Connecting artificial and biological neurons towards Neurobiohybrid Systems

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Do you EVER think it could be possible?

Outline

- Introduction
- Biological and artificial neurons
- Neurobiohybrid system
- How to build neurobiohybrid system?
- Current trends
- What are the challenges for neurobiohybrid system?
- What are the applications for neurobiohybrids systems
- Companies research institutes and start up working on the topic
- Conclusion

Introduction

Human Brain : Black box 86 millions of neurons

Mix of biology and electronic

Biohybrid systems

Objectives

Highlight importance
Show current state of the research
Explain challenges and furtur progress

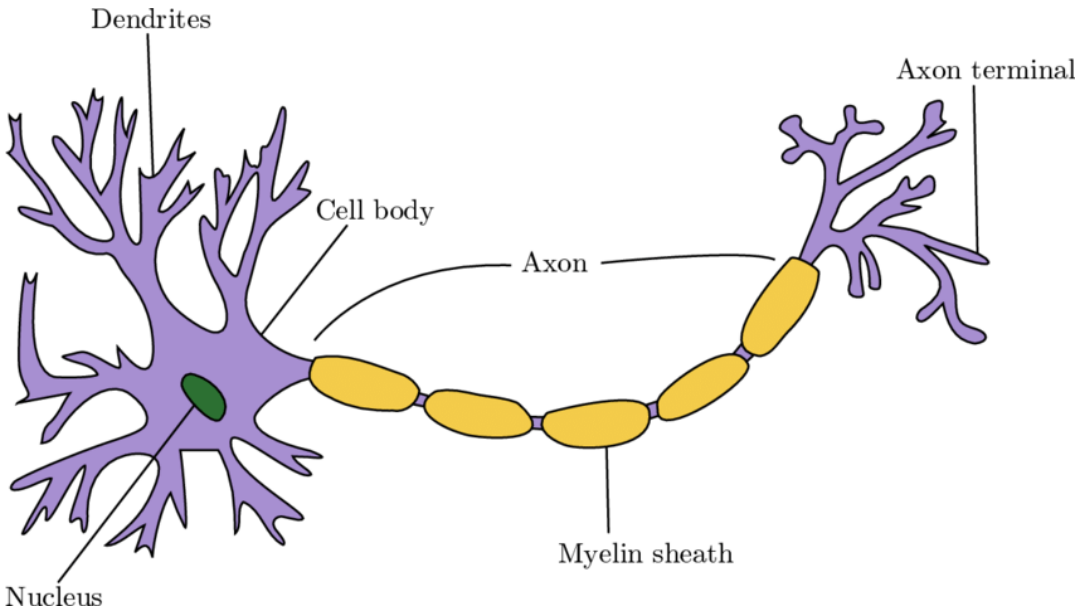
Keywords definitions

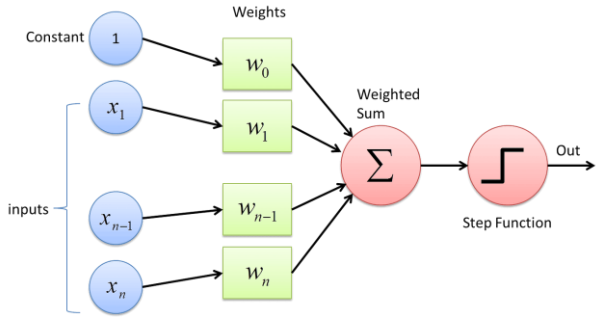
- Neurobiohybrid system: combination of bio and artificial neurons
- Neuromorphic: Technology mimicking the brain's function.
- BioMEMS (Biomedical Microelectromechanical Systems): Tiny devices integrating biology and mechanics for medical use.
- Deep Brain Stimulation (DBS): Implanting electrodes in the brain to treat neurological disorders.

