Title: Nature-Inspired Nanodevices for Programmable Immune Modulation

Abstract:

Advances in immunomodulatory nanomedicine rely on the development of precision smart materials capable of targeting cellular and molecular mechanisms that regulate immune effector functions. By learning from nature's design principles—such as those observed in extracellular vesicles (EVs) and viruses—biomimetic nanoparticles (NPs) can be engineered to recreate or enhance specific interfacial interactions with immune cells.

We present a multidisciplinary approach leveraging biomimetic nanomaterials to modulate the function of antigen-presenting cells (APCs) and T cells, with potential applications in theranostics and immunotherapy. Using bottom-up strategies, we generate artificial, and hybrid nanomaterials derived from dendritic cell (DC) membranes at distinct activation states. These particles directly engage T cells and induce differential functional responses, influenced by the molecular composition and structural organization of the NP surface. Proteomic profiling and mechanistic studies identify a critical role for membrane proteins in engaging with T cells and other DCs.

On the other hand, we investigate the impact of topological and geometric organization of functional biomolecules on APC activation and maturation. Using functionalized DNA-origami nanostructures, we achieve nanometer-scale precision in the spatial arrangement of immunostimulatory ligands such as CpG motifs and antigens. These engineered nanodevices are differentially recognized by APCs, triggering dendritic cell maturation and cytokine production in a geometry- and topology-dependent manner.

Together, these findings lay the groundwork for the rational design of next-generation biomimetic nanodevices capable of precise immune modulation. Our integrative approach, combining nanotechnology, immune cell biology, and proteomics, offers powerful tools for advancing targeted immunotherapies, regenerative medicine, and novel vaccine platforms.

Short bio:
André Pérez Potti graduated in biology (University of Vigo, 2012) and obtained a PhD Nanotechnology (University College Dublin, 2017), focused on nanoparticle-mediated modulation of humoral immunity. He moved to Karolinska Institutet for a postdoc at the Center for Infectious Medicine (CIM, 2019-2021) where he studied T cell phenotypical and functional heterogeneity in physiological and disease states, with focus on tissue-resident T cells. In 2022 he joined the group BioNanoTools at Singular Center of Biological Chemistry and Molecular Materials (CiQUS-USC) and obtained a tenure track position as Ramón y Cajal Researcher. Currently his work focuses on studying mechanisms of modulation of T cell function by engineered biomimetic nanomaterials.