Herringbone Microfluidic Mixer

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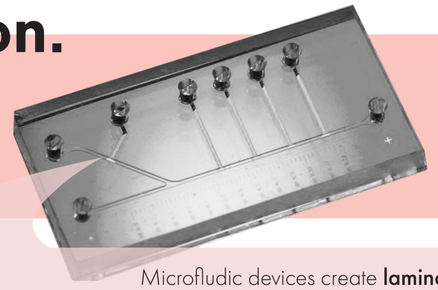
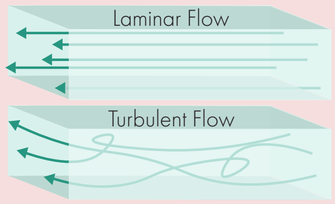
Introduction.

Microfluidic devices precisely manipulate microliters of liquids, which can help support the **growth of cells and tissues.**





Microfluidic devices create **laminar flow** due to a low Reynolds number (low velocity of liquid and small channel size).

However, laminar flow hinders mixing of mediums of such as drugs or chemical reactions.

In this work, we make a microfluidic mixer that disrupts laminar flow.

$$\text{Reynolds Number} = \frac{\rho V D}{\mu}$$

ρ = density of fluid
V = velocity of fluid
D = diameter of pipe
μ = dynamic viscocity

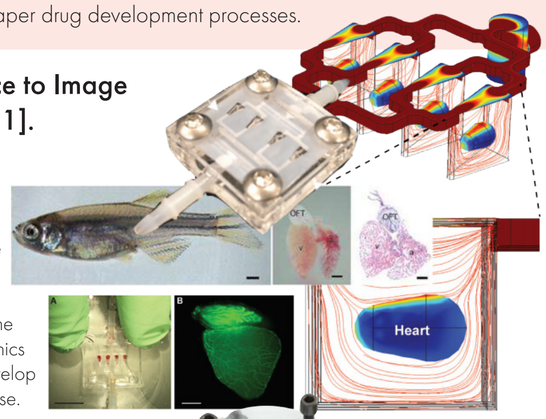
Impact of LLSE's Work.

The Laboratory for Living Systems Engineering (LLSE) at USC develops microfluidic devices to culture cellular microenvironments and test novel medications for more accurate trials and cheaper drug development processes.

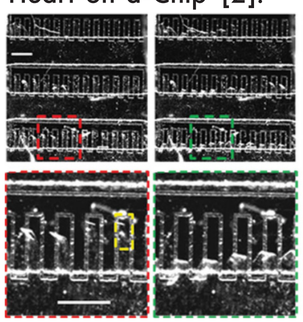
Microfluidic Device to Image Zebrafish Hearts [1].

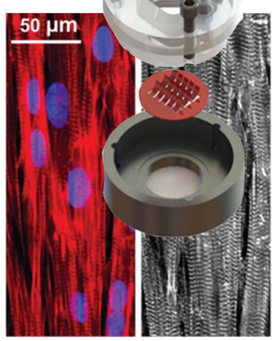
Researchers at LLSE have recently developed a device to observe the regeneration process of the heart.

With their work, we may one day understand the mechanics of regeneration to help develop medications for heart disease.



Heart-on-a-Chip [2].

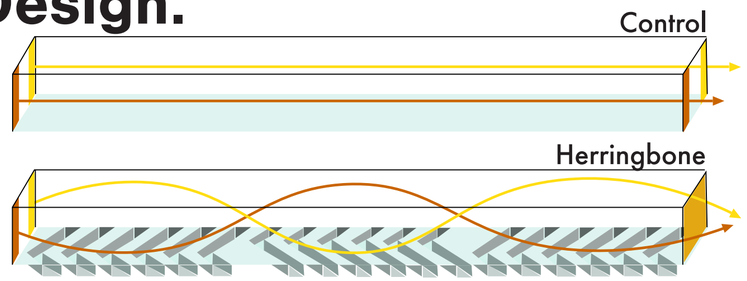




Dr. McCain also worked on a project to incubate heart cells with flaps to understand contraction during diastole and systole.

In the future, researchers can screen drugs to understand the effects on the heart and other organ systems.

Design.

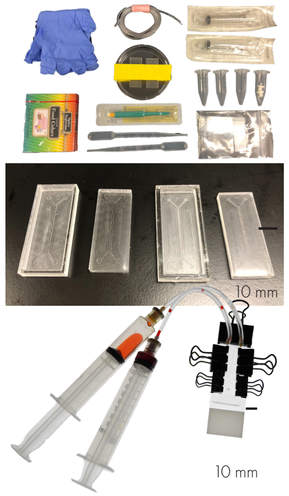


Created by Stroock et al. 2002 at Harvard University, the Herringbone mixer features grooves that facilitate mixing and turbulent flow [3].

Methods.

