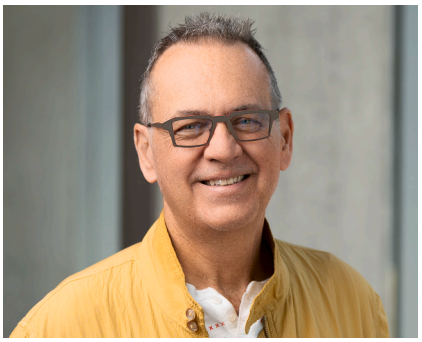
Cell Biomaterials

CellPress

Voices

Immunoengineering: Voices and impressions on the inaugural MOBILIsE symposium

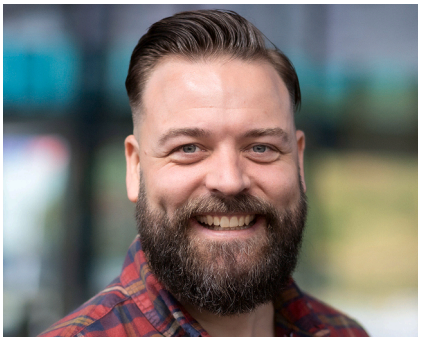
The MOBILIsE project is an ERA-CHAIR initiative at the Institute for Research and Innovation in Health (i3S, University of Porto) funded by the EU H2020 program and focused on molecular bioengineering to underpin and advance innovative therapies for benefiting human health. Immunoengineering, the ability to modulate host immunity through engineered therapeutics (molecules, biomaterials, and cells), has been pivotal for development of immunotherapies. From June 16 to 18, 2025, i3S hosted the first symposium of the MOBILIsE project on "Immunoengineering: from molecules to biomaterials and cell therapies." It brought bioengineers exploring biomolecular engineering tools and techniques to manipulate immune function for clinical translation in cancer, infection, and regenerative medicine. This Voices article mirrors the excellent contributions from speakers and participants on current trends and challenges in immunoengineering and in the development of immunotherapies (from bench to bedside), as well as the enthusiasm of the organizers and hosts of the MOBILIsE symposium.



Jeffrey A. Hubbell
New York University, USA

Molecular engineering to tip immune balances between tolerance and aggression

In this symposium, I presented approaches to engineer antigens and cytokines to tip the immune balance between tolerance and aggression. In the context of tolerance, induction of regulatory T cells is critical, and antigen specificity can arise from exogenously administered antigens in the form of an inverse vaccine or from endogenous antigens in a site of inflammation. In either case, we explore methods to induce or deliver cytokines to regions of lymph nodes where immunity develops and is regulated. In recent work in allergic asthma, we developed an approach to deliver allergic antigens and induce regulatory cytokine expression to re-bias immunity back to tolerance, inducing allergen-specific regulatory T cells and thus preventing asthmatic responses to a pulmonary antigen challenge. In an experimental model of autoimmune neuroinflammation, we are developing an approach to deliver the tolerogenic cytokine IL-10 to all the secondary lymphoid organs of the body from a simple subcutaneous administration. Here, antigen-specific Tregs were developed in response to myelin antigens that drain from the inflammation site. In the context of aggression, we have developed an approach to deposit inflammatory cytokines in the tumor microenvironment to tip the balance between cytotoxic T lymphocytes and Tregs, whether by agonizing innate immune cells such as macrophages and dendritic cells or adaptive immune cells, in particular T cells.



Roy van der Meel
Eindhoven University of Technology, Netherlands

Nature-inspired platform nanotechnology for RNA delivery to immune cells

RNA has emerged as a powerful therapeutic modality but requires chemical modifications and sophisticated delivery nanotechnology. Realizing RNA's full therapeutic potential beyond its current hepatic and vaccine applications requires systemic delivery platform technology with tunable biodistribution features and improved biocompatibility. At the MOBILIsE symposium, I had the pleasure to present our recently developed modular apolipoprotein nanoparticle (aNP) platform technology that is specifically designed to deliver RNA to immune cells and their progenitors in the bone marrow. Besides outlining how the aNP platform was engineered and optimized using an *in vivo* library screening approach, I provided a glimpse of current and future immunotherapy applications. In the context of immuno-oncology, we are evaluating the aNP platform's capacity for delivering mRNA encoding pro-inflammatory cytokines to boost anti-tumor immunity and to enable *in vivo* chimeric antigen receptor (CAR)-T cell generation, eliminating the need for complex *ex vivo* manipulation.

