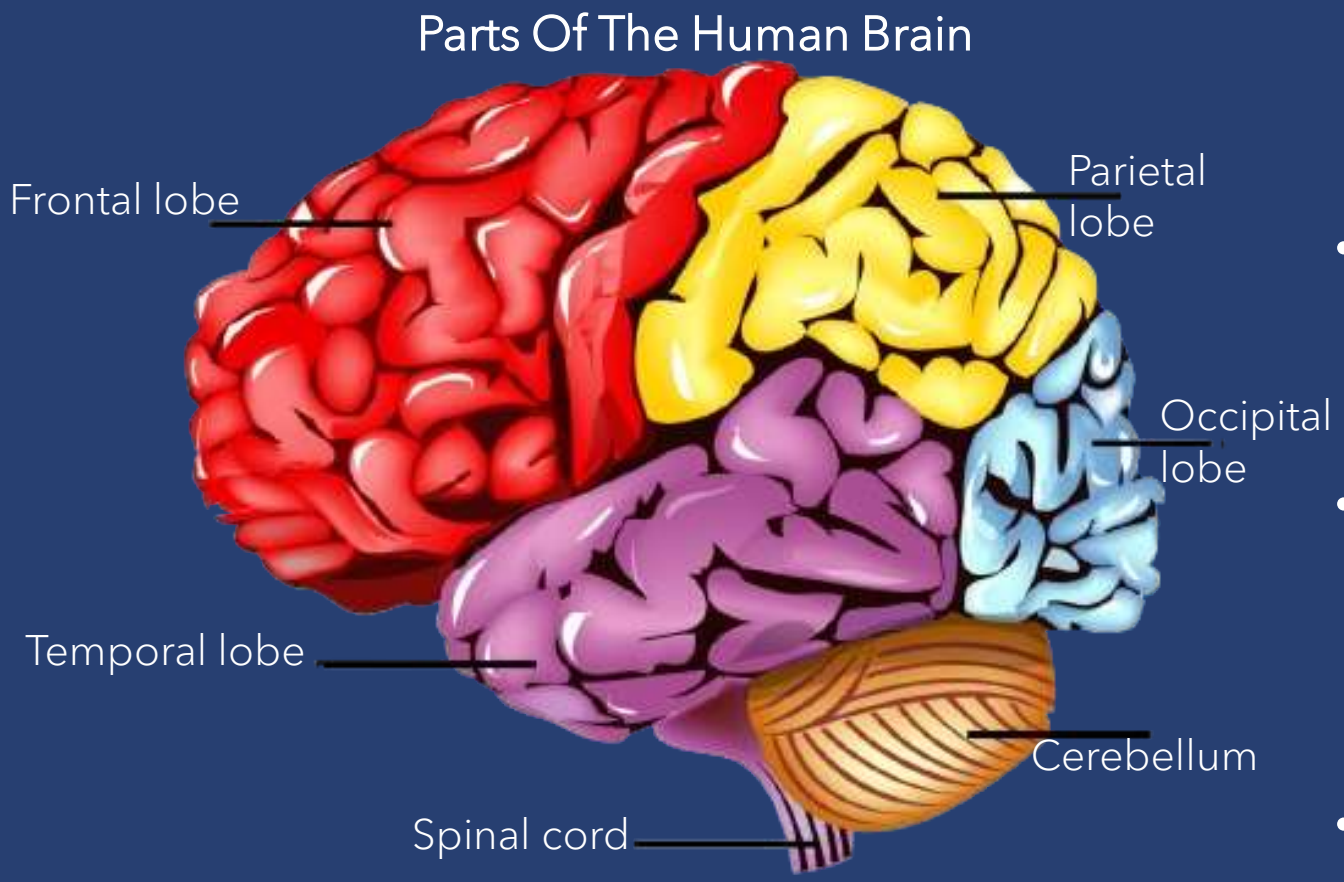
- Intelligence, learning, judgement
- Speech and Memory
- Sense of hearing, vision, taste and smell

Brain Stem (Medulla Oblongata)

- Changes in heart rate.
- Breathing, blood pressure, vomiting, swallowing
- Digestion

Source: ninds.nih.gov

Structure of Brain



- **Frontal Lobe** - Problem-solving, decision-making, attention, intelligence, and voluntary behaviors.
- **Temporal Lobe** - Understanding, language, memory acquisition, face recognition, object recognition, perception.
- **Parietal Lobe** - Allow us realize sensation through touch, pressure, temperature , visuospatial processing, reading, and number representations .
- **Occipital Lobe** - Assess the size, depth, and distance, determine color information, object and facial recognition, and mapping the visual world.

Source: ninds.nih.gov

Process of thinking

Sensory Receptors: Detect **stimuli** and convert them into electrical signals.

Primary Processing: Basic processing occurs in sensory areas (e.g., visual cortex).

Context and Memory: It helps interpret the **stimulus**.

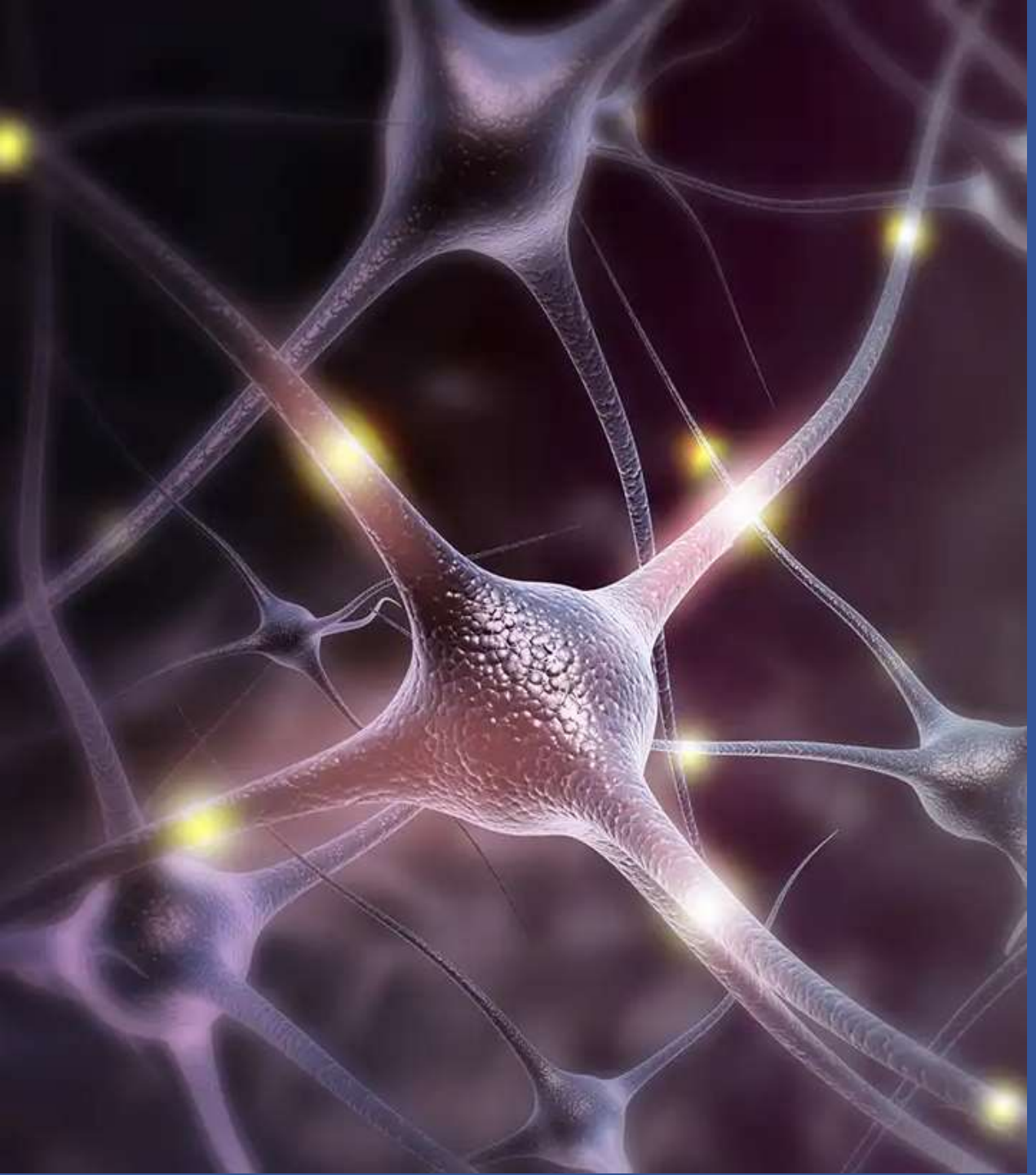
Response Generation: The brain sends a response to muscles or effectors.

