Student Worksheet

Multifacted Microfluidics

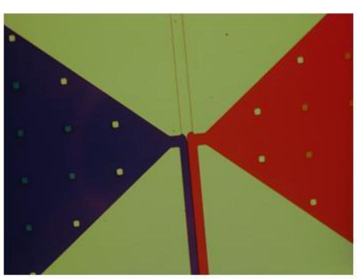
Introduction:

Microfluidics is a technique for manipulating liquid samples at very small scales. These micro and nano-sized devices that are also called lab-on-a-chip because of their applications in biochemical testing and analysis. They typically have sets of channels, sensors, and mixing chambers that can run several tests at one time. Sample size may be as small as a drop of blood or urine. Common examples from everyday life include: home pregnancy tests, strept tests, drug tests, yeast infection tests, and glucose monitoring.

Microfluidic devices have enhanced basic research and are currently demonstrating potential for use in diagnostic medicine. Miniaturized devices allow for faster response times, smaller sample size and low cost sample/specimen analysis. Applications for microfluidic devices are almost limitless in the areas of biology, chemistry, physics and engineering.

The lesson provides three different techhniques to create microfluidic devices. The methods use safe and simple materials including Jell-O®, Wikki Stix, Shrinky Dinks®, and a polymer called PDMS. These designs are an example of soft lithography in a less rigorous setting - no cleanroom required. Typically, to make a microfluidic device one begins by making a mask using photolithography in a cleanroom. You will be making a mask and microfluidic device in your lab using these common and safe materials. Your teacher will decide which method you will use for your fabrication and what experimental variables you will test. Below is an image or a device which demonstrates laminar flow as shown by red dyed and blue dyed fluids entering the same channel.

Red and blue dye



Photograph of laminar flow in a PDMS device. Courtesy Arizona State University.

Pre lab: Watch the videos from The Lutetium Project – *Microfluidics Adventures #1-3.*
https://www.youtube.com/watch?v=b8zE2i755-k;
https://www.youtube.com/watch?v=68p3qAm4i7U;
https://www.youtube.com/watch?v=EYuyRUjnTgc

Vocabulary:

Your teacher may assign the vocabulary as an in class or homework assignment. As a class, you should a discussion about definitions you found difficult or add to the list after viewing the Microfluidics Adventures videos.

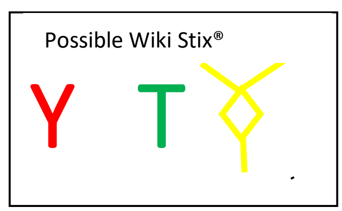
1. *Solution*
2. *Mixture*
3. *Diffusion*
4. *Soluble*
5. *Insoluble*
6. *Laminar flow*
7. *Nanoscale*
8. *Nanometer*
9. *Nanotechnology*

Materials per group (will vary depending on method)

Styrofoam plates	Toaster oven
Jell-O® gelatin	Vegetable oil
Boiling H_2O	Hot plate
Measuring cup	400 or 500 mL beaker
Bowl to mix Jell-O®	Thermometer
Refrigerator	PDMS (polydimethylsiloxane)
Wikki-Stix®	Mixing cup
Scotch tape	Plastic spoon or spatula
Stirring straws	Vacuum chamber/desiccator
Double sided scotch tape	Glass slides (50mm x 75mm)
Aluminum pie pans	Blunt needles, probes, or biopsy punch
Plastic petri dishes (150mm)	Syringes for injection of fluids (1 or 5 ml)
Food coloring	Pipets
Shrinky-Dinks® (available online)	Oven capable to heating to 60°C
Laser-Jet printer or marking pens	Materials for testing – will vary based on experiments
Scissors, scalpel, razor blades	Safety gloves and goggles

Directions for the Activity: Three methods to make device

1. JELL-O® activity:



This is a macro model of a microfluidic device. Each student will need a Styrofoam plate and 6-8 Wikki-Stix®. Wikki-Stix® can easily be bent into a multitude of forms (T-shaped, Y-shaped or multi- patterns). Create your own microfluidic pattern with the Stix. Place the design on the plate. Use double stick tape to anchor the design to the plate. Gently press to secure evenly. Anchoring the final design with tape will prevent the JELL-O® sticking to the form. Cool the JELL-O® mixture to room temp before pouring onto the form.

