



Al-Mustaqbal University / College of Engineering

Prosthetics & Orthotics Eng. Department

Third Class

Subject (ARTIFICIAL NEURAL NETWORKS)

Code (UOMU0103057)

DR. Lec. Ahmed ALmhanna

Lecture 1



# ARTIFICIAL NEURAL NETWORKS

## Introduction to Artificial Neural Networks & Historical Background

### 1. What is an Artificial Neural Network?

An Artificial Neural Network (ANN) is a computational model inspired by the structure and function of the human brain. It consists of a large number of interconnected processing units called neurons, which work together to solve complex problems such as pattern recognition, classification, prediction, and control.

ANNs are a fundamental component of modern machine learning and artificial intelligence. Unlike traditional rule-based systems, ANNs learn from data — they improve their performance by adjusting internal parameters through a process called training.

#### 1.1 Key Characteristics of ANNs

- **Massive Parallelism:** Many neurons operate simultaneously, allowing fast computation.
- **Learning Ability:** The network can learn from examples without being explicitly programmed.
- **Generalization:** After training, ANNs can handle new, unseen data effectively.
- **Fault Tolerance:** Damage to a few neurons does not destroy all stored information.
- **Adaptability:** ANNs can retrain to adapt to new environments or changing data.

### 2. Biological Inspiration

The human brain contains approximately 100 billion neurons, each connected to thousands of others through synapses. Information is transmitted as electrical signals.



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The brain processes sensory input, controls motor functions, stores memories, and enables conscious thought — all through neural activity.

Scientists and engineers have long been inspired by the brain's remarkable ability to learn and recognize patterns. This biological inspiration gave rise to the concept of artificial neural networks.

## 2.1 The Biological Neuron

### Structure of a Biological Neuron

**Dendrites** — Tree-like extensions that receive input signals from other neurons.

**Cell Body (Soma)** — Processes incoming signals and generates output.

**Axon** — Long fiber that carries the output signal away from the cell body.

**Synapses** — Junctions between neurons where signals are transmitted.

**Myelin Sheath** — Insulating layer that speeds up signal transmission along the axon.

A neuron 'fires' (sends a signal) when the combined inputs it receives exceed a certain threshold. This threshold mechanism is a crucial concept that is mirrored in artificial neurons.

## 3. Historical Background

The development of ANNs spans several decades. Below is a chronological overview of the key milestones in neural network history.

Year	Researcher(s)	Contribution
1943	McCulloch & Pitts	First mathematical model of a neuron. Showed that networks of neurons could compute logical functions.
1949	Donald Hebb	Proposed Hebbian Learning: 'Neurons that fire together, wire together.' — foundational learning rule.
1957	Frank Rosenblatt	Invented the Perceptron — first trainable neural network model capable of binary classification.



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<b>1960</b>	Widrow & Hoff	Developed the ADALINE model and the LMS (Least Mean Squares) learning rule.
<b>1969</b>	Minsky & Papert	Published 'Perceptrons' book — showed limitations of single-layer networks. Led to first AI winter.
<b>1982</b>	John Hopfield	Introduced Hopfield Networks — recurrent networks used for associative memory.
<b>1986</b>	Rumelhart et al.	Popularized the Backpropagation algorithm — enabled training of multi-layer networks. Sparked renewed interest.
<b>1989</b>	LeCun et al.	Applied backprop to train Convolutional Neural Networks (CNNs) for handwritten digit recognition.
<b>1997</b>	Hochreiter & Schmidhuber	Introduced Long Short-Term Memory (LSTM) networks for sequential data.
<b>2006</b>	Geoffrey Hinton	Deep Belief Networks — reignited interest in deep learning through unsupervised pre-training.
<b>2012</b>	Krizhevsky et al.	AlexNet won ImageNet competition — proved deep CNNs outperform traditional methods. Start of modern DL era.



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## 4. The AI Winters and Revivals

The history of neural networks is marked by periods of great enthusiasm ('summers') and periods of reduced funding and interest ('winters').

### 4.1 First AI Winter (1969-1980)

Minsky and Papert's 1969 book demonstrated that perceptrons cannot solve non-linearly separable problems like XOR. This led to a dramatic reduction in ANN research funding throughout the 1970s.