Transmit Signals: Signals travel through **neurons** to the brain.

Higher-Level Processing: Information is integrated with past experiences in association areas.

Cognitive and Emotional Processing: The brain assesses the stimulus's significance.

Learning from past encounters: The brain remembers and responds differently for newer similar encounters



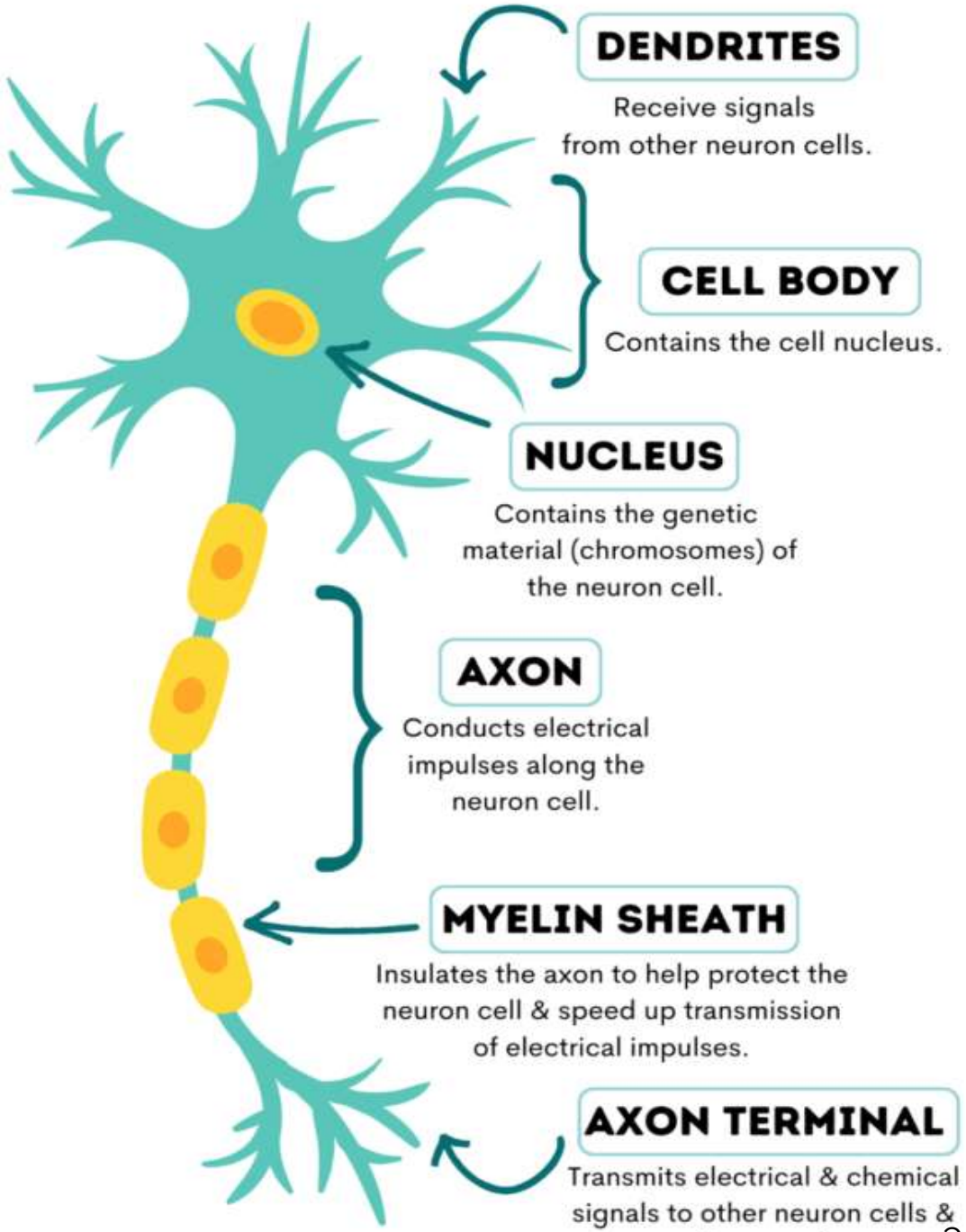
Neurons

- Neurons are the **fundamental units** of the brain and nervous system, the cells responsible for receiving sensory input from the external world, for sending motor commands to our muscles, for **transforming** and **relaying** the electrical signals at every step in between.
- A specialized cell, primarily involved in transmitting information through **electrical** and **chemical signals** from our body to our brain and back to our body.
- The creation of new neurons in the brain is called **neurogenesis**, and this can happen even in adults.

Source: qbi.uq.edu.au

Parts of a Neuron

- The primary function of a neuron as a cell is to **receive**, **transmit** and **store** electrical impulses.
- To achieve the broader function, the nerve cell is divided into multiple smaller parts which are visible in the diagram adjacent to the text.
- The image also tells us about the functions of each individual part of the neuron.
- The signal transfer in a neuron is complex but it can be explained with scientific proofs that the signal transfer as **electrical impulse** within a single neuron cell and when transmitting to another cell, it gets converted to chemical aka **Neurotransmitters**.