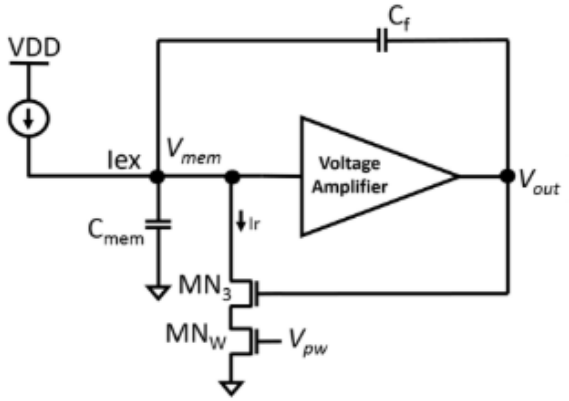
Extract from the topic

Meaning given by wikipedia

Biological and artificial neurons







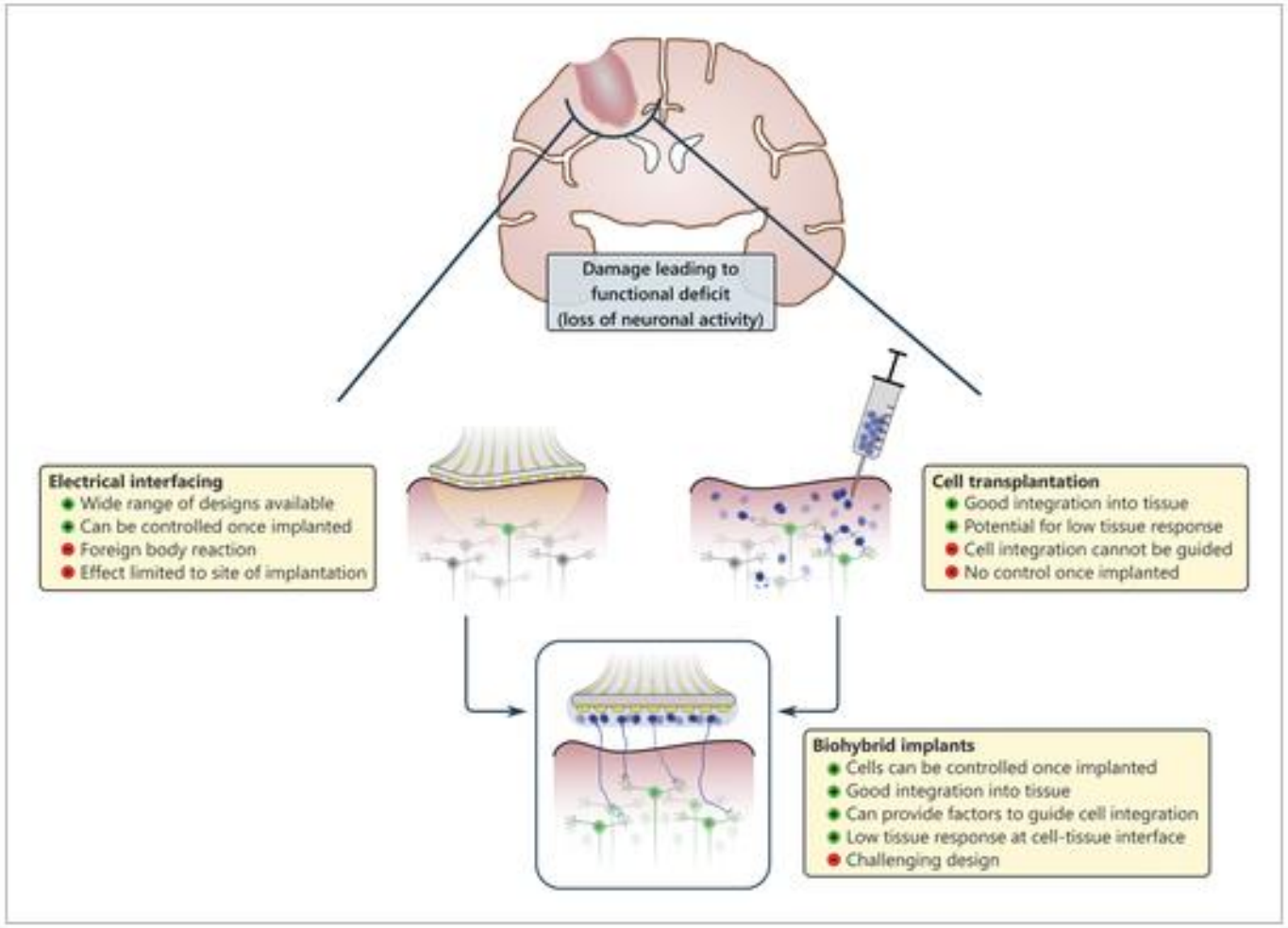
[1]

