Brainoware

For Prelims: Brainoware, Neuromorphic computing, Tissue engineering, Organoid Neural Network, **Artificial Neural Network**

For Mains: Concept of organoid neural networks (ONNs), Organoids and their ethical utilization, IT & Computers

Source: TH

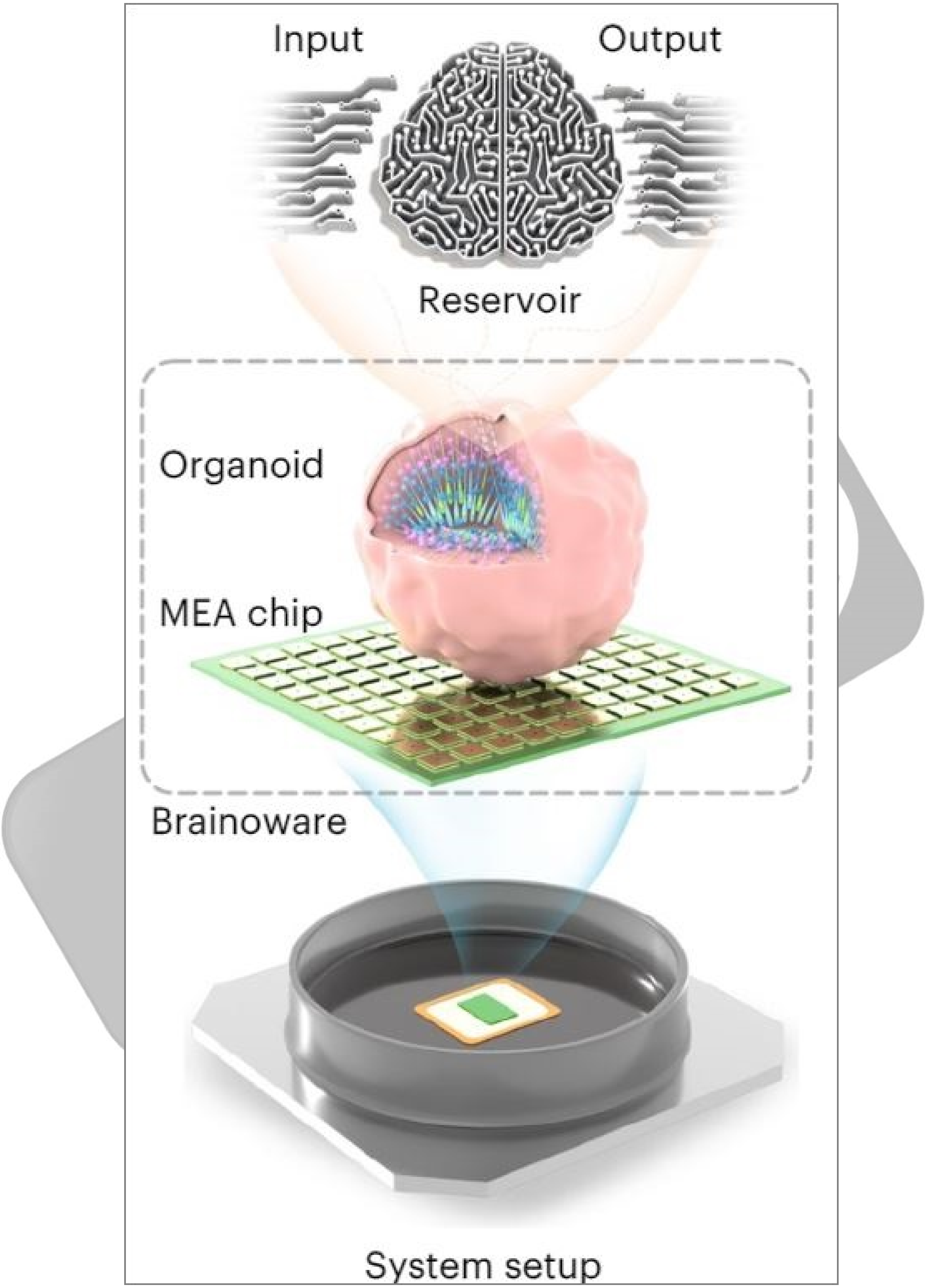
Why in News?

Recently, scientists have seamlessly integrated **brain-like tissue with electronics** to create **Brainoware**, an 'organoid **neural network (ONN)'** capable of recognising voices and solving complex mathematical problems.