Source: qbi.uq.edu.au

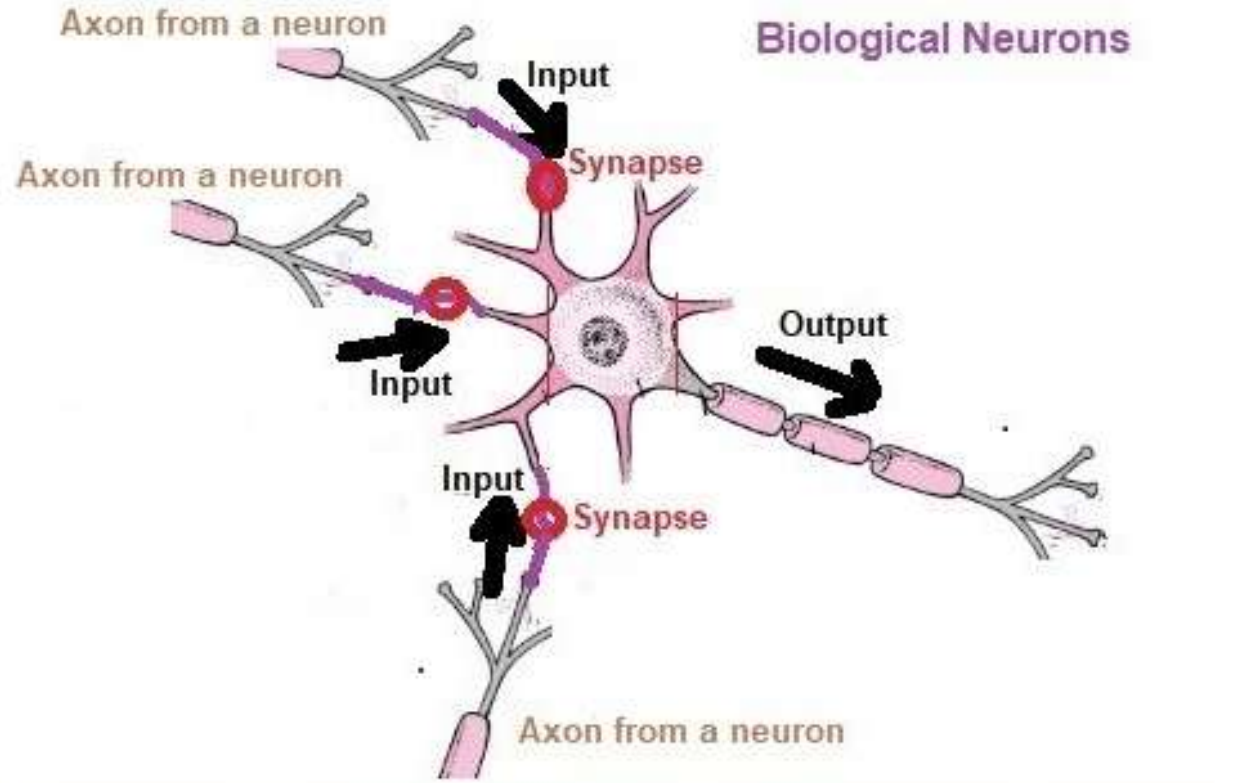
Bio-Mimicry

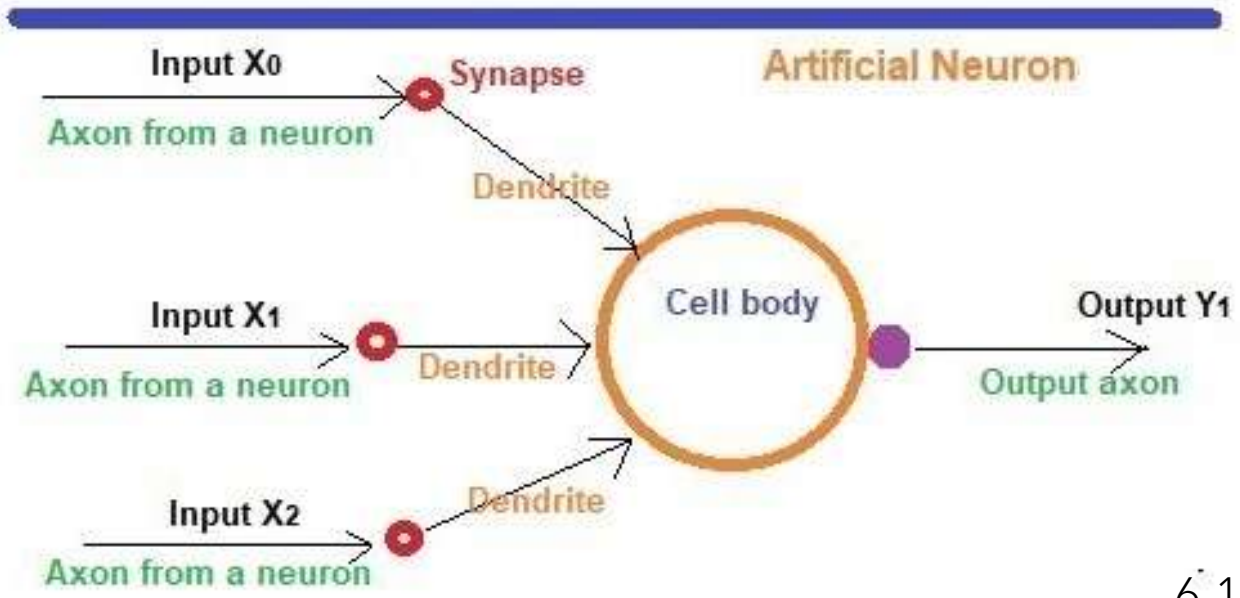
- Neural network and the **nodal architectures** are motivated by models of the human brain and nerve cells. Our current knowledge of the brain is limited to its anatomical and physiological details provides only a partial understanding of its complex adaptive working.
- However, many genius in this field have been able to provide with their own **theories** and with the compilations of those theories we have been able to make a soft copy of brain – **Neural Networks**!
- Neural Network is an attempt to replicate the complex adaptive **human brain into software** that a computer can understand.
- The very first recorded attempt was made by IBM – **Blue Brain** in 2005.

Artificial Neuron

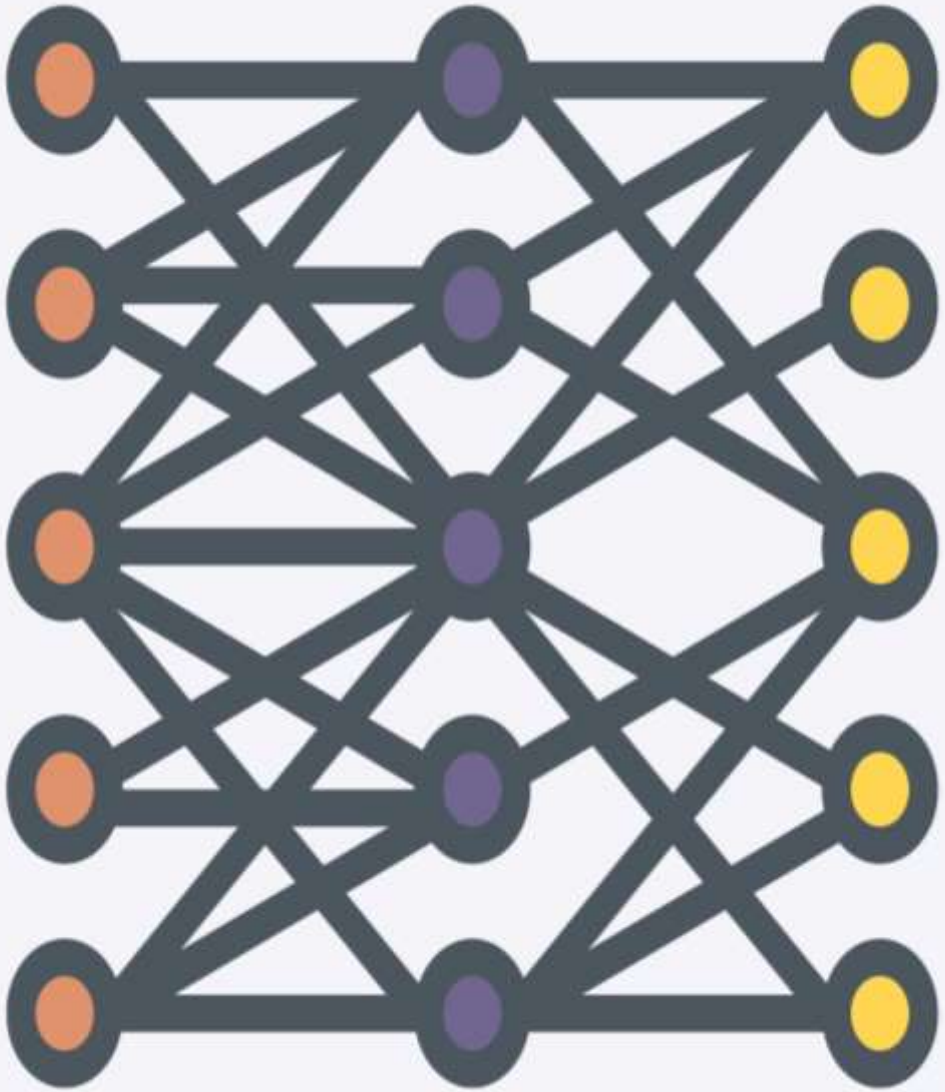
- Artificial Neuron (Node) **mimics** the characteristics of the biological neuron.
- They are fundamental components in machine learning models.
- Similarities in a Biological and Artificial Neuron are shown in the table below:

Biological Neuron	Artificial Neuron
Dendrite	Inputs
Cell nucleus or Soma	Nodes
Synapses	Weights
Axon	Output





Source: Introduction to Artificial Neural Networks



Neural Networks

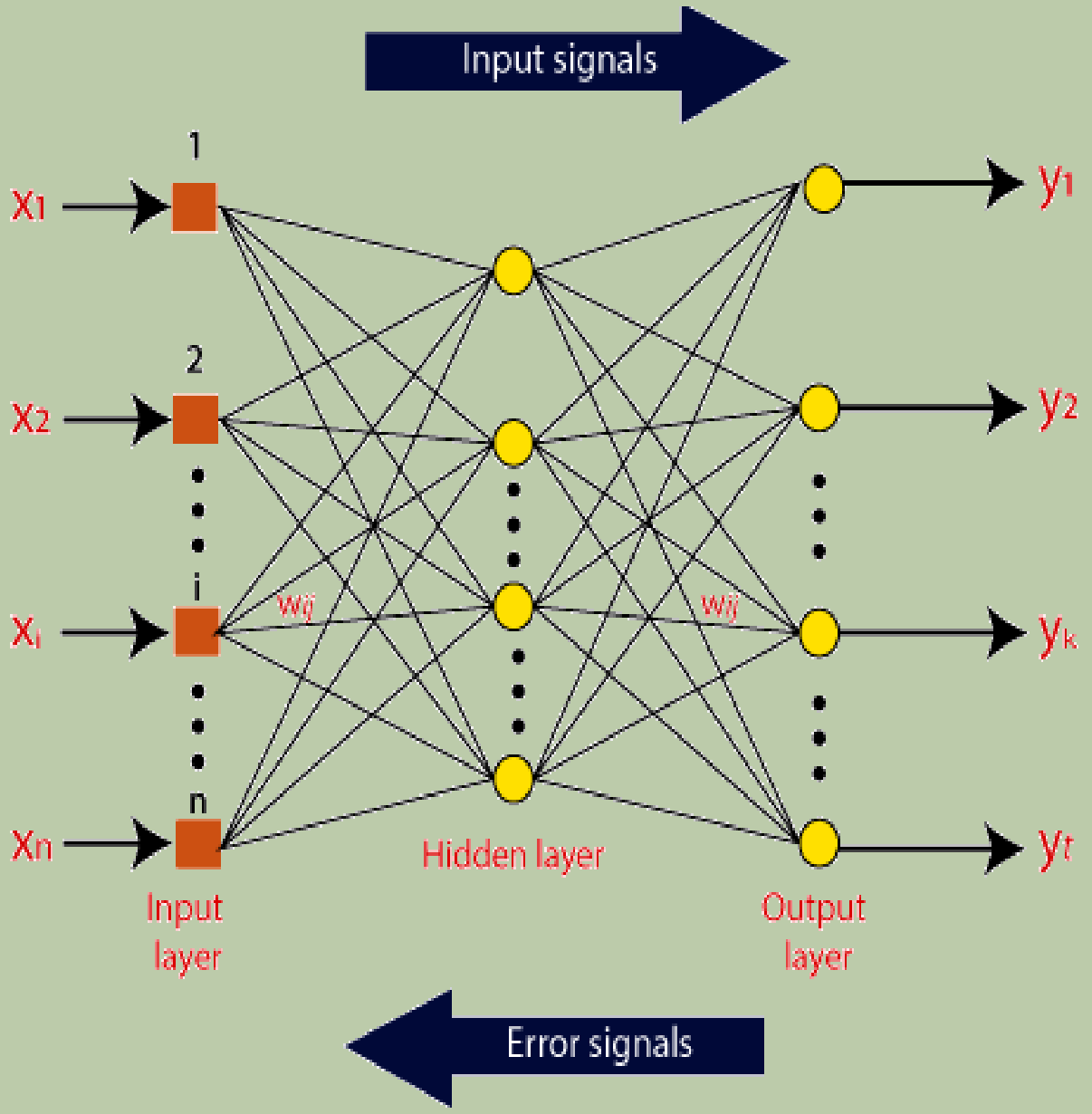
- Neural network is the study of networks consisting of nodes connected by **adaptable** weights, which store **experimental** knowledge from task examples through a process of learning.
- The Artificial Brain i.e. Neural Networks are made up using **multiple artificial neurons** i.e. Nodes.
- A typical Neural Network has **input** and **output** layers, most of them also have **hidden** layers to process the input thoroughly, each layer have multiple nodes depending on the overall function of the Network.
- Neural Network can be thought of as a human brain model with many neurons inside it that connect in a specific order and makes the network functional.