F. Danneville, C. Loyez, K. Carpentier, I. Sourikopoulos, E. Mercier, et A. Cappy, « A Sub-35 pW Axon-Hillock artificial neuron circuit », *Solid-State Electronics*, vol. 153, p. 88-92, mars 2019, doi: 10.1016/j.sse.2019.01.002.

What is Neurobiohybrid Systems?

Paper found institutes locations

Historical developpement



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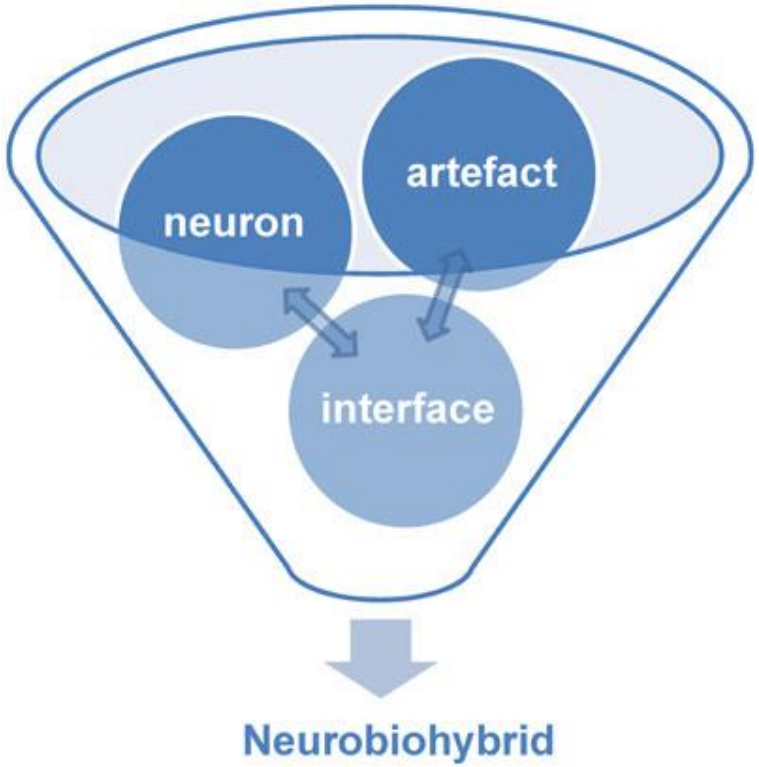
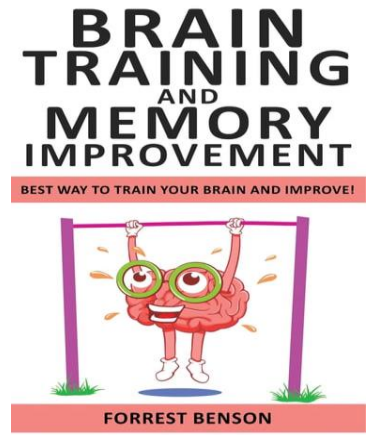


S. Vassanelli et M. Mahmud, « Trends and Challenges in Neuroengineering: Toward “Intelligent” Neuroprostheses through Brain-“Brain Inspired Systems” Communication », *Front. Neurosci.*, vol. 10, sept. 2016, doi: 10.3389/fnins.2016.00438.