Jennifer H. Elisseeff
Johns Hopkins University, USA

Therapeutic regenerative immunology

At the MOBILIsE symposium, I spoke about our research in regenerative medicine and how we are dissecting immune-stromal cell networks to understand the fundamentals of tissue structure and to develop new therapies. We are using biomaterials as model systems for studying accelerated repair and fibrosis with a focus on the adaptative immune system and senescence. By leveraging multi-omics and transgenic models, we are now understanding key features of senescence and senotypes that enable precise targeting to modulate matrix production and vascularity. As we move forward, we are applying discoveries from our model systems to develop new regenerative immunotherapies.

Juliane Walz
University Hospital Tübingen, Germany

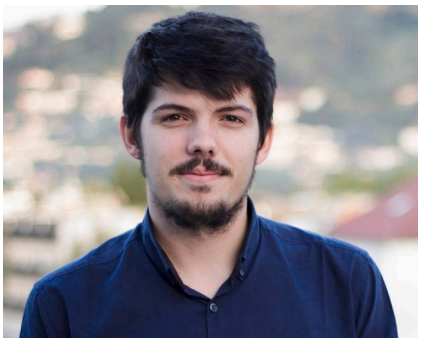
Peptide-based immunotherapy: Bench-to-bedside developments

The overall goal of my research efforts at the University of Tübingen, Germany, is the development of peptide-based immunotherapy concepts for malignant disease based on (1) the direct mass spectrometry-based analysis of the immunopeptidome, providing an unprecedented platform for the identification and characterization of human leukocyte antigen (HLA)-presented tumor antigens; (2) the characterization and optimization of spontaneous and vaccine-induced antigen-specific immune response; and (3) the translation of novel peptide-based immunotherapeutic strategies from bench to bedside, with seven clinical trials currently evaluating own-developed peptide vaccines for cancer patients. In my talk at the MOBILIsE symposium on immunoengineering, I summarized the basic principles and novel developments for peptide vaccines in cancer in terms of antigen selection, combinatorial approaches, and clinical application.

Carlos-Filipe Pereira
Lund University, Sweden

Empowering immunotherapy with cellular reprogramming

At the MOBILIsE symposium, I presented our research on immune cell reprogramming for cancer immunotherapy. We are reprogramming cancer cells into dendritic cells (DCs) to enhance antigen presentation and elicit tumor-specific T cell responses. Our *in vivo* cell fate engineering approach uses three transcription factors to reprogram cancer cells within the tumor microenvironment, overcoming immune suppression and generating durable anti-tumor immunity that synergizes with checkpoint inhibitors. In collaboration with our startup, Asgard Therapeutics, we are translating this work into the clinic by developing a viral vector encoding the reprogramming factors, aiming to create an off-the-shelf therapy that elicits tumor- and patient-specific immunity. To expand therapeutic reach, we are building a combinatorial transcription factor platform with single-cell readouts, capable of inducing diverse immune cell types, including multiple DC subsets, monocytes and macrophages, and natural-killer cells. By identifying the transcriptional circuits underlying immune cell identity, this platform offers a powerful toolbox for engineering immune responses in cancer, autoimmunity, and tissue regeneration.



Tiago Ramalho
Público Newspaper, Portugal

Making scientific research in immunoengineering more accessible to the public

As a science journalist, events like the first MOBILIsE symposium in molecular bioengineering are primary opportunities to discover the trends and new research being conducted worldwide. Specifically, it was an opportunity for me to learn about the science of "inverse vaccines" and interview Jeffrey A. Hubbell. This contact with pioneers and researchers is crucial for journalists, going to a direct source of knowledge and having the ability to ask questions, and also for the lay audience who benefit from this open connection between these "two cultures." It's an opportunity to develop both worlds—journalism and science—that does not exist that often, and it should be valued.