Source: Introduction to Artificial Neural Networks

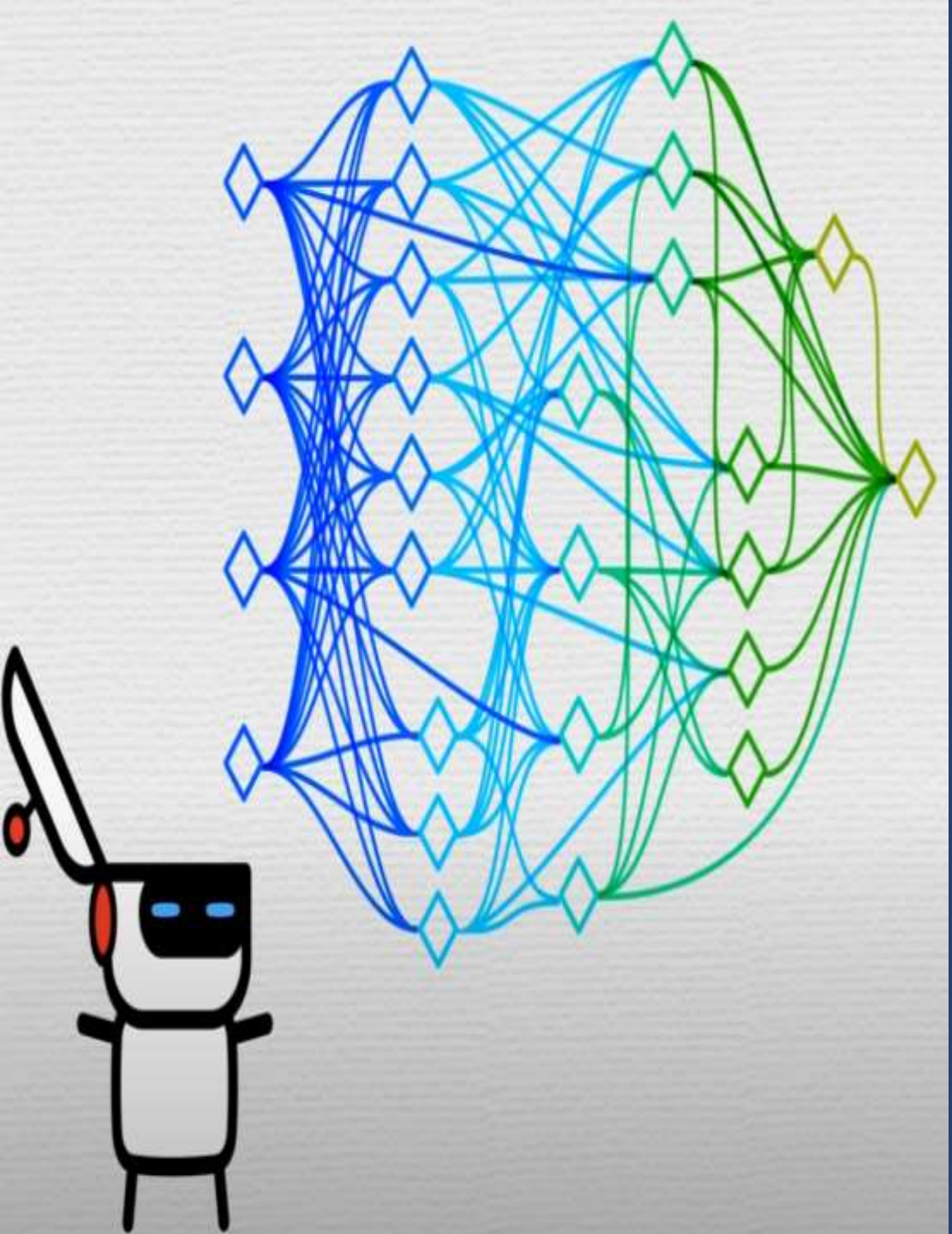
Phases of NNs

The ANNs can be split into **3 phases**:

1. **Learning**: The Neural Networks first learn using the database that has been provided with labels. In this stage, the neural network **forms expressions** to simply classify the data into different categories.
2. **Testing**: In this phase, the Neural Network is given an **input**, and the **output** is **compared** to the **desired output** using the labels provided in the dataset.
   The ANN then change their expressions to **finetune** in case of inappropriate outputs.
   This also helps measure the accuracy of the Neural Network.
3. **Prediction**: This is the actual usage phase where the inputs given aren't labeled and the ANN **predicts** and gives the output.



Source: Introduction to Artificial Neural Networks



Learning

- The concept of a machine learning through data still feels like magic to most but it is all about calculus.
- Here is what happens when a machine is learning:
  1. A builder bot randomly **builds** up a thousands of neural networks with **random** weights and bias.
  2. A teacher bot **tests** the bots using the data **provided by us** as a dataset.
  3. The bots **generates expressions** based on their assigned weights and biases and give a **random result**.
  4. The teacher bot **analyses** the result for every bot and the few **best scorer bots** are then sent to the builder bot and the rest are **discarded**.
  5. Now, the builder bot builds newer bots **based of the patterns** of the top scoring bots.
  6. The process **repeats** steps **2 - 5** until the user is satisfied with the accuracy.

Source: YouTube.com

Effect of Arrangement

Neural Networks can be **classified** based on multiple factors like:

- **Patterns** of connection between the neurons (architecture of the network)
- **Activation** function applied to the neurons.
- Method of **determining weights** on the connection (training or learning method)

There are multiple methods for **training an artificial neural network** like:

- Supervised Learning – Feedback for every output
- Unsupervised Learning – No Feedback
- Reinforcement Learning – Feedback for correct / incorrect

Source: Introduction to Artificial Neural Networks

Based on connection type

- Feed-Forward Neural Networks
- Recurrent Neural Networks

Based on hidden layers

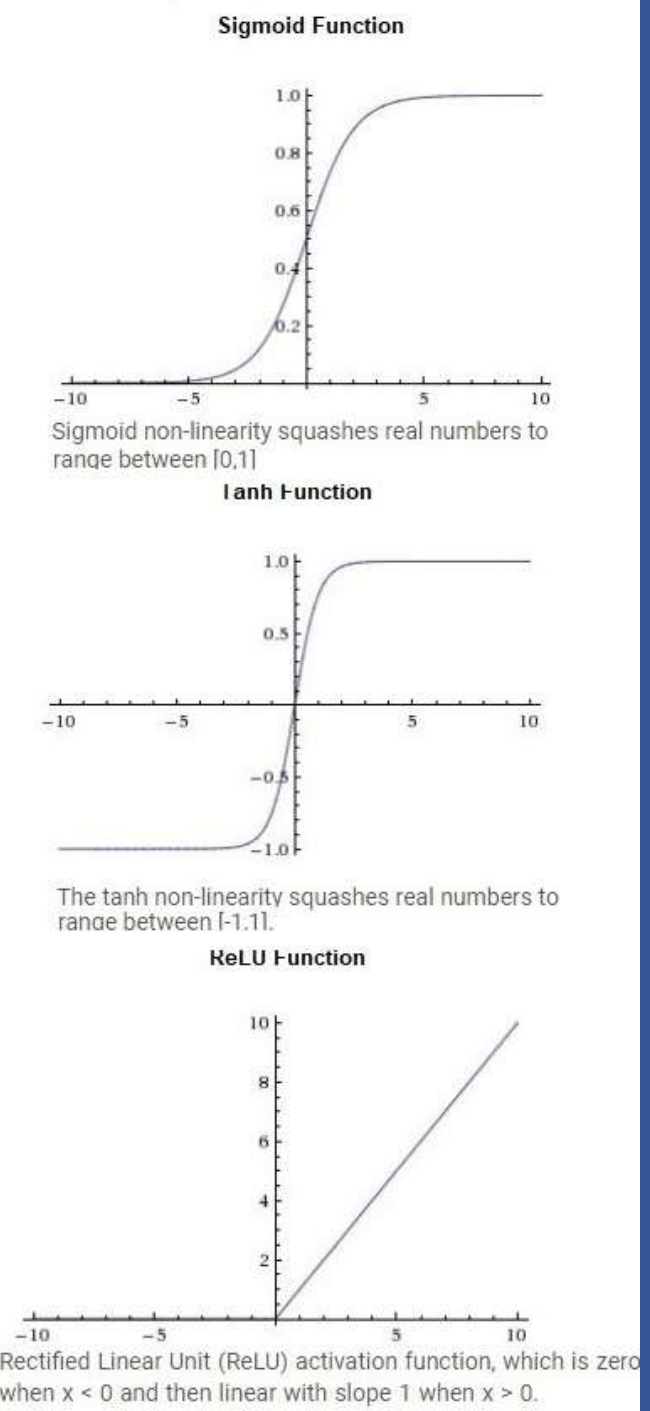
- Single layer neural network
- Multi layer neural network