Advantages

- Restoration of body lost part and neurodegenerative deseases
- Improve sensory
- Enhance brain Memory

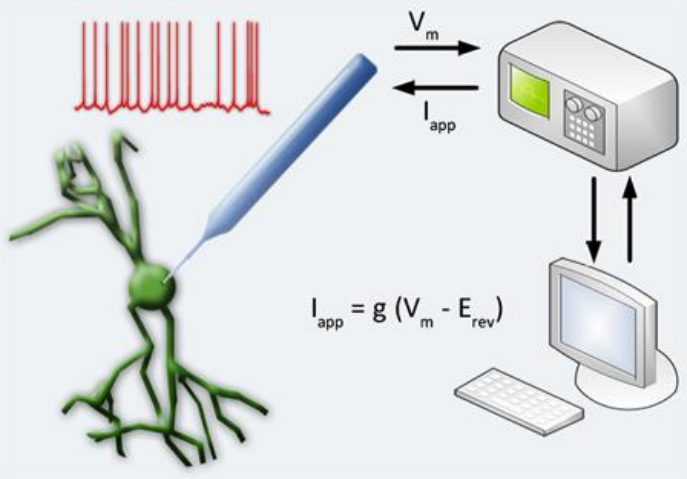


How to build neurobiohybrid systems?

Techniques for Connecting Artificial and Biological Neurons

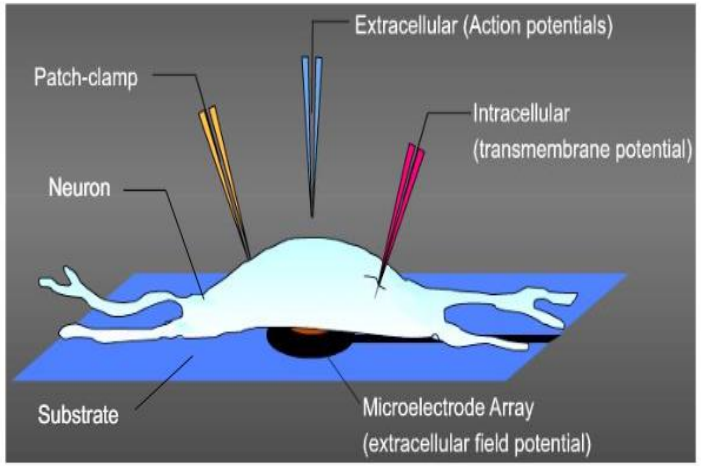
- **Dynamic clamp**

Real-Time Interaction: Allows real-time modulation of neural activity.
Precision: High temporal resolution for detailed studies



- **MicroElectrodes Arrays**

High Spatial Resolution: Can record from and stimulate multiple neurons simultaneously.
Versatility: Used for various applications, including neural mapping and drug testing.



[1]

J. C. Barreiro, « Departamento de Ciências Médicas ».

What are the challenges for neurobiohybrid systems?