Rita Acúrcio
iMed, Universidade de Lisboa, Portugal

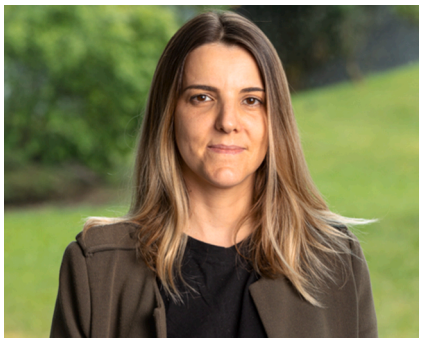
Rewriting the rules: Navigating solid tumors for smart nano-vaccine therapies

During the session on cancer vaccines and adjuvant therapies, I presented our recent advances in engineering nanomedicines to improve cancer immunotherapy in solid tumors. While immune checkpoint inhibitors (ICIs) have transformed cancer treatment, their effectiveness remains limited in solid tumors due to the dense and immunosuppressive tumor microenvironment (TME), which hinders immune cell infiltration and therapeutic response. To overcome this, I showcased our multifunctional polymeric nanoparticles designed to co-deliver tumor-associated antigens, toll-like receptor ligands, and TME modulators that enhance dendritic cell targeting and activation. By engineering the nanoparticle surface, we improved their delivery to the TME and significantly boosted dendritic cell maturation. These nanoparticles induced robust antigen-specific immune responses across several tumor models and reshaped the immune landscape within the TME, rendering tumors more susceptible to ICIs. I also joined in the roundtable discussion titled "How can molecular bioengineering transform immunotherapies?" to discuss the power of biomaterial design in bridging research and clinical application. Sharing these perspectives reinforced that, by learning from each other's expertise, we can more effectively tackle the complex challenges in immunotherapy and move the field forward.

Dario Venetz
Roche, Switzerland

Synthetic cytokine receptors for CAR-T cell therapy

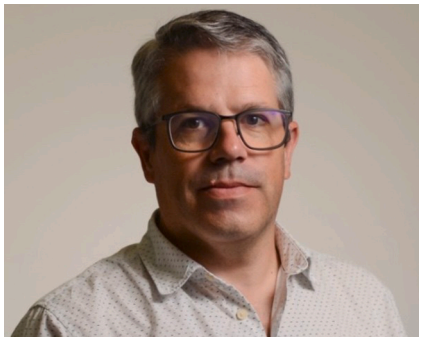
My team is exploring novel synthetic cytokine/receptor concepts for next-generation cell therapy applications. I had the privilege to present the work of my PhD students at the MOBILIsE symposium on immunoengineering. Two different technologies, allowing CAR-T cell-specific cytokine signaling, were presented. The first is centered around a new, functionally inert tag enabling CAR-T cell-specific *cis*-targeting of attenuated cytokines. We could show that the system induces full cytokine agonism in CAR-T cells even with ligands that are inactive on non-engineered immune cells. The second project showcased the design and development of a novel small-molecule-inducible heterodimeric receptor system. Both technologies were applied to different cytokine pathways, and their functionality was extensively characterized *in vitro* using CAR-T cells. Subsequent *in vivo* studies confirmed the superior efficacy of CAR-T cells armored with these synthetic receptors compared to conventional CAR-T cells, underscoring the potential of cytokine armoring for next-generation cell therapies.



Susana Monteiro
University of Minho, Portugal

How can molecular bioengineering transform immunotherapies? The views of the roundtable moderator