Based on memory

- Static neural network
- Dynamic neural network

Based on weight

- Fixed neural network
- Adaptive neural network



Weights, Bias, Activation

- Weight at the synapse represents the synaptic strength. It gets **multiplied** to the input signals to derive the weighted signal strength. Weights are learnable (can be tweaked) and control the strength of influence of one neuron on another
- Bias is used to offset the output / result. It helps the model to shift the activation function towards the positive or negative side, basically help it to bring the result closer to the desired outcome by **addition** or subtraction
- Activation function represents the frequency of the spikes along the axon. Some of the commonly used activation functions are **Sigmoid**, **Tanh** and Rectified Linear Unit (**ReLU**) which are represented in the diagram adjacent.
- The output signal for sigmoid activation can be represented as:

```
def output(self, inputSignal):
    processed_input = (inputSignal * self.weight) + self.bias
    return sigmoid(processed_input)

def sigmoid(input):
    sigmoid  = 1/(1+math.exp(-input))
    return sigmoid
```

Source: linkedin.com

Types of Neural Networks

Please Refer to
https://www.youtube.com/watch?v=u7obuspdQu4
To understand vividly about the different types of the neural networks.

Source: YouTube.com

PROS:

- Neural networks are **flexible** and can be used for both **regression** and **classification** problems.
- Once trained, the predictions are pretty **fast** and **accurate**.
- Neural networks work best while compiling **large data**.
- Neural networks can be trained with **any number of inputs** and layers. It works by splitting the problem of classification into a layered network of simpler elements.

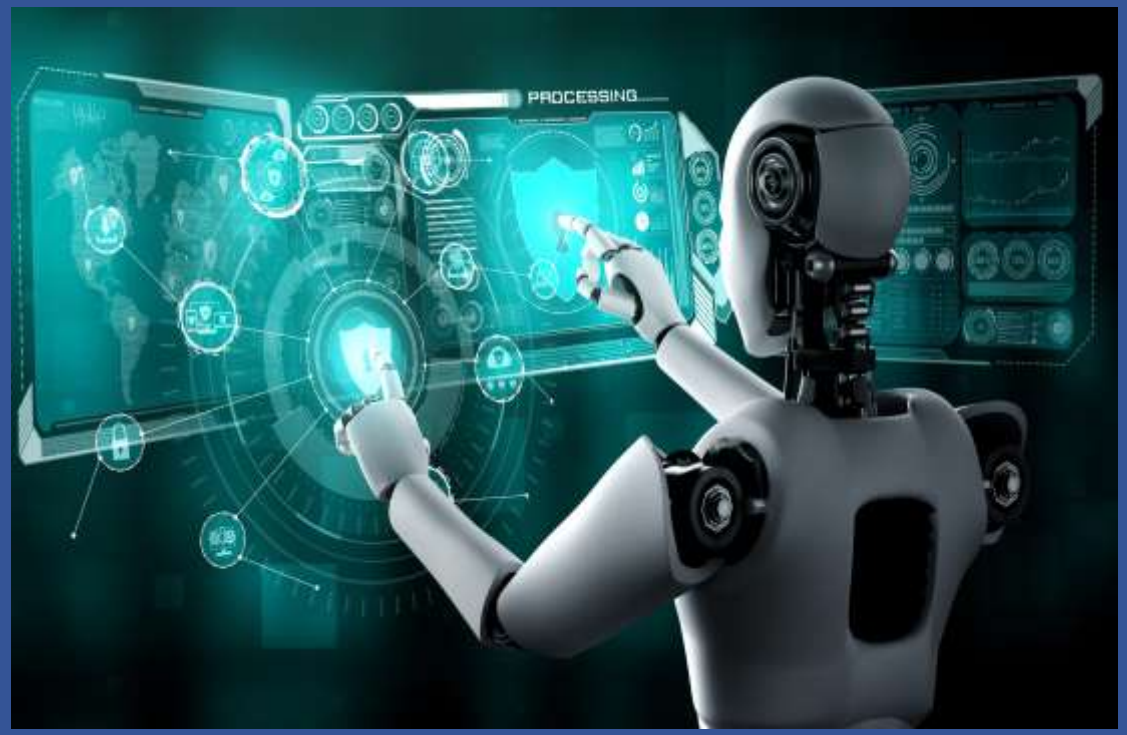
CONS:

- Neural networks are black boxes, meaning we **cannot know** how much each independent variable is influencing the dependent variables.
- It is **computationally** very **expensive** and time consuming to train with traditional CPUs.
- Neural networks **depend** on a lot of **training data**. This leads to the problem of **over-fitting** and generalization.
- Machine don't understand **Emotion**.

Source: packtpub.com

Upcoming Improvements

- **Energy-Efficient Neural Networks**: Creating architectures that significantly **reduce energy consumption** during training and inference, making AI more sustainable and accessible for edge devices.
- **Explainable AI (XAI)**: Improving methods to make neural networks **more interpretable**, allowing users to **understand model decisions**, which is crucial for trust in high-stakes applications like healthcare and finance.
- **Neural Network Compression**: Developing techniques to **compress large models** without sacrificing performance, enabling deployment on resource-constrained devices.



