Generation of Chemical Gradient of Varying Shapes Using Microfluidic Devices

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Abstract

Cell Migration is a pivotal process in conception, development and maintenance of all multi-cellular organisms. It is also a key process in diseases like cancer. When cell migration takes place because of cells' exposure to a chemical gradient of one or more chemicals (chemokines), it is called Chemotaxis. While mimicking in vivo conditions as a whole is very important to study chemotaxis, it is also important to be able to uncouple and manipulate the parameters like spatial constraints and chemical concentrations to study their individual effects. To study multiple cells in a single experiment, a setup that generates a chemical gradient of desired profile for prolonged duration is necessary. An ideal setup will also enable the control over the exposure time of the cells to the chemical gradient and also reduce the shear experienced by the cells. Development and application of microfluidics enabled better temporal and spatial control over the concentration gradient and cells. Microfluidic devices allow the user to mimic the spatial constraints of in vitro in vivo. These systems also enable the generation of stable and desired concentration gradients for prolonged duration unlike the systems used earlier to study cell migration. Our work concentrates on developing efficient microfluidic systems for chemotactic studies and also to meet a practical end such as on-chip clinical tools.
Before a microfluidic device can be used for studying cells, it needs to be analyzed for its applicability in such a study. However, fabrication of all the candidate designs, experimentation and analysis of the chemical gradient generated by them for different conditions for their suitability for the cell study are time and resource consuming endeavors. COMSOL Multiphysics software provides us with an in silico environment where we can test our designs in 2D and 3D, thus reducing the resources and time required for testing the designs, all the while producing results very close to the actual.
In one of our studies presented here we show the generation of different concentration profiles and in the other, we uncouple the cells from the flow of the fluids by making a simple design change thus reducing their exposure to shear.

Reference

1.D.A. Lauffenburger and A.F. Horwitz, Cell Migration: A Physically Integrated Molecular Process, Cell, Vol. 84, 359-369, 1996.
2.P. Friedl and K. Wolf, Tumour-Cell Invasion and Migration: Diversity and Escape Mechanisms, Vol. 3, 362-374, 2003.
3.S.H. Zigmond and J.G. Hirsch, Leukocyte Locomotion and Chemotaxis: New Methods for Evaluation and Demonstration of a Cell-Derived Chemotactic Factor, J Exp Med., 387-410, Vol. 137, 1973.
4.D. Irimia et. al., Polar Stimulation and Constrained Cell Migration in Microfluidic Channels, Lab Chip, Vol. 7, 1783-1790, 2007.
5.D. Fuller et. al., External and Internal Constraints on Eukaryotic Chemotaxis, PNAS, Volume 107, 9656-9659, 2010.

Figures used in the abstract

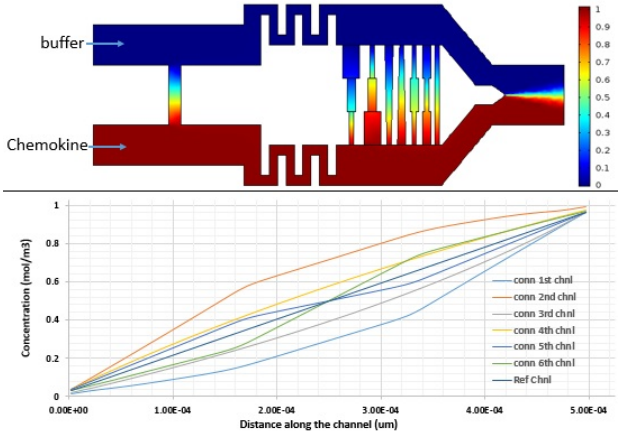

Figure 1: Development of Different Concentration Profile (Design 1).

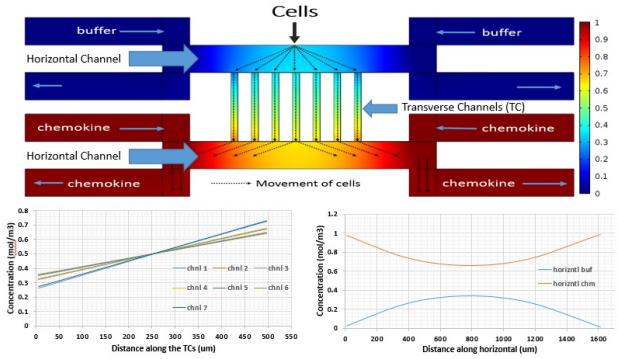

Figure 2: Development of Different Concentration Profile (Design 2).

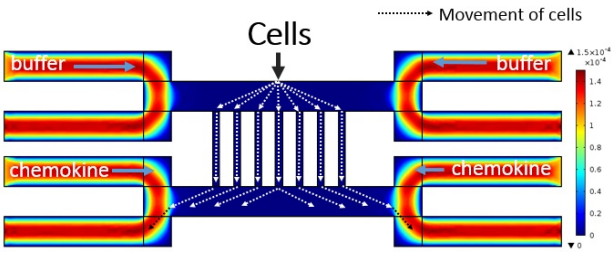

Figure 3: Velocity (in m/s unit) Profile in Design 2.