The Nobel Prize in Physics 2024

For Prelims: Nobel Prize, Artificial neural networks, Machine learning, Artificial Intelligence, ChatGPT, Artificial neurons, Nobel Prize in Physics 2023, Deep learning, Recurrent Neural Networks

For Mains: Advancements in AI and machine learning, IT & Computers, Artificial Neural Network.

Source: TH

Why in News?

The **2024 Nobel Prize in Physics** has been awarded by the **Royal Swedish Academy of Sciences** to **John J. Hopfield and Geoffrey E. Hinton,** two pioneers whose groundbreaking work laid the foundation for **modern artificial neural networks (ANNs) and machine learning (ML).**

- Their work has had profound implications for various fields, from physics to biology, finance, medicine and chat **Artificial Intelligence (AI)** apps, including **OpenAI's ChatGPT (Generative Pre-trained Transformer).**

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What is the Contribution of John Hopfield?

- **Hopfield Network:** John Hopfield, is best known for creating the **Hopfield network, a type of recurrent neural network (RNN)** that has been foundational in ANN and AI.
  - Developed in the 1980s, the Hopfield network is designed to store simple **binary patterns (0s and 1s)** across a network of artificial nodes (artificial neurons).
  - A key feature of the network is **associative memory,** which allows it to **retrieve complete information from incomplete or distorted inputs** (similar to how the human brain recalls memories when triggered by familiar sensations, like a scent).

- The Hopfield network, based on **Hebbian learning** (a concept in neuropsychology where repeated interactions between neurons strengthen their connections).
    - By drawing parallels to atomic behavior, Hopfield used statistical physics to make the network perform **pattern recognition and noise reduction** by minimising energy states, a breakthrough in advancing neural networks and AI by mimicking biological brain functions.
- **Impact:** Hopfield's model system has been used to solve **computational tasks, complete patterns, and improve image processing.**

What is the Contribution of Geoffrey Hinton?

- **Restricted Boltzmann Machines (RBMs):** Building on Hopfield's work, in the 2000s, Hinton developed a learning algorithm for **Restricted Boltzmann Machines (RBMs),** which enabled deep learning by stacking multiple layers of neurons.
    - The RBMs could learn from **examples rather than explicit instructions.** This was revolutionary because it allowed the machine to recognize new patterns based on similarities with previously learned data.
    - The Boltzmann machine could recognize categories it had never encountered if they matched learned patterns.
- **Applications:** Hinton's work has led to breakthroughs in numerous fields, from healthcare diagnostics to financial modeling and even AI technologies like **chatbots.**
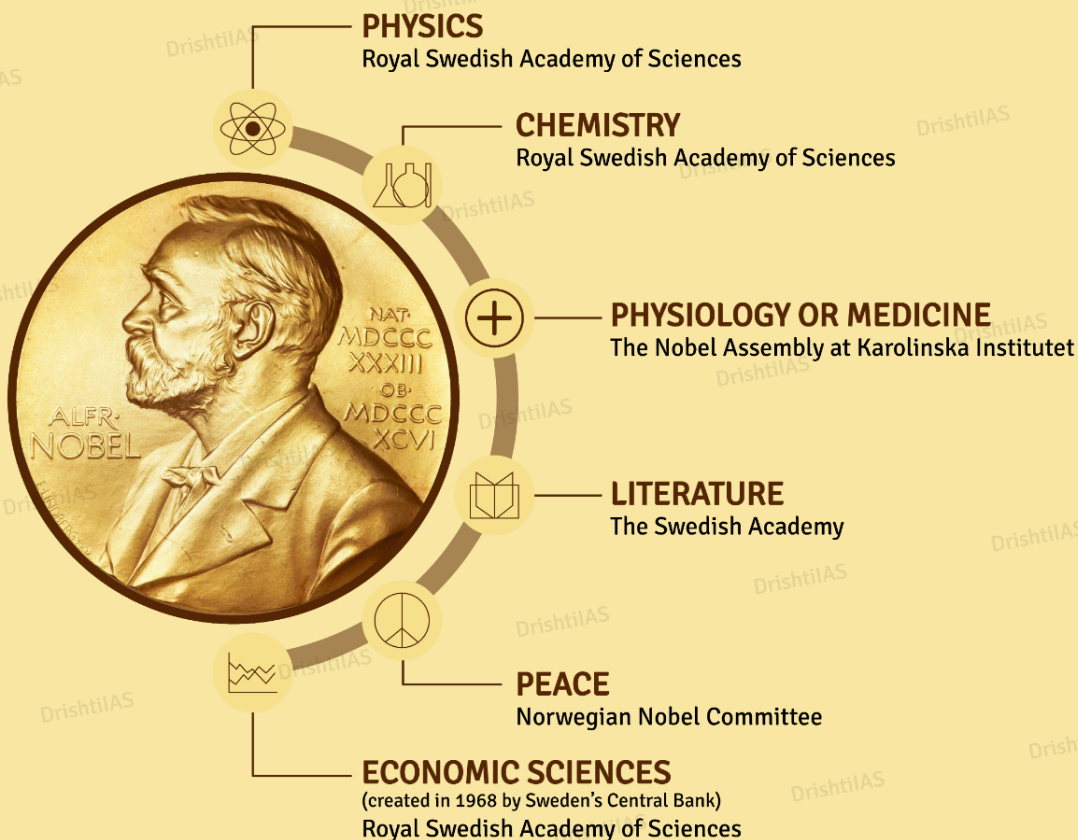
Note:

The Nobel Prize in Physics 2023 was awarded to **Anne L'Huillier, Pierre Agostini, and Ferenc Krausz** for their work in **attophysics (**focuses on generating and utilising extremely short light pulses to examine fast processes, particularly those involving electrons**)**.

Nobel Prize

✦ Established by the **will of Alfred Nobel (inventor of Dynamite)**

✦ Awarded to those who have conferred the **greatest benefit to humankind,** during the preceding year

✦ **First awards** were handed out in **1901**

PHYSICS
Royal Swedish Academy of Sciences

CHEMISTRY
Royal Swedish Academy of Sciences

PHYSIOLOGY OR MEDICINE
The Nobel Assembly at Karolinska Institutet

LITERATURE
The Swedish Academy

PEACE
Norwegian Nobel Committee

ECONOMIC SCIENCES
(created in 1968 by Sweden's Central Bank)
Royal Swedish Academy of Sciences

✦ The Prize Ceremony is held in **Stockholm, Sweden,** in December **every year**

⌃ The **Peace Prize** is not awarded at Stockholm ceremony but presented annually in **Oslo, Norway,** on the same day

✦ Each Nobel laureate receives a **gold medal, a diploma, and a monetary award**

✦ Nobel Prize **cannot be given posthumously** (after death). Also, **up to 3 people can share a Nobel Prize award between them**

✦ **First Indian Nobel Laureate:** Rabindranath Tagore for Literature, 1913

⌃ **First Indian Woman Nobel Laureate:** Mother Teresa for Peace, 1979

What are Artificial Neural Networks (ANNs)?

- **About:** ANNs are inspired by the structure of the brain, where **biological neurons** are interconnected to perform complex tasks. In ANNs, **artificial neurons (nodes)** process information collectively, allowing data to flow through the system, similar to brain **synapses.**
- **Common Architectures of ANNs:**
    - **Recurrent Neural Networks (RNNs):** It is trained on **sequential or time series data** to create a **machine learning (ML) model** that can make sequential predictions or conclusions based on sequential inputs.
    - **Convolutional Neural Networks (CNNs):** Designed for **grid-like data** (e.g., images), CNNs use three-dimensional data for image classification and object recognition tasks.
    - **Feedforward Neural Networks:** The simplest architecture, where information flows in one direction from input to output with fully connected layers.
        - It is simpler than recurrent and convolutional neural networks.
    - **Autoencoders:** Used for unsupervised learning, they take input data, compress it to keep only the most important parts, and then rebuild the original data from this compressed version.
    - **Generative Adversarial Networks (GANs):** They are a powerful type of neural network used for unsupervised learning. They consist of **two networks:** a **generator,** which creates fake data, and a **discriminator,** which distinguishes between real and fake data.
        - Through this adversarial training (a machine learning technique that helps models become more robust), GANs produce realistic, high-quality samples.
        - They are versatile AI tools widely used in image synthesis, style transfer, and text-to-image synthesis, revolutionising generative modelling.