Challenges of neurobiohybrid systems

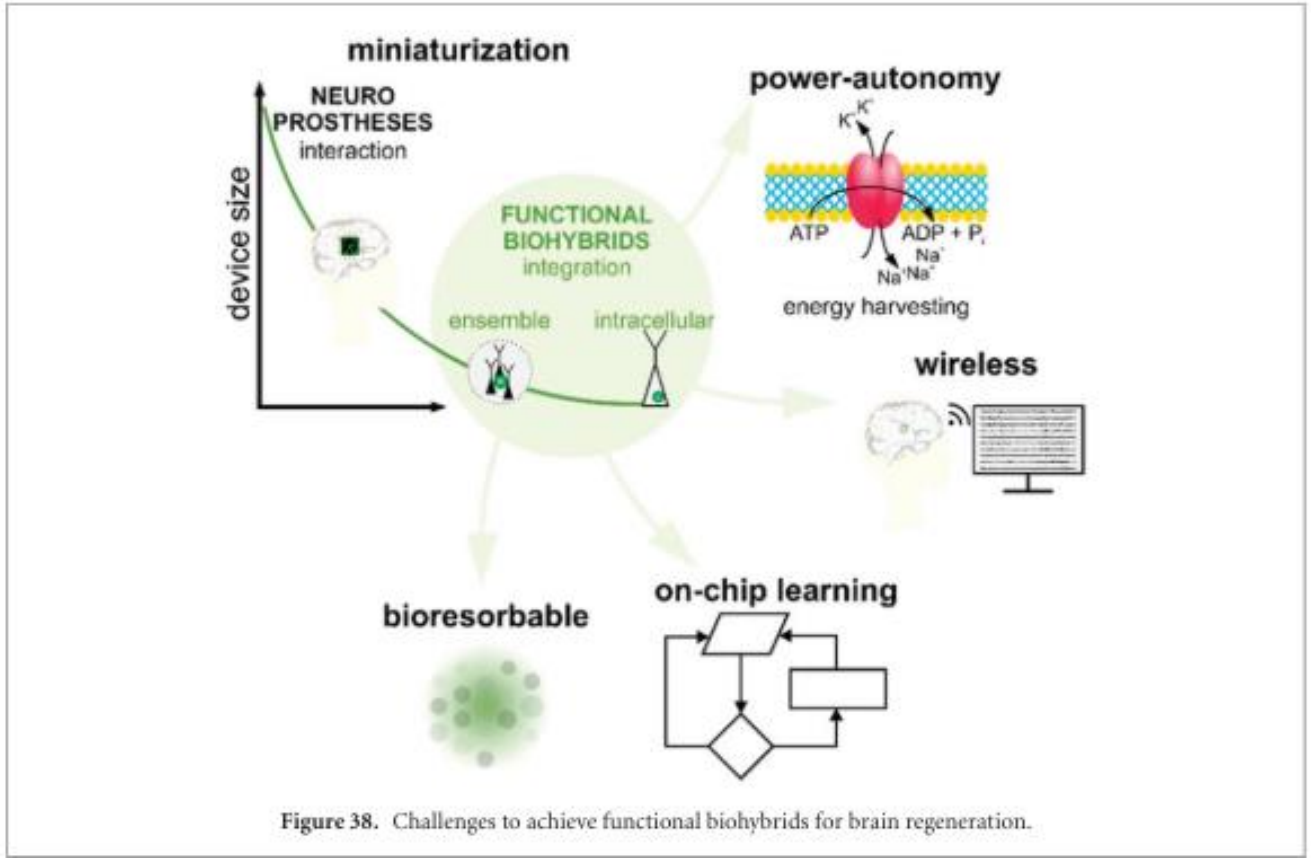


Figure 38. Challenges to achieve functional biohybrids for brain regeneration.

[1]