Source: arxiv.org

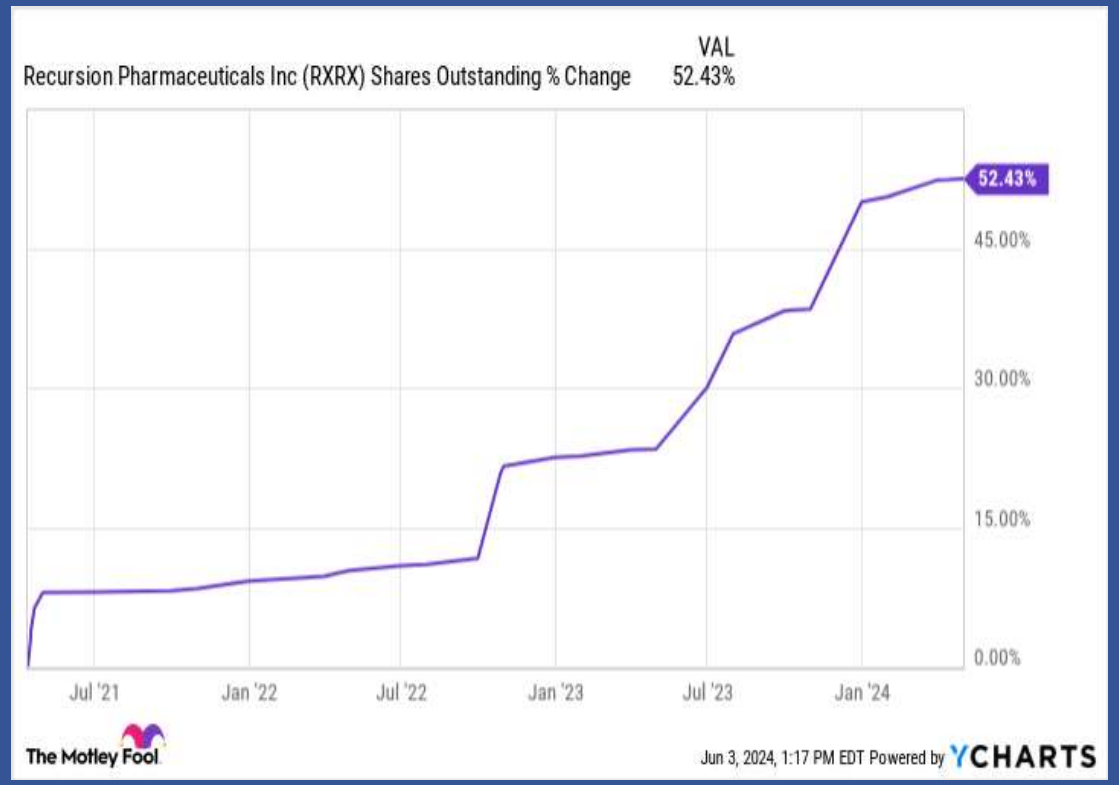
Princeton Plasma Physics Laboratory

- **Initial Struggles**:
- Traditional methods for plasma heating and control in fusion research were **slow** and **complex**, making real-time decision-making **challenging**.
- **AI Adoption**:
- PPPL integrated machine learning to **optimize plasma heating**, **reducing computation time** from **minutes to microseconds** while maintaining 90% accuracy.
- **Post-AI Impact**:
- AI accelerated simulations, enabling **real-time adjustments** in plasma behavior.
- Improved plasma heating efficiency and contributed to ongoing fusion research advancements.
- **Enhanced** understanding of plasma stability, crucial for future commercial fusion power plants.
- AI significantly boosted PPPL's capabilities, pushing fusion research closer to practical energy solutions.

Source: sciencedaily.com

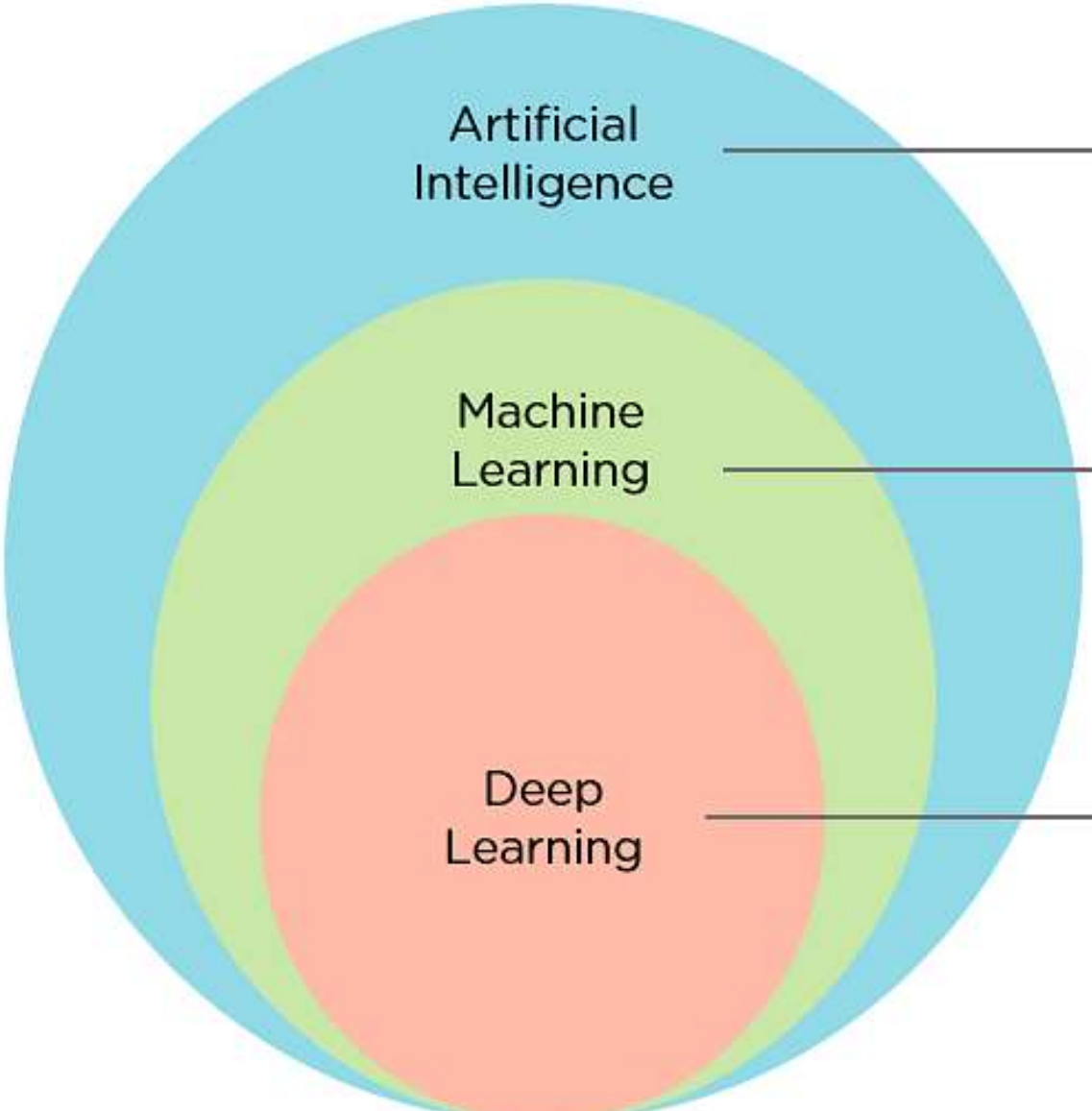
Recursion Pharmaceuticals

- **Initial Struggles**:
  - Faced slow drug discovery using traditional methods, leading to **limited revenue** and slow progress.
- **AI Adoption**:
  - In 2017, Recursion integrated **AI** and neural networks to analyze cellular images, processing **2 million images weekly**.
- **Post-AI Impact**:
  - Reduced drug discovery time from **years to weeks**.
  - By 2020, raised **$465 million** and grew to a **$5 billion valuation**.
  - Expanded its drug pipeline from a few to **37 drugs** in development.
  - AI transformed Recursion's efficiency and revenue, making it a leader in biotech innovation.



