One Drop:
Lab on a Chip

Megan Richards, Kaley Brungardt, and Kendra Schuette
Disease Diagnostics

● Traditional Approach
  ○ Assay test: search for biomarkers in blood
    ■ Complex equipment
    ■ Lengthy test time
    ■ Expensive ~700 million dollars of testing
  ○ Biopsy: remove tissue from body and perform extensive pathological tests
    ■ Invasive
    ■ Time consuming

● New Approach
  ○ Lab on a Chip
Project Objectives

- Design an assay that simplifies the diagnosis of breast and ovarian cancer
- Design a microfluidic ‘lab on a chip’ device that will mix blood and reagent streams to generate turbulent flows within a fluidic chamber
- Enable enough mixing for device to detect tumor biomarkers in blood
- 3D Print a Prototype of our most probable design
Technical Requirements

- Size needs to be smaller than a credit card
- Mixing of blood and reagent accomplished without any external forces
- Application to be single-use
- Low cost (<$1 in materials)
- We must generate turbulence on a small scale
  - Reynold’s Number doesn’t need to be >2000
Creating Turbulence

- Difficult to create turbulence in small microfluidic chambers\textsuperscript{2,3,4} (microns in diameter)
  - Loops & turns
  - 3D geometries
- Surface tension (capillary force) and viscous forces (frictional drag) must be calculated\textsuperscript{1}.
- The best design will depend on channel length and capillary-driven flow rates for quick mixing

\textsuperscript{1}http://www.industrial-electronics.com/DAQ/industrial_electronics/input_devices_sensors_transducers_transmitters_measurement/flow_meters/flow-technology.html
Original Four Designs
Redesign
Redesign with Obstructions
COMSOL Research

- Learn software from ground up
  - Help from Matt Campbell from AMI Manufacturing
  - Import SolidWorks & AutoCAD files and set parameters to study fluid profile within microchannels

- Used to determine which of our designs provides the best mixing
  - Simulations can give us numerical analyses of velocity and concentrations at inlets & outlets

- Mimic simulations from Dr. He’s studies
  - Many simulations
  - One takes 96 hours
COMSOL Results- Generic Tube

- First successful COMSOL simulation
  - Nearly 3 hours to compute inlet & outlet velocities and concentrations
  - Set predetermined parameters
    - Laminar flow
      - We don’t have the software to handle turbulent flows
    - Transport of diluted species
    - Water + Diluted Blood (consistency of water)
  - Post simulation, a 12 page report is produced by the software
Generic Tube:
Concentration Slice

<table>
<thead>
<tr>
<th>Outlet Conditions</th>
<th>Maximum Concentration (mol/m$^3$)</th>
<th>Minimum Concentration (mol/m$^3$)</th>
<th>Range (mol/m$^3$)</th>
<th>Average Velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No obstructions tube</td>
<td>.75404</td>
<td>.23639</td>
<td>.51765</td>
<td>.014670</td>
</tr>
</tbody>
</table>
### Ladder Tube: Concentration Slice

<table>
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<tbody>
<tr>
<td>Ladder tube</td>
<td>.71882</td>
<td>.27538</td>
<td>.44344</td>
<td>.014521</td>
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</table>
## Crossed Ladder Tube: Concentration Slice

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<tr>
<th>Outlet Conditions</th>
<th>Maximum Concentration (mol/m$^3$)</th>
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<tr>
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<td>0.69840</td>
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</table>
## Diagonal Planes Tube: Concentration Slice

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<td>Diagonal Planes tube</td>
<td>.57433</td>
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## Results

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Inlet velocity .0074m/s  
Inlet 1 concentration 0 mol/m$^3$  
Inlet 2 concentration 1 mol/m$^3$
## Results: Diagonal Planes Modifications

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<th>Range</th>
<th>Average Velocity (m/s)</th>
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</thead>
<tbody>
<tr>
<td>Same length, more obstructions</td>
<td>.55050</td>
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<td>.017433</td>
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<tr>
<td>Longer length, same obstructions</td>
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<tr>
<td>Longer length and more obstructions</td>
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<td>.46833</td>
<td>.05818</td>
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</tr>
</tbody>
</table>

Inlet velocity .0074m/s
Inlet 1 concentration 0 mol/m$^3$
Inlet 2 concentration 1 mol/m$^3$
Final Recommendation

Diameter = 500 microns
Channel Height = 15 mm
Chip Dimensions = 3.3 x 1.8 cm

Average Concentration at outlet: 0.49832 mol/m^3

High Mixing Efficiency 99.6%
Future Work

● Modify the diagonal planes tube height and number of obstructions to facilitate an even higher mixing efficiency
● Wet lab research will be conducted with red and blue dyes to verify that the COMSOL results were accurate
● The team will create a cap that attaches to the inlets of the microfluidic chip

Future Senior Design Teams
○ Design a reagent
○ Work with our advisor, Dr. He, to produce a cell phone application to read concentration from the chip
References

QUESTIONS?