- This innovative system extends **neuromorphic computing**, to a new level by directly integrating brain tissue into a computer.

What is Brainoware?

- **About:**
  - Brainoware is an innovative computing system that **melds brain-like tissue with electronics.**
  - Brainoware integrates **brain organoids** with microelectrodes, forming an **'organoid neural network (ONN)'** that directly incorporates living brain tissue into the computing process.
    - Brain organoids are 3D tissues that simulate the **structure and function of the human brain.** They are derived from **human embryonic** stem cells, and are able to self-organize.
    - Brain organoids are similar to the **brain's cell composition and structure, and can reflect the brain's developmental process.** They are used as models to study human brain development and brain-related diseases.
  - ONNs are different from **artificial neural networks**, which are made of silicon **chips** because they use **biological neurons that can adapt and learn** from their environment. //



Input
Output
Reservoir
Organoid
MEA chip
Brainoware
System setup

- **Operational Mechanism:**
    - Three-Layered Architecture: Input, Reservoir, and Output
        - **Input Signals Processing:**
            - Input signals, in the form of electrical stimulation, are processed through the ONNs.
        - **Reservoir:**
            - The reservoir, acting as a black-box, converts signals into mathematical entities that the computer can efficiently process, eliminating the need for constant back-and-forth data transfer.
        - **Output Readout:**
            - The output layer, modified conventional computer hardware, interprets Brainoware's neural activity, providing a tangible result.
- **Advantages over Traditional Neuromorphic Computing:**
    - **Memory and Processing Separation:**
        - Traditional neural networks face a challenge where **memory units and data processing units are separate**, leading to increased time and energy demands for complex problem-solving.
        - Previous attempts to **improve efficiency involved neuromorphic chips with short-term memory.** However, these chips could only partially mimic brain functions and required further enhancements in processing capability and energy efficiency.
    - **Biological Neural Network Integration:**
        - Brainoware utilizes a biological neural network, comprising live brain cells, to address the inefficiencies in traditional neuromorphic computing.
            - Unlike AI hardware, brain cells store memory and process data without physically separating the two, resulting in significantly lower energy consumption.
- **Challenges and Considerations:**
    - The system does face challenges, including the **technical expertise and infrastructure required** to maintain a biological neural network.
        - Ethical concerns also arise, questioning the consciousness of organoids and their use in a mechanistic way.
- **Future Prospects:**
    - While Brainoware is in its early stages, continued study of the 'organoid neural network' could provide foundational insights into learning mechanisms, neural development, and the cognitive implications of **neurodegenerative diseases.**
        - This could potentially contribute to advancements in neuroscience and medical research.
        - It opens possibilities at the intersection of **tissue engineering, electrophysiology, and neural computation.**

Aspect	Traditional Neural Networks	Brainoware (Biological Neural Network)
Memory and Processing	Separate units	Unified – no physical separation
Energy Efficiency	Lower efficiency	Higher efficiency
Biocomputing Approach	Silicon chips	Biological components
Learning and Recognition	Requires extensive training	Comparable accuracy with less training
Accuracy in Tasks	Dependent on training epochs	Comparable accuracy with fewer epochs
Cell Types in Neural Network	Standard silicon cells	Brain organoids with varied cell types
Research Area	Traditional AI	Biocomputing

Key Terms

- **Neuromorphic Computing:**
  - It is a type of **artificial intelligence (AI).** It uses specialized **hardware and software algorithms** to simulate neurons and synapses to process data more efficiently than traditional computers.
    - Neuromorphic computing uses **artificial neurons and synapses** to process data in a similar way the human brain does.
    - It relies on parallel processing, allowing multiple tasks to be handled simultaneously. Its adaptable nature enables real-time learning and decision-making.
  - The current neuromorphic computing market is majorly driven by increasing demand for **AI and brain chips** to be used in cognitive and brain robots.
- **Tissue Engineering:**
  - It is a biomedical engineering field that uses engineering and life sciences to create **biological substitutes** that can restore, maintain, or improve tissue function.
    - The goal of tissue engineering is to assemble functional constructs that restore, maintain, or improve damaged tissues or whole organs.
- **Neural Computation:**
  - It is the **processing of information by networks of neurons.** It is a type of brain activity that aims to **understand how neurons work together** to process information.
- **Electrophysiology:**
  - It is a branch of physiology that **studies the electrical properties of biological cells and tissues**. It also explores the electrical activity of living neurons and the molecular and cellular processes that govern their signaling.