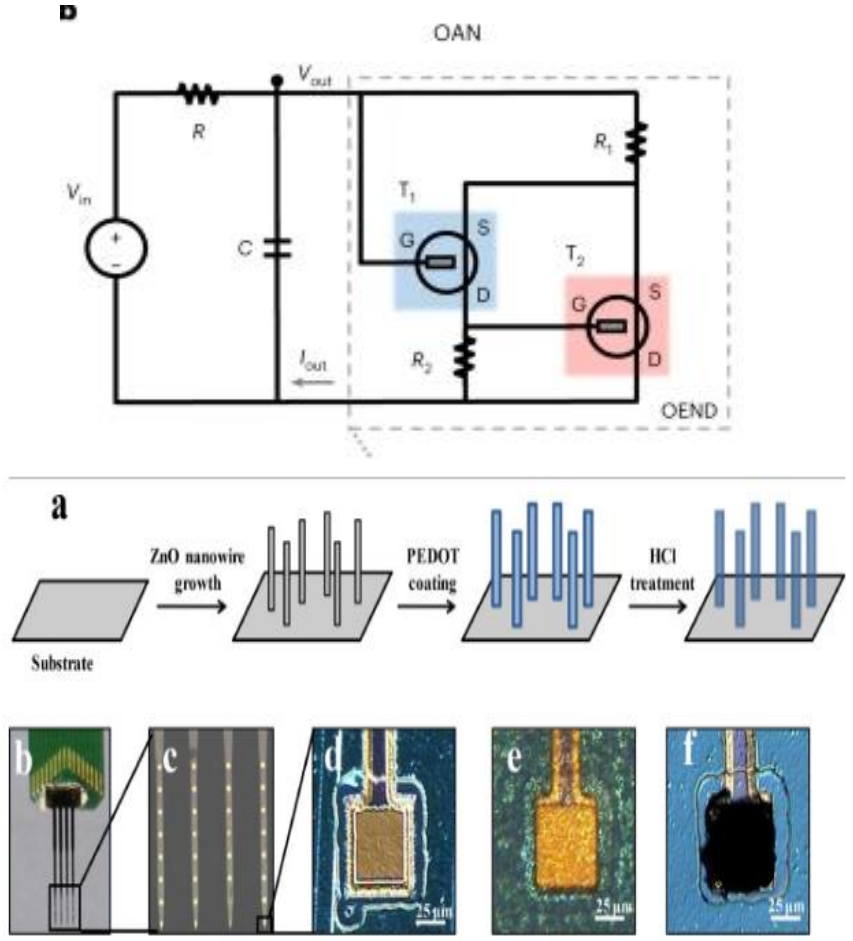
D. V. Christensen *et al.*, « 2022 roadmap on neuromorphic computing and engineering », *Neuromorph. Comput. Eng.*, vol. 2, nº 2, p. 022501, mai 2022, doi: 10.1088/2634-4386/ac4a83.

Currents trends

- Organic Arificial Neuron

Excellent Electrical Conductivity
Biocompatibility
Mechanical Flexibility
Chemical Stability
Electrochemical Properties

- PEDOT (Poly(3,4-ethylenedioxythiophene) nanotube array



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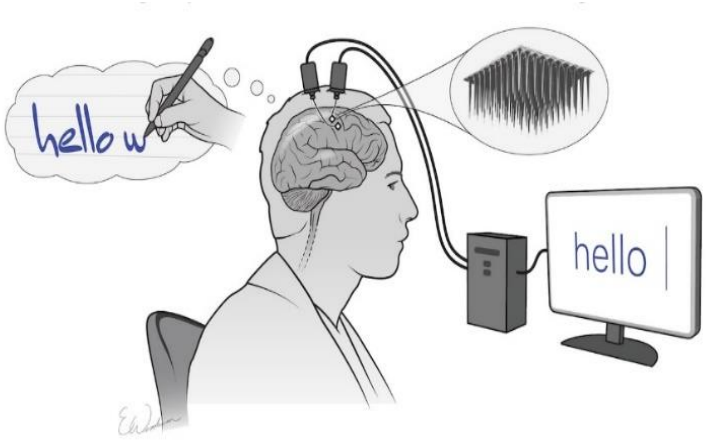
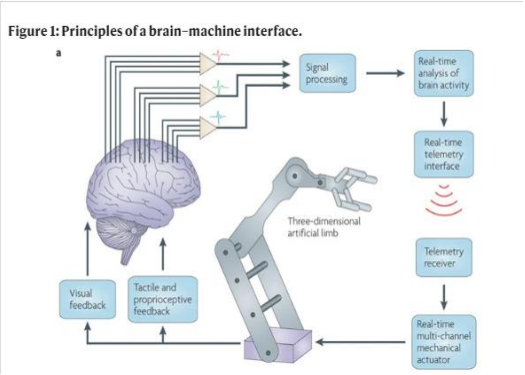
T. Sarkar *et al.*, « An organic artificial spiking neuron for in situ neuromorphic sensing and biointerfacing », *Nat Electron*, vol. 5, nº 11, p. 774-783, nov. 2022, doi: 10.1038/s41928-022-00859-y.

