USING DIFFUSION GRADIENTS TO MANIPULATE FLUID SHAPE

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Abstract

Gradients play a role in biological processes and help us understand pathological and physiological phenomena such as cancer metastasis and immune response. We aimed to characterize the fluidic properties of various concentration gradients in the human body by creating simple pillar arrangements in a microfluidic channel using a simulation program. We extended these simulations to in vitro macroscopic models by fabricating macrofluidic devices with the same pillar arrangements. Three models of various sizes were fabricated using two different techniques: laser cutting and 3D printing. We saw differences in fluid shapes compared to those that were predicted using the computer application, with the larger models resulting in greater fluctuations. Future studies can improve the fidelity of the model by eliminating the fluid deformations and transferring the fluidic processes onto a bigger scale so that it may be relevant to real life situations.

Introduction

GOAL: To see if a computer simulation that operates on a microscale, involving manipulation of a pillar sequence along a channel to generate a fluidic gradient, can reproduce similar results on a macroscale device.

- The computer simulation is time and cost efficient since the macroscale device is optimized and thus the results would be more relevant.
- Gradients exist naturally in vivo, but there are few representative methods; therefore, creating tools that can explore microcellular environments allows us to gain more knowledge about gradients.
- By performing in vitro experiments with in vivo processes, we can further understand how these processes function in our body.

Materials/Methods

1. Flowgame Simulation
   - Used simulation to create the channel layout and pillar array
   - Simulated top view of the gradient to mimic embryonic growth of chicken lung
   - Optimized channel layout to be less than fifteen pillars

2. AutoCad
   - Optimized angles at which the inlets merged to reduce mixing
   - Scaled the original model to create three different sizes.

3a. Laser Cutter
   - Printed 3 layers of acrylic
   - Glued pillars into the channel
   - Top and bottom: ⅛ in; Channel: ¼ in
   - Channel length: 22.4 cm

3b. 3D Printer
   - Mold for two smaller models
   - Plasma bonded to glass slide
   - Channel length: 8 cm & 4 cm

4. Experimental Design – Laser cut model
   - Calculated flow rate using Reynolds number
   - Set syringe pump flow rate and ran fluid through channel

3D model
   - Calculated flow rate using Reynolds number
   - Observed the fluid flow under microscope
   - Analyzed microscopy images of fluid and pillar interactions

Calculations

\[ Re = \frac{4 \pi Q}{\mu D} \]

\[ Pe = \frac{245.5}{L} \]

Results

We encountered multiple errors with our laser cut model. There were air bubbles that formed while the fluid was being pumped, therefore affecting the rate at which the three fluids entered the channel. In our first experiment using red and yellow food dye, the red dye entered the channel before the yellow did. However, diffusion did not exist until after the fluids made contact with the pillars. As for our second experiment, the water and the green food dye started mixing beforehand. This was possibly due to the Péclet number not being high enough, therefore not allowing the fluids to diffuse naturally as it entered the channel.

The microscopy images below depict fluid and pillar interactions within our 4 cm model. We discovered that as the fluid collided with the pillar, it slightly diffused into two even flows, which was exactly what we wanted to see.

Fluid deformability as it contacts the pillars along the channel; fluid flow accurately simulates the top view gradient

Conclusion

- There were multiple measurement and accuracy errors with our laser cut model which directly affected the fluid flow and its diffusibility through the channel.
- However, our smaller models constructed from the 3D mold produced better results, showing fluid diffusion caused by the pillar sequence.
- Despite the fact that our laser cut model did not produce the expected results due to fabrication errors, the macroscale simulation can still be translated to a macroscale within reasonable parameters.

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References