Natural and artificial neurons

The brain's neural network is built from living cells, neurons, with advanced internal machinery. They can send signals to each other through the synapses. When we learn things, the connections between some neurons gets stronger, while others get weaker.

NEURON

SYNAPSE

STRONGER

WEAKER
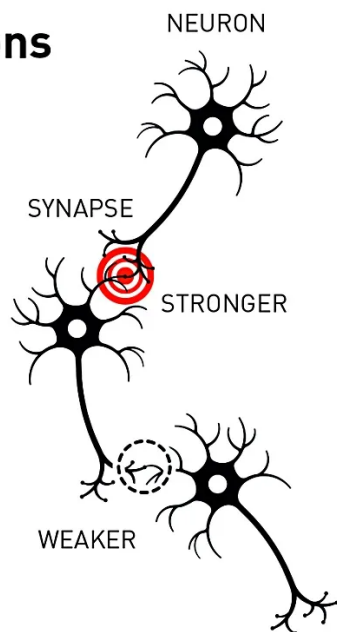
Artificial neural networks are built from nodes that are coded with a value. The nodes are connected to each other and, when the network is trained, the connections between nodes that are active at the same time get stronger, otherwise they get weaker.

NODE

1

STRONGER

1

WEAKER

0
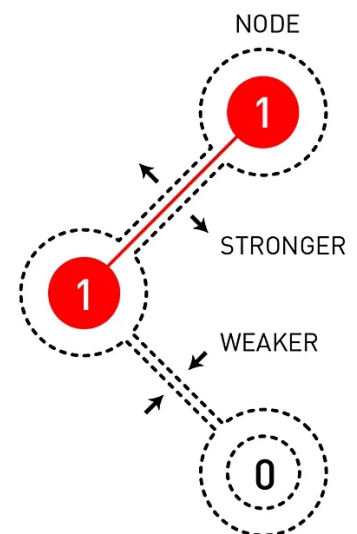
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What is Machine Learning?

- **About:** It is a branch of **Artificial intelligence (AI)** that uses data and algorithms to enable **computers to learn from experience** and improve their accuracy over time.
- **Operating Mechanism:**
    - **Decision Process:** Algorithms predict or classify data based on input, which can be labelled or unlabeled.
    - **Error Function:** This function evaluates the model's predictions against known examples to assess accuracy.

- **Model Optimization Process:** The model iteratively adjusts its weights to improve its predictions until it reaches an acceptable level of accuracy.
- **Machine Learning vs. Deep Learning vs. Neural Networks:**
    - **Hierarchy:** AI encompasses ML; ML encompasses **deep learning**; deep learning relies on neural networks.
    - **Deep Learning**: A subset of machine learning that uses **neural networks with many layers (deep neural networks)** and can process unstructured data without needing labelled datasets.
    - **Neural Networks**: A specific type of machine learning model structured in layers (input, hidden, output) that mimic how the human brain works.
    - **Complexity:** As transition from AI to neural networks, the complexity and the specificity of tasks increase, with deep learning and neural networks being specialised tools within the broader AI framework.

Artificial intelligence(AI)

AI is the simulation of human intelligence in machines programmed to think and learn like humans, capable of problem-solving, reasoning, and adapting to new information.

