Bioelectric Signals in the Gut-Brain Connection: How Bacteria Influence Neuronal Activity

Mr. Juan Lombardo Hernández[1,2], Mr. Alberto Binello[2], Ms. Ivana Rapetta[1], Ms. Ariana Leaño Hinojosa[1], Mr. Javier Benitez de la Cruz[1], Dra. Maria Teresa García Esteban[1], Dr. Antonio Murciano[1], Dr. Stefano Geuna[2], Dr. Luca Cocolin[2], Dra. Celia Herrera Rincón[1]
[1]Universidad Complutense de Madrid, Madrid, Spain, [2]University of Turin, Turin, Italy

Bioelectric signaling-encompassing ion flows, voltage gradients, and electric fields-is fundamental not only for excitable cells, such as neurons, but also for organism-wide processes such as development, regeneration, and cancer. Recent evidence extends the role of bioelectricity beyond eukaryotic systems, revealing its importance in bacterial physiology and gut microbiome regulation. While it is clear that bacteria in the gut and neurons in brain communicate (the microbiota-brain-gut-axis), most of the fundamental questions in this field are wide-open. Crucially, the community and state-of-the-art work focuses almost exclusively on molecular (hormone receptors, immune cell signaling, etc.) and not – as we propose to do – on top-down, information-based approaches, which are needed to fully understand the high-level meaning behind the mechanisms.

In this study, we investigated the influence of bacteria on neural bioelectric properties by analyzing transcriptomic responses following short-term direct interactions between neurons and the probiotic bacterium Lactiplantibacillus plantarum. We further examined neuronal viability, synaptic plasticity, and bioelectric profiles across different bacterial species, interaction durations, and concentrations, comparing probiotic and opportunistic strains. Our results demonstrate that neurons detect bacterial presence in the culture medium, triggering significant transcriptomic changes related to bioelectricity, excitability, and synaptic plasticity. These responses are species-specific and modulated by interaction conditions.

Our results suggest that bioelectricity plays a key role in neuron-bacteria interactions, reveling an underexplored interkingdom communication network. Understanding how the gut microbiome influences neuronal function and identifying bacterial species and conditions that promote beneficial neural effects could open new avenues for targeted interventions and therapeutic strategies for nervous system disorders.