Press release, 16 March 2021

Repairing the brain through new technological approaches in neuroscience

Two FET projects – HERMES and STARDUST – aim to improve the treatment of widespread brain disorders such as Parkinson's and epilepsy by developing and adopting the latest neurotechnology techniques: "biohybrid neuronics" and "in-vivo optogenetics"

Brain disorders account for much of the health burden in Europe, exceeding HIV, cancer and heart ischaemia. In addition, age-related neurological disorders are of particular concern as the EU's population continues to get older. This is why new research in neurotechnology, neuroprostetics, regenerative medicine and other associated fields of neuroscience is needed.

Treating **brain disorders** presents exceptional challenges due to the highly complex nature of the organ itself. For example, regenerative medicine – an approach that attempts to regrow, repair, or replace damaged or diseased cells, organs or tissue – has to tackle issues about how to integrate grafted cells or tissue within the host brain. Along with regenerative medicine, brain-inspired neuroprostheses promise highly controllable devices for brain function replacement, but their performance is still far from optimal and they cannot rebuild brain matter.

This project has received funding from the European Union's Horizon 2020 FET Programme under grant agreement No. 824753.

To address these challenges, the EU-funded HERMES project seeks to establish so-called **“biohybrid neuronics”** (neural electronics), which are the symbiotic integration of bioengineered brain tissue, microelectronics and artificial intelligence. In a nutshell, the brain tissue transplants will allow doctors to repair affected areas with bioengineered brain tissue, to reproduce brain function with neuromorphic engineering and to guide brain dynamics with artificial intelligence.

Led by the Istituto Italiano di Tecnologia (IIT), the interdisciplinary consortium focuses on **temporal lobe epilepsy (TLE)**, the most common form of epilepsy, affecting at least 6 million people in Europe; and also the most frequently unresponsive to medications. As the hippocampus is the primarily stricken area of the brain in TLE, the aim is to apply bioengineered hippocampal tissue grafting.

The STARDUST project is another EU-funded initiative that addresses brain disorders. Led by the Aarhus University together with eight other research institutes, it instead focuses on developing **a wireless implantable micro-scale device for “in-vivo optogenetics”**. This neuromodulation method uses a combination of techniques from optics and genetics to control the activities of individual neurons in living tissue. Electrophysiology, electrical recording techniques for measuring the flow of ions and drug delivery, complements the optogenetic approach with a focus on **Parkinson's**, a degenerative, age-related disease (the average age of onset is 60) currently affecting more than 1.2 million people in Europe.

The development of a fully implantable device, **a kind of "pacemaker for the brain"** able to tackle Parkinson's, raise a number of technological challenges. These include the size of the device, power delivery to drive its electronics and light-emitting diodes, and its communication feedback loops. Biological challenges also lie along the way, one of which is to find a proper target in the brain affected by Parkinson's disease, to make sure the optogenetics techniques can enable drug delivery through light.

STARDUST's developments are expected to be flexible and could therefore eventually target different brain areas broadening their scope beyond Parkinson’s. Indeed, **the ability to control cell activity** through a miniaturised, untethered device opens up unprecedented possibilities for clinical management, even the cell reprogramming to reverse cancerous tumour growth.

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