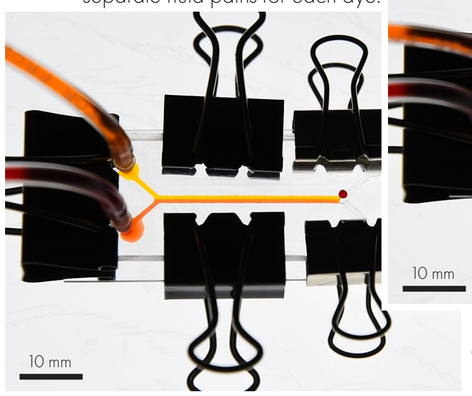
Constructing the device

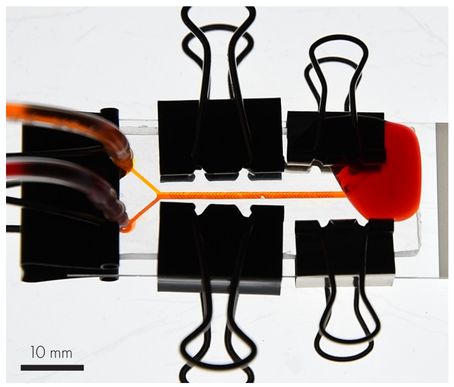
1. Micromill polycarbonate mold for both control and herringbone device & smoothen through sanding [4].
2. Pour silicone or polydimethylsiloxane (PDMS) into the mold & heat cure.
3. Punch out 2 holes using biopsy punch for syringe tubing to enter.
4. Clip the PDMS device to a glass slide using binder clips.
5. Plug the hole using a barbed connector and plastic tubing to syringes.
6. Push dyes through the device and observe flows.



▶ Top: Components of the herringbone device
Middle: Polycarbonate molds and PDMS devices
Bottom: the complete device constructed with 2 syringes, food coloring dye, and microfluidic device.

▼Control device has no grooves and has distinct seperation of color and maintained separate fluid paths for each dye.

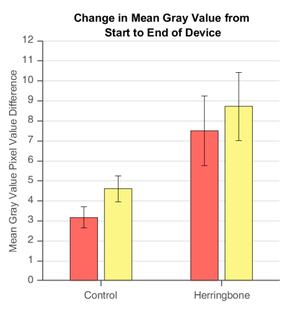


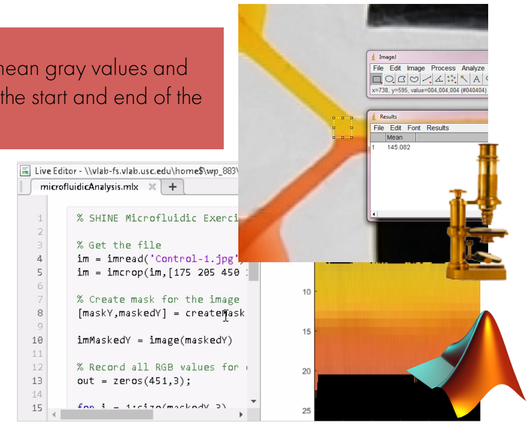


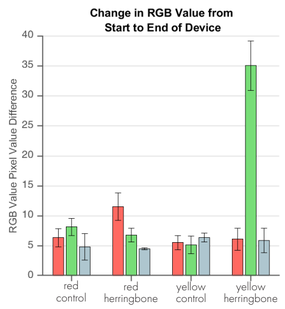
▲ Herringbone device similarly starts off with a seperation of dye, but then mix into one color due to the introduction of turbulent flow due to the grooves.

Results.

Using MATLAB and ImageJ, mean gray values and RGB values were pulled from the start and end of the channels.







Over 5 frames of a perfusion video per device, the herringbone mixer had a greater change in mean gray value and RGB values control, showing that the dyes mixed more throughly compared to the control device. The red channel in the herringbone device had a change of mean gray pixel value of 7.500± 3.477 while the yellow channel had a change of 8.721±3.417. When evaluating RGB values, the red channel had the greatest change in its red pixel value by 11.575±4.560 while the yellow value had the greatest change in its green pixel value by 35.037±8.281.

Average Change in RGB Value from Start to End of Device

	Red Control			Yellow Control			Red Herringbone			Yellow Herringbone		
	Red	Green	Blue	Red	Green	Blue	Red	Green	Blue	Red	Green	Blue
Average	6.373	8.174	4.841	5.576	5.199	6.395	11.575	6.812	4.531	6.125	35.037	5.944
Standard Deviation	3.043	2.912	4.376	2.386	2.981	1.472	4.560	2.256	0.316	3.602	8.281	4.085

Average Change in Mean Gray Value from Start to End of Device

	Red Control	Yellow Control	Red Herringbone	Yellow Herringbone
Average	3.182	4.606	7.500	8.721
Standard Deviation	1.065	1.283	3.477	3.417

Next Steps.

- Continue exploring the field of microfluidics and lab-on-a-chips
- Work on my own microfluidic device that separates bacteria from blood
- Major in biomedical engineering in college and join a research lab during my time there

Reflection.

Some tips for future students: take advantage of all the resources at SHINE, especially mentors and teammates because some of the people you may meet here may change your life. Put in effort because you love it rather than you need because it is required. Be willing to take risk and be sincere and genuine with what you do.

References.

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Acknowledgements.

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