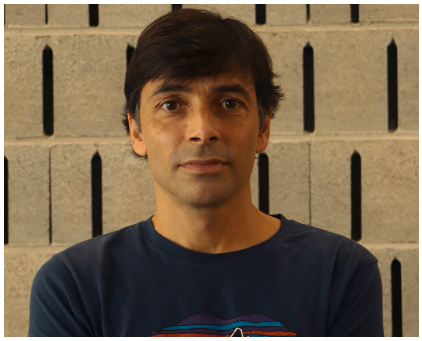
That was the guiding question of the roundtable I was privileged to moderate at the MOBILIsE symposium. Pedro Castanheira (Immunethep), Rita Acúrcio (iMed, Universidade de Lisboa), Dario Venetz (Roche), and Sérgio Chacim (IPO-Porto) brought different lenses to reprogramming immunity—through pathogen-inspired molecules, nanovaccines, synthetic cytokine receptors, and CAR-T cell implementation. The conversation moved from breakthroughs to future visions, highlighting the shift toward personalized strategies. We discussed boundaries to creativity; mismatched ''languages''; gaps between discovery, development, and clinical translation; and what it takes to bring combinatorial bioengineering into real-world use. From infectious diseases to cancer, the challenges echoed across fields and closed with one final question: if you could start over today, what problem would you choose? What stayed with me was their shared conviction to stay the course—their own questions remain too urgent to abandon. That perseverance across collaborative sectors may be the most powerful force to transform immunotherapies after all.



Pedro Castanheira
Immunethep, Portugal

How molecular bioengineering can transform immunotherapies: A biotech industry perspective in the roundtable discussion

I participated in the roundtable discussion by contributing with a biotech industry perspective from my work at Immunethep. We use protein engineering to develop vaccines and monoclonal antibodies that help restore the immune system's ability to fight bacterial infections, particularly those caused by antibiotic-resistant pathogens. During the discussion, I highlighted how molecular bioengineering enables the design of highly targeted immunotherapies that can overcome bacterial immune evasion strategies. I also emphasized the importance of translating these scientific advances into real-world applications through strong collaboration between academia, clinical research, and biotech companies. Our work at Immunethep exemplifies how engineering biology at the molecular level can lead to new solutions in infectious disease, helping to address one of the most pressing challenges in global health.



Rui C. Pereira
Institute for Research and Innovation in Health (i3S), University of Porto, Portugal

Multidisciplinary research in immunoengineering

Participating in the inaugural MOBILIsE symposium devoted to immunoengineering was an exceptionally rewarding experience, both as part of the scientific organizing committee and as a selected speaker. The excellent science brought by the keynote speakers and discussions around the various presentations ignited the alliance between immunology and bioengineering.

As a biologist interested in the interplay between biomaterials, brain tumor microenvironment, and human immunology, I was honored and pleased to present our preliminary work on the use of a supramolecular carrier for delivering human innate immune cells to the brain tumor microenvironment for medulloblastoma immunotherapy.

This first symposium was a pioneering catalyst for the design of the next generation of biomolecular strategies to be translated into transformative clinical solutions in oncology, infectious diseases, and regenerative medicine.

Helena Azevedo
Institute for Research and Innovation in Health (i3S), University of Porto, Portugal

Bringing the critical mass to discuss recent advances, current trends, and challenges in immunoengineering

As a meeting chair, it was a privilege to host the inaugural MOBILIsE symposium at i3S in Porto, gathering leading experts and innovators in immunoengineering. The symposium program included sessions and topics on immunomodulatory molecules and biomaterials, regenerative immunology, nanomedicines for precision immunotherapy, cancer vaccines, cell engineering for cell-based immunotherapies, and bioengineered immunocompetent *in vitro* (organ-on-chip) models. The symposium offered many opportunities for participants, especially early-career researchers, to present and share their work with a focused and interdisciplinary audience, to get feedback from world-renowned scientists and industry professionals, and to foster new collaborations. Discovering how immunoengineering is revolutionizing immunotherapies at the MOBILIsE symposium was truly exciting and inspiring for bioengineering the next generation of immunomodulatory therapies.

ACKNOWLEDGMENTS

The MOBILIsE symposium thanks the financial support by the MOBILIsE project, funded by the European Union's Horizon 2020 research and innovation program (grant agreement no. 951723), Fundação Luso-Americana para o Desenvolvimento (FLAD, Proj 2025/0125), and the University of Porto for sponsoring the participation of the keynote and invited speakers in the in-person symposium, and the Royal Society Journals for offering prizes to PhD students who won the best oral and poster presentations during the symposium.

DECLARATION OF INTERESTS

The authors declare no competing interests.