Preface

Nowadays, one of the main branches of microfluidic development is cell engineering. A number of the devices for the cell cultivation, *Organ-on-a-chip*, lysis, single-cell analysis, and cell-based toxicity tests are being reported. A variety of the structures that can be created leads to obtaining the devices more closely mimicking the in vivo environment than classic cell culture. The microfluidic devices can mimic the in vivo environment at various levels of its organization. It is expected that research on microfluidic in vivo-like systems will effect in the evaluation of methods that can replace animals in different fields of biomedical research.

The application of the microfluidic systems creates a possibility to revolutionize the methods applied in the cell biology research. Compatibility of the microchannels to dimensions of the cells as well as the ability to control parameters of the cell microenvironment makes them an attractive tool for biological research. Cells and their internal components have physical dimensions of microns so tools developed with a microscale technology are invaluable and well suited for manipulation, testing, and probing in microfluidic environment. Typical single processes as growth, treatment, selection, lysis, separation, and analysis are successfully realized in the microdimensional systems. The *Lab-on-a-chip* devices have a great potential for improving sensitivity and complexity of experiments, where studies of cellular growth and responses to external factors are conducted. The analytical devices integrated with cell culture create a possibility for continuous monitoring of cell behavior and biochemical processes as well. The usage of microscale analytical systems would have a great impact on cell biology knowledge as microfluidic devices have potential to improve the sensitivity and complexity of cellular experiments.

The heart is one of the most important organs and performs a principal task in the organism providing a blood through the vascular bed. Since cardiovascular diseases (CVDs) are known to be the main cause of mortality in humans, there is a huge interest in development of novel therapies for myocardial dysfunction. There are a number of proposed approaches; however, a big hope has been placed in stem cell therapies.

Chapter 1 is an overview of basics of the microfluidic systems for cellular application, presenting important parameters of the microdevices, which have the greatest impact on the cell behavior.

The main advantage to using the microsystems is their ability to imitate in vivo conditions which are missing in static macroscale cell cultures. In the next chapter, the materials which find applications in *Lab-on-a-chip* devices for cellomics, their properties, microfabrication techniques, and examples from the literature were described.

Organ-on-a-chip systems are novel platforms, which imitate the key functions of a living organ, including specific microarchitectures, cell-cell and tissue-tissue interactions, and extracellular communication. Microtechnology offers the possibility of creating more complex, multi-organ platforms known as *Body-on-a-chip* or *Human-on-a-chip*. Such integration allows to conduct research on inter-tissue and inter-organ interactions as well as human metabolism simulation, which plays a key role in studies on toxic and dose-related effects of novel therapies.

The next two chapters introduce two crucial application fields of this volume: characteristics and engineering of stem cells and reconstruction attempts of heart, the most “mystic” of human organs.

Stem cells widely used in the studies aiming to understand and also control differentiation of various cell types as well as to design the therapeutic strategies allowing to treat various degenerative diseases and to regenerate damaged tissues and organs. Current review focuses on the selected studies aiming at their efficient derivation and application in cellular therapies.

We summarize recent advances in therapies of the heart and methods that could be used to enhance their efficacy in clinical application.

Heart-on-a-chip systems are specific types of *Organ-on-a-chip* systems. The aim of the fabrication of such systems is to develop an in vivo-like cardiac model, in which the investigation of cardiac cell processes, as well as the elaboration of new therapies for heart failure, will be possible.

Based on the properly designed microsystems, it is possible to perform rapid drug screening and analysis of the effects of electrical stimulation. Thanks to this, new mechanisms and cardiac cell functions can be discovered and can consequently be useful in regenerative medicine.

In the last chapter, we present cardiac cell culture microtechnologies based on stem cells—the microsystems utilized for stem cells (SC) differentiation into cardiomyocytes (CMs). Various types of SC differentiation performed in *Lab-on-a-Chip* systems are presented in this chapter, including cardiogenesis using biochemical, physical, and mechanical stimulations. Finally, we summarize the research focused on heart regeneration using *Lab-on-a-chip* systems and we outline future perspectives for the microsystems usage for SC differentiation into CMs.

The chapters of this volume were written by well-recognized experts in stem cells and their applications in therapies, in heart diseases, and their therapies based on stem cells. Some of the chapters were written by our research team long-term expertise in *Lab-on-a-Chip* technology or related areas. It was important for us that each chapter gives an overview of the state of the art in the corresponding field.

This was achieved by including a relevant number of references, pointing out a reader where further information can be found, especially in such an interdisciplinary field as *Lab-on-a-Chip* technology. Therefore, we hope that the reader may find the extensive and up-to-date literature lists at the end of the chapters.

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