AI Timeline - Major Milestones

- **1950s** — Turing Test Proposed; First AI Programs Developed
- **1956** — Dartmouth Conference Coins "Artificial Intelligence"
- **1960s** — Eliza Chatbot Created; Early Neural Networks Emerge
- **1996** — Deep Blue - a Chess-Playing Program
- **2012** — Deep Learning Breakthrough in Image Recognition
- **2014** — Generative Adversarial Networks (GANs) Introduced
- **2020** — GPT-3 Demonstrates Advanced Language Generation
- **2022** — Chatgpt Launches, Bringing Conversational AI to Masses
- **2023** — Generative AI Boom; Major Tech Companies Release AI Models

KEY COMPONENTS OF AI

- Machine Learning
- Deep Learning
- Cognitive Computing
- Neural Network
- Computer Vision
- Natural Language Processing (NLP)
- AI

Applications of AI

- ↪ **Healthcare:** Personalised medicine
- ↪ **Finance:** Algorithmic trading
- ↪ **Transportation:** Autonomous vehicles
- ↪ **Marketing & Customer Service:** Targeted advertising, chatbots
- ↪ **Education:** Adaptive learning systems, personalised tutoring
- ↪ **Agriculture:** Crop monitoring
- ↪ **Cybersecurity:** Threat detection
- ↪ **Energy:** Smart grid management, consumption forecasting

Concerns

- ↪ Deepfakes & misinformation
- ↪ Algorithmic bias
- ↪ Automation & job displacement
- ↪ Privacy issues
- ↪ Data ownership & liability issue
- ↪ Ethical decision-making complexes

Regulating AI

- ↪ **Global Partnership on AI (GPAI)** launched in 2020
- ↪ **Bletchley Declaration (2023):** Enhance Global Collaboration on AI
- ↪ **G20 New Delhi Leaders' Declaration (2023):** Harnessing AI responsibly for good and for all
- ↪ **Hiroshima AI Process (2023)** by G7

India and AI

- ↪ **National Strategy For AI 2018**
- ↪ **AI For All:** Self-learning online program
- ↪ **GPAI Summit 2023** hosted by India
- ↪ **IndiaAI Mission 2024**
- ↪ **US India Artificial Intelligence (USIAI) Initiative:** AI cooperation in critical areas
- ↪ **AIRAWAT** (AI Research, Analytics and Knowledge Assimilation Platform): Supercomputer
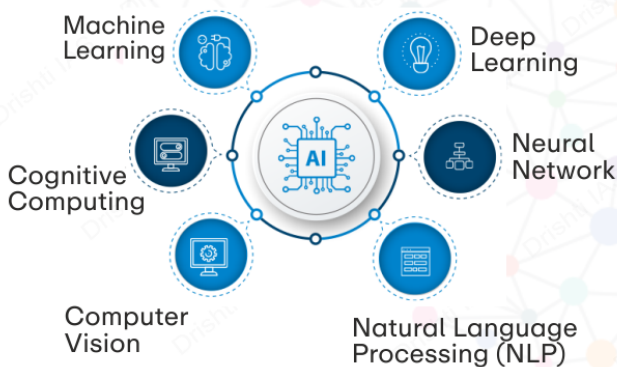
Drishti Mains Question:

Analyze the impact of neural networks and machine learning on modern technology. Provide examples of their applications in various sectors.

UPSC Civil Services Examination, Previous Year Questions (PYQs)

Prelims

Q. With the present state of development, Artificial Intelligence can effectively do which of the following? (2020)

1. Bring down electricity consumption in industrial units
2. Create meaningful short stories and songs
3. Disease diagnosis
4. Text-to-Speech Conversion
5. Wireless transmission of electrical energy

Select the correct answer using the code given below:

(a) 1, 2, 3 and 5 only
(b) 1, 3 and 4 only
(c) 2, 4 and 5 only
(d) 1, 2, 3, 4 and 5

Ans: (b)

Mains:

Q. Impact of digital technology as a reliable source of input for rational decision making is an issue. Critically evaluate with suitable examples. **(2021)**