Source: fiercebiotech.com

ARTIFICIAL INTELLIGENCE VS MACHINE LEARNING VS DEEP LEARNING



Ability of a machine to imitate intelligent human behavior

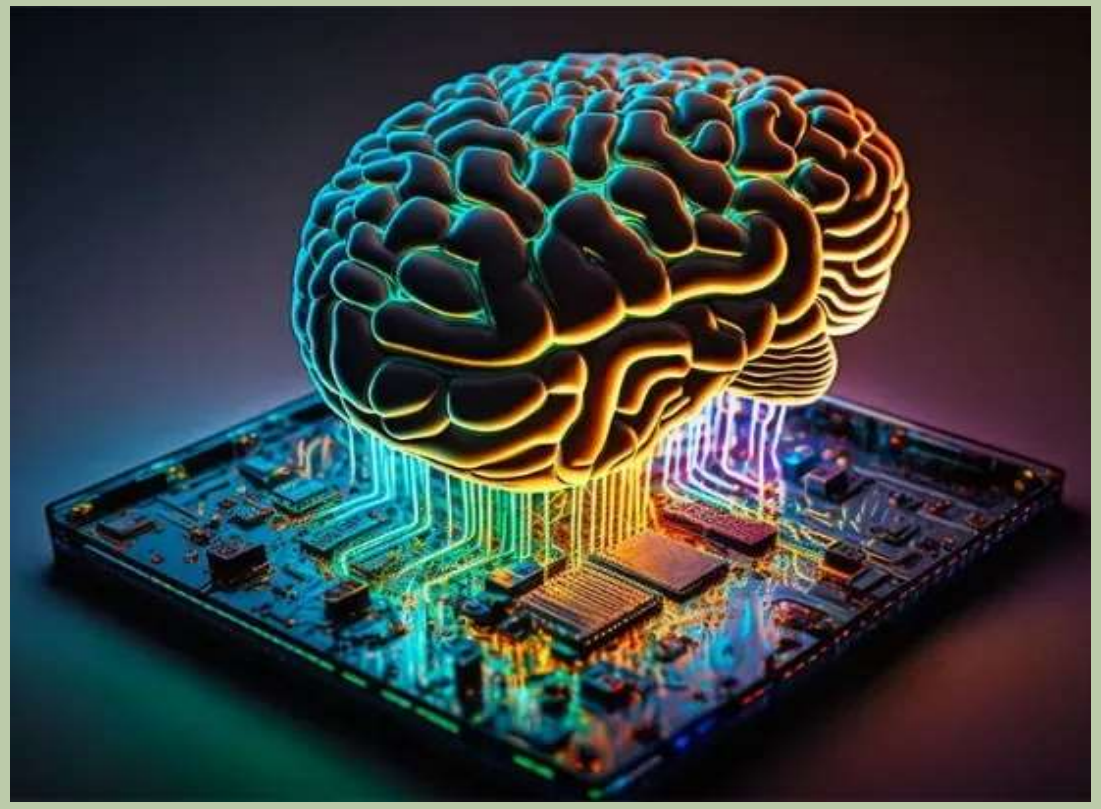
Application of AI that allows a system to automatically learn and improve from experience

Application of Machine Learning that uses complex algorithms and deep neural nets to train a model

Deep learning is just a powerful set of techniques for learning in neural networks

Neuromorphic Chips

- Neuromorphic architectures are most often modeled after the neocortex in the brain. That's where higher cognitive functions like sensory perception, motor commands, spatial reasoning and language are thought to occur. The **neocortex's layered** structure and intricate connectivity are critical to its ability to **process complex information** and enable human thinking.
- The neocortex is made up of neurons and synapses that **send** and **carry information** from the brain with near-**instantaneous speed** and **incredible efficiency**. It's what tells your foot to immediately move if you accidentally step on a sharp nail.
- Neuromorphic computers try to **replicate that efficiency**. They do so by forming what are called **spiking neural networks**. These are formed when spiking neurons, which hold data as if they were biological neurons, are connected via artificial synaptic devices that transfer electrical signals between them.

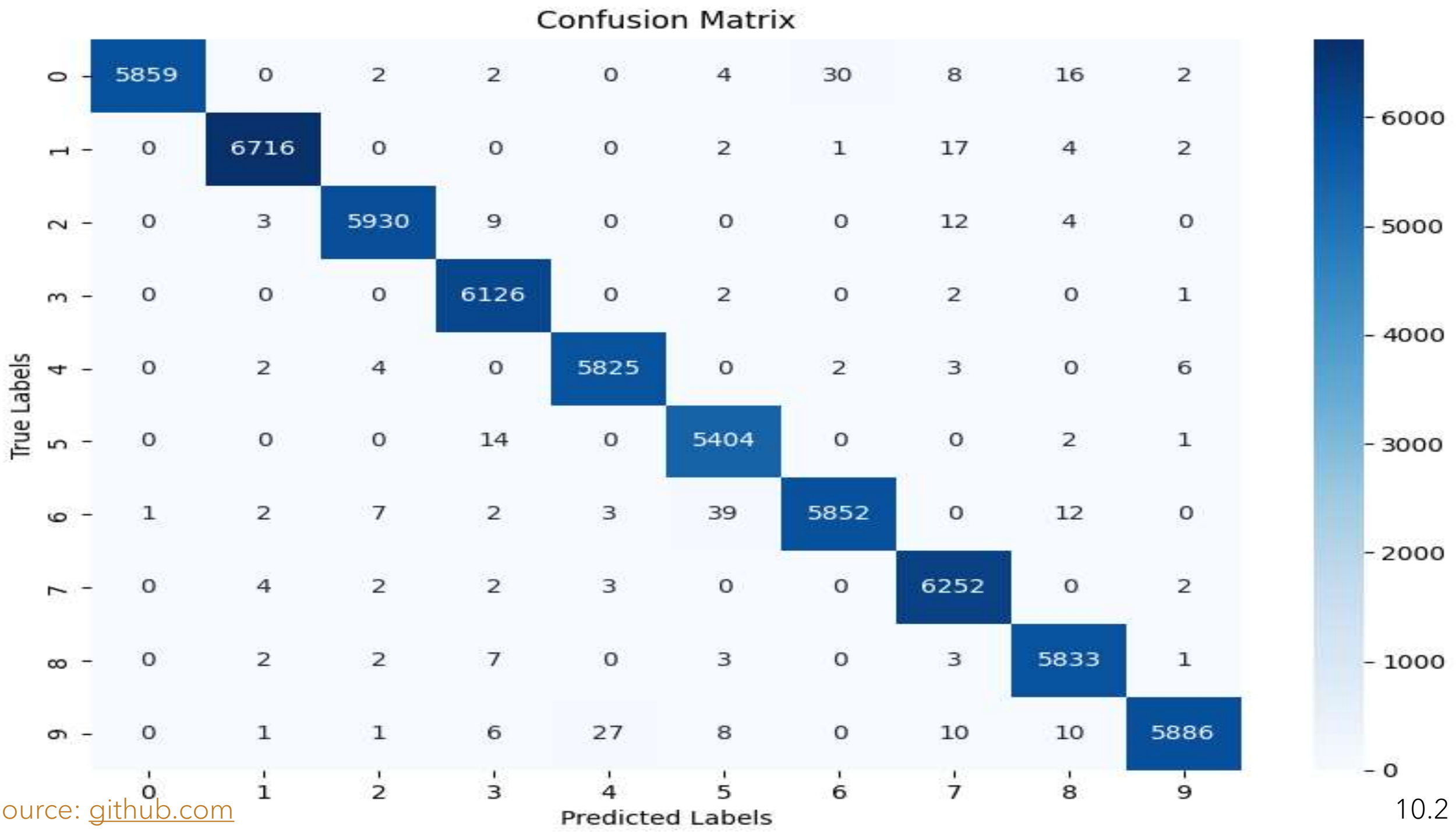


Source: builtin.com

Live Usage – Digit Recognizer

- Now let's have a look at an actual application of a neural network, in our case we will draw and look a digit and ask the neural network to predict it.
- With this Live Usage we will explain how a model can be inaccurate, how does it classify digits, how much time does it take for a simple task like such.
- We will also try to visualize some errors and learn about how the machine learns theoretically.

Source: github.com



Source: github.com

Recap

- **Parts and Function of Human Brain:** We explored about various regions and their functions.
- **Neurons and its functioning:** We studied about the building blocks of our nervous System - Neurons.
- **Neural Network:** We reviewed different types of Neural Network and its functioning.
- **Machine learning:** We gained insights into the algorithms that enable computers to improve their performance on tasks by learning from data rather than being explicitly programmed.
- **Neuromorphic chips:** We discovered the Specialized hardware Neuromorphic Chips that's are designed to mimic the neural structure and functioning of the human brain.
- **Digit Recognizer:** We analyzed the program that Identifies and classifies handwritten digits using machine learning techniques.

QUESTIONS.