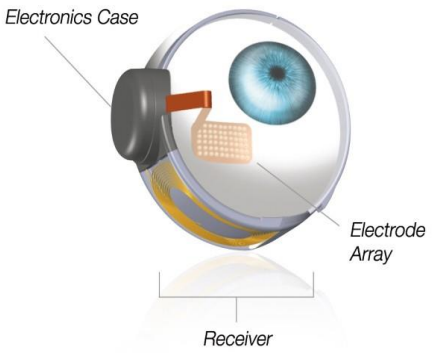
What are the applications for neurobiohybrids systems?

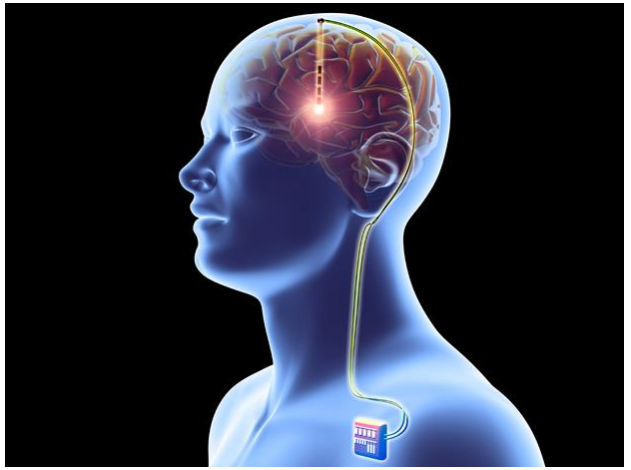
Applications

Brain machine interface
Neuroprothesis
Neural implants









Companies and Research Institutes working on neurobiohybrid Sytems

Companies

Feature	Blackrock NeuroPort	Synchron Stentrode	Neuralink Implant
Type	Invasive BCI	Minimally Invasive BCI	Invasive BCI
Primary Application	Recording and stimulating neural activity	Recording neural signals for motor control	High-resolution neural recording and stimulation
Risks	Higher risk due to direct brain tissue implantation	Lower risk due to non-invasive nature of blood vessels	Risks associated with brain surgery and long-term implantation
Longevity	Long-term implantation with potential risk of tissue response	Designed for long-term use with reduced inflammatory response	Designed for long-term implantation
Commercial Status	FDA-approved for clinical research	FDA Breakthrough Device designation, ongoing trials	FDA-approved for clinical research
Data Transmission	Wired or wireless data transmission	Wireless data transmission	Wireless data transmission
Power Source	External power supply or battery	External power supply	Wireless charging

https://neuralink.com/
https://blackrockneurotech.com/

Research Institutes

Whyss center (Geneva)

working addresses indications such as epilepsy, Alzheimer's disease and locked-in syndrome as a result of ALS (amyotrophic lateral sclerosis) or brainstem stroke.

McGovern Institute for Brain Research (USA)

The mission is to understand the brain and to apply that knowledge to improve human health and well-being.

The Brain and Mind Institute at EPFL (Swiss Federal Institute of Technology)

The Brain and Mind Institute is known for its advanced research in neuroprosthetics and brain-computer interfaces, among other areas in neuroscience.

Source:
https://mcgovern.mit.edu/
https://wysscenter.ch/approach/
https://www.epfl.ch/schools/sv/bmi/brain-mind-institute/about-bmi/

Conclusion:

- Challenges and Gaps:

Neurobiohybrid systems research is relatively underexplored.

Limited articles

- Insights and Understanding:

Construction methods, challenges, and future applications

- The future of neurobiohybrid systems is promising, but success hinges on interdisciplinary collaboration and comprehensive research efforts.

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FOR YOUR
ATTENTION