### 4.2 Second AI Winter (1987-1993)

Despite the success of backpropagation, limitations in computing power and the rise of expert systems caused another slowdown. Training deep networks was computationally infeasible on the hardware of the time.

### 4.3 The Deep Learning Revolution (2006-Present)

The combination of three factors triggered the modern deep learning era:

- **Big Data:** The internet produced vast amounts of labeled training data (images, text, audio).
- **GPU Computing:** Graphics Processing Units enabled parallel computation, reducing training time from weeks to hours.
- **Algorithmic Advances:** Better initialization methods, activation functions (ReLU), dropout regularization, and batch normalization made deep networks trainable.

## 5. Applications of ANNs

### Major Application Domains

**Computer Vision:** Image classification, object detection, facial recognition, medical imaging.

**Natural Language Processing:** Machine translation, sentiment analysis, chatbots, text generation.

**Speech Recognition:** Voice assistants (Siri, Alexa), automatic transcription systems.

**Healthcare:** Cancer detection, drug discovery, patient outcome prediction.

**Finance:** Stock market prediction, fraud detection, credit risk assessment.

**Autonomous Vehicles:** Self-driving cars — perception, path planning, decision making.

**Robotics:** Robot control, manipulation, navigation in unstructured environments.

**Games & Simulation:** AlphaGo, AlphaZero — superhuman performance in complex games.

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## 6. Why Use ANNs?

Traditional programming requires a human expert to define explicit rules for every scenario. This becomes impractical for complex tasks like image recognition or language understanding. ANNs learn the rules automatically from data.

Traditional Programming	Artificial Neural Networks
Rules are written by humans	Rules are learned from data
Brittle — fails on edge cases	Robust — handles noisy/incomplete data
Requires expert knowledge	Requires labeled training examples
Hard to scale to complex tasks	Scales to extremely complex tasks
Cannot improve automatically	Continuously improves with more data

## 7. Types of Neural Networks (Overview)

Over decades of research, many architectures have been developed. Here is a brief overview of the major types:

**Feedforward Networks (FNN):** The simplest architecture. Data flows in one direction from input to output. Used for classification and regression.

**Convolutional Neural Networks (CNN):** Specialized for grid-like data (images). Use convolution operations to detect local patterns. State-of-the-art for vision tasks.

**Recurrent Neural Networks (RNN):** Contain loops allowing information to persist. Designed for sequential data like text, speech, and time series.

**Long Short-Term Memory (LSTM):** A special type of RNN that can learn long-range dependencies. Overcomes the vanishing gradient problem.

**Generative Adversarial Networks (GAN):** Two networks (generator and discriminator) compete to produce realistic synthetic data.

**Transformer Networks:** Attention-based architectures. The foundation of modern large language models (GPT, BERT).



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## 8. The Learning Paradigms

### 8.1 Supervised Learning

The network is trained on labeled examples (input-output pairs). It learns to map inputs to correct outputs by minimizing the difference between predicted and actual outputs. Examples: image classification, spam detection.

### 8.2 Unsupervised Learning

The network receives only inputs with no labels. It discovers hidden patterns, structures, or groupings in the data. Examples: clustering, dimensionality reduction, generative modeling.

### 8.3 Reinforcement Learning

The network (agent) learns by interacting with an environment. It receives rewards for good actions and penalties for bad ones, gradually learning an optimal strategy. Examples: game playing, robot control.

## Lecture 1 — Key Takeaways

1. ANNs are computational models inspired by the human brain's neural structure.
2. The field began with McCulloch & Pitts (1943) and has evolved through multiple phases.
3. ANNs went through two 'AI Winters' before the modern deep learning revolution.
4. Three key drivers of modern DL: big data, GPU computing, and algorithmic improvements.
5. ANNs are applied across computer vision, NLP, healthcare, finance, and autonomous systems.
6. ANNs learn from data rather than following explicitly programmed rules.
7. Major learning paradigms: supervised, unsupervised, and reinforcement learning.

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## 9. Review Questions

- Q1. What is the biological inspiration behind Artificial Neural Networks?
- Q2. Name three key milestones in ANN history and explain their significance.
- Q3. What caused the first AI Winter and how was it eventually overcome?
- Q4. Compare traditional programming with neural network-based approaches.
- Q5. List three real-world applications of ANNs and explain why ANNs are suitable for each.
- Q6. What are the three main learning paradigms in neural networks?

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