Ventures in time and space

Professor Dr Doris Heinrich, Head of Fraunhofer ATTRACT Research Group '3DNanoCell' in Würzburg, Germany, and Professor of Biophysics at Leiden University, The Netherlands, discusses her research on cellular cytoskeleton dynamics and applications in regenerative medicine

Could you describe the basis of your research? How are you working to achieve your objectives?

My research focuses on control of cellular functions for use in regenerative medicine. The aim is to develop smart implants and 3D scaffolds for tissue engineering. In standardised diagnostic assays, designed for the specific control of targeted cell functions, my research teams apply chemical, mechanical and/or electrical cues to probe and trigger cell functionality. To reach the nanoscale, we control these cues with the aid of multifunctional nano-tools.

An in-depth understanding of cytoskeleton regulation in living cells is required for the implementation of such methods. Whilst the genome is the blueprint of all life processes, the interaction of each individual cell with its environment determines gene expression, and thus cellular functionality. Molecular concentration gradients and mechanical interactions with the 3D scaffold of the extracellular matrix influence the behaviour of living cells, including processes such as migration, cell division, differentiation and apoptosis.

In vitro 3D scaffolds are applied as substrates to build tissue using living cells. These scaffolds are designed in combination with nanoscale surface structures to achieve optimal cell invasion and adhesion. This ensures the permanent survival of living cells and therefore tissue formation, further opening the way to next generation smart implants.

What makes the cytoskeletal dynamics of living cells under defined external stimuli of particular interest to you?

Applying defined external stimuli to living cells enables the investigation of cytoskeletal reorganisation and hence cell behaviour, which is the first step towards understanding cellular functionality. The next step would be the engineering of tools to control cell functions. We intend to trigger cells to act in a defined way. For example, initiating cell migration towards regions in the brain, where a stroke has destroyed tissue and impaired brain function, will repopulate this region and restore full brain functionality.

You lead the Fraunhofer ATTRACT Group '3DNanoCell' in the development of standardised diagnostic assays for the management and control of cell functions. Could you provide some insight into this work?

Almost every cell type is specialised to certain functions within the human body, so its cellular environment is unique. The mechanical, chemical and electrical properties of the extracellular matrix ensure that cells perform their proper functions. Diseases are often due to an imbalance in this system, which arise from malfunction or death of human cells. To examine the mechanistic origin of diseases, it is important to culture cells in their native environment, or to simulate it as closely as possible. Thus, we engineer artificial nanoscale 3D environments adapted to specific cell types, in order to perform standardised drug screening and diagnostics.

What are you currently working on?

We are working on nanoscale drug delivery systems, targeted to individual cell types. We have also developed biophysical tools to apply spatio-temporally controlled cues. These include magnetic tweezers, to control intracellular transport, and advanced microfluidic devices, to control cell migration and differentiation. Fields of implementation are tissue engineering and smart implants.

How have you overcome the challenges you have faced in your research?

The biggest challenge we face is the interdisciplinarity of this project, and the necessity to work in different established scientific cultures. Having worked in all of these disciplines previously, I can now function as a 'translator' when communicating with people from different research fields.

Could you outline the applications of your research, and how do you predict the field will evolve over the next few years?

Applications of my research include novel products for regenerative medicine and *in vitro* diagnostics. These comprise standardised 3D nanostructured assays for drug screening and diagnostics, smart active implants, tissue engineering, and new biophysical systems for the control of cell functions.

My research groups are continuously expanding and I predict that regenerative medicine will grow rapidly. The demographic changes in society and the resulting rising costs of healthcare make new solutions urgently necessary. New generations of active implants, cell-based diagnostics and cell carrier systems address attractive industrial markets of the future.