IBEC
Institut de Bioenginyeria de Catalunya

COLLABORATIVE IBEC INTERNATIONAL PhD PROGRAMME

Position

1. Project Title:
   Bridging Minds: Integrating Synthetic Cells with Neuromorphic Networks for Tissue Communication

2. Research project/ Research Group description

Brain-inspired computing paradigms are at the forefront of automating essential visual and linguistic tasks by mimicking the brain's information processing capabilities. The parallels between artificial and biological neural networks open exciting avenues for developing advanced brain-machine interfaces aimed at alleviating neurodegenerative diseases. Neuromorphic devices are emerging as groundbreaking platforms that exhibit learning and adaptation potential, capable of interfacing with neurons and muscles to support patients suffering from degenerative conditions. Yet, significant challenges remain in connecting these sophisticated electronic components with biological tissues and enabling them to autonomously learn through biofeedback. This project seeks to bridge (bio)neuromorphic technologies and synthetic cells, marking a pivotal step towards seamless tissue integration. The synthetic cells will function as transducers, converting electrical signals into biological signals interpretable by living cells.

Our objective is to establish a connection between synthetic cells and the surfaces of neuromorphic devices, training them to respond through mechanisms such as membrane polarization, localized or global curvature changes, pore opening for neurotransmitter release, and the production of synthetic extracellular vesicles. These innovations will facilitate bidirectional communication between devices and cells, enhancing the capabilities of brain-machine interfaces and introducing novel neuromorphic adaptability and learning, thus paving the way for transformative therapies.

This is a joint project between the IBEC groups "Bioinspired Interactive Materials and Protocellular System" (BIMPS) and the TU/e ICMS "Neuromorphic Engineering" led by Prof Rodriguez-Emmenegger, and Prof van de Burgt. BIMPS lab designs materials to interact with living ones, exploiting concepts of polymer science, molecular self-assembly, hierarchy, and biology. Prof. van de Burgt's group focuses on developing and optimising state-of-the-art organic neuromorphic devices that are based on novel organic mixed-ionic electronic materials for applications in neuromorphic computing, adaptable bioelectronics, sensors and brain-inspired robotics.

3. Job position description

Project Aim: This project seeks to pioneer a brain-inspired biointerface capable of learning and adapting in real time. By merging neuromorphic devices with synthetic cells, we aim to establish a platform for bidirectional communication between electronics and living tissues, enabling breakthroughs in brain-machine interfaces and therapies for neurodegenerative diseases.

The PhD program encompasses four interrelated chapters:

1. **Synthetic Cells at the Neuromorphic Interface**: This chapter will focus on integrating synthetic cells—designed as dendrimersomes and combisomes—onto neuromorphic devices. These novel vesicles, developed in BIMPS, possess programmable membranes that respond to electrical or ionic stimuli. The collaboration with ICMS will explore whether these membranes can mimic neuronal behaviors, such as polarization and spike transmission.
2. **Electromechanical Actuation**: This chapter will investigate how synthetic cell membranes can convert electrical signals into mechanical responses, such as localized or global curvature changes. Leveraging the polyelectrolyte composition and flexibility of the combisome membranes, we will program mechanical forces directly from electrical inputs, creating a new paradigm for translating bioelectric signals into mechanical actions.
3. **Neurotransmitter Release**: We aim to develop precise mechanisms for gating synthetic cell membranes to release neurotransmitters in response to electrical stimuli. This will involve studying electroporation and the creation of membrane pores via microphase-separated regions or protein-based tension-gated channels. The unique properties of combisomes and dendrimersomes enable seamless incorporation of these gating proteins and fine control over lateral tension.
4. **Interfacing with Neurons**: Finally, we will test whether these systems can achieve functional communication with neurons, demonstrating the ability to transmit and interpret bioelectrical signals at a fundamental level.

This interdisciplinary approach unites bioinspired synthetic biology, neuromorphic engineering, and advanced materials science to create a groundbreaking adaptive biointerface. We are looking for an early-career scientist who is bold to immerse into this highly cross disciplinary work bridging neuromorphic computing, material science, bottom-up synthetic biology and biology.

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Group Leader at IBEC

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