Myocardial infarction is a condition that affects more than 7 million individuals in the United States. Conventional therapies are limited by the inability of the myocardium to regenerate after injury and the shortage of organs for transplantation. A novel alternative to conventional therapies is the in vitro cultivation of cell-based cardiac grafts that can be surgically attached to the myocardium. This tissue engineering approach relies on starting with a sample of donor tissue and harvesting from it pure populations of one or more important cell types (such as cardiomyocytes or cardiac progenitor cells). Currently, existing techniques for cardiomyocyte separation and cardiac progenitor cell isolation are rudimentary (e.g. placing cells in a culture flask and waiting for undesired cell types to settle, or using cell strainers).

A novel approach to cardiac cell separation is the use of microfluidic systems as they have the ability to overcome the limitations of existing techniques with the additional ability to work with much smaller quantities of donor cardiac tissue. This dissertation describes how such microfluidic cell separation systems can be harnessed to potentially separate cardiomyocytes and cardiac progenitor cells from the native myocardium for the in vitro cultivation of a cell-based cardiac graft or injection of pure cardiac progenitor cells for myocardial repair. The systems created can be incorporated with in vitro cell culture equipment and furthermore, they are low-cost and easily operated on-site in clinical settings.

The largest growth of microfluidics is expected in the field of point-of-care (POC)
diagnostics and a potential application of microfluidics is in the field of ocular diagnostics. Analysis of a patient’s vitreous chamber is a critical step in disease diagnosis and personalized medicine. Biopsies are obtained through two types of procedures, (i) vitreous aspirate or (ii) pars plana vitrectomy and which is performed depends on an ophthalmologist’s initial assessment. A vitreous aspirate extracts a small vitreous biopsy by way of a hypodermic needle (~300 µL), while a vitrectomy is the surgical removal of the vitreous humor; the naturally clear, cell-free gel that fills the space between the lens and the retina. As a result of a vitrectomy, a 100 – 250 mL (due to dilution) vitreous biopsy is obtained that can contain 0 – 200,000 cells along with necrotic infiltrate. The large, dilute sample that contains fragile cells is difficult to characterize using conventional techniques and the current diagnostic yield is only 20%.

A novel alternative to conventional diagnostic techniques is a microfluidic platform as both small (vitreous aspirate) and large (vitrectomy) biopsies can be analyzed. This dissertation describes how an immunoassay conducted on a microfluidic device can be used to accurately examine vitreous biopsies, both small and large, for important biomarkers. Also described is how low concentrations of cells can be immunophenotyped by virtue of ligand-receptor interactions within a microfluidic device. This platform would be of direct benefit to physicians performing a diagnostic vitrectomy in an attempt to distinguish between ocular diseases such as uveitis and primary intraocular lymphoma (PIOL). Symptoms of both diseases are similar and distinguishing between these two conditions is a major challenge faced by ophthalmologists. In addition, the device can be used to test for biomarkers such as vascular endothelial growth factor (VEGF), which has been recently linked to several retinal diseases, including proliferative diabetic retinopathy (PDR).