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Directions:
Follow the instructions on the JELL-O® box to make the Jigglers mix.

- Stir 2.5 cups boiling H_2O into a bowl containing the contents of one JELL-O package.
- Mix until completely dissolved.
- Pour the cooled liquid onto a Styrofoam plate completely covering the design.
- Refrigerate overnight.
- You will carefully peel the Styrofoam plates from the JELL-O® mold and Wikki-Stix® and invert the mold onto an aluminum pie pan. The channels created by the Wikki-Stix® should be face down on the aluminum pan.
- Using a blunt needle/probe or stirring straw, have students punch two holes (number of holes will depend on the design) in the JELL-O® mold. One hole will be an inlet hole into which the you will inject fluid; ideally, on opposite ends of the horizontal cross of the T or the upper ends of the Y. The second hole is an outlet hole for the fluid and will be at the base of the stem of the T or Y. You may also wish to create a device with dual inlets or duel outlets. (Dual inlets should create laminar flow while dual outlets should create less resistance to flow). When using dual inlets use different colors of food dye. The device is now ready for testing.

2. Shrinky-Dinks activity:

This is a micro model of a microfluidic device. Shrinky-Dinks® are heat sensitive plastic sheets (polystyrene) plastic film that when heated crosslink or hybridize resulting in the "shrinkage" of the film. In this activity, a design can be drawn or printed from a Laser-Jet printer representing the microfluidic device. The finished product is approximately two-thirds its original size. This technique demonstrates the micro dimensions of a microfluidic device. The template mold can be produced in a matter of minutes.

Directions:

- You will design you flow-through apparatus and then using a permanent marker they will draw it on the Shrinky-Dink® sheet. _*An alternate method*_ is to design the device using PowerPoint and then print it with a laser printer on the film. Designs should be around 10 - 15 cm^2. Cut out the device leaving about 1 cm around it.
- Follow the instructions for heating the Shrinky-Dinks®. Place the design on a flat surface in a standard toaster oven for 3-5 minutes at 350^{O}F. The plastic will curl while shrinking. They will uncurl after complete shrinking. Continue to bake the Shrinky-Dink® for about 7 minutes after shrinking. The extra time helps the ink stick to the plastic. _*An alternate*_ method proposed by Hemling et al (see resources) is to fill a 500mL beaker 1/3rd full of of vegetable oil and heat on a hotplate to 150^{o}C. Using tweezers, place film into the oil and leave until it curls and uncurls (~1 minute). Once completed, place between two glass plates and allow to cool.
- You will be creating your devices using polydimethylsiloxane or PDMS. Mix according to instructions, typically the mix ratio is 10:1 - base to catalyst. Mix in cups using either a plastic spoon or a stirring stick. It will become white and cloudy with bubbles. Degas the mixture using a desiccator/vacuum system. It is recommended to degas the mixing

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cup for 10-15 minutes before pouring it into petri dish. Place the cut Shrinky-Dink® design (ink side up) in a plastic petri dish. Use double sided tape to hold it in place. Press gently to ensure evenly secured. Pour the PDMS mixture over the Shrinky-Dink® completely covering the design. Repeat the degassing procedure until all bubbles are eliminated (15-30 minutes). Allow the PDMS to cure at room temperature for 48 hours. *Alternative method* is to bake at 60^{o}C for 2-3 hours or overnight.

- Wear gloves to remove the mold. You should GENTLY cut it away with a scalpel/razor blade and remove the mold from the petri dish. The PDMS should show a negative imprint of the pattern.
- Adhere the mold to a glass plate. Use double-stick tape and secure evenly.
- Using a blunt needle, probe, or biopsy punch, punch holes into the PDMS for inlets and outlets. The device is now ready for testing.

3. Wikki-Stix® with PDMS activity:

This activity falls between the JELL-O® macro scale and the Shrinky-Dink® micro scale.

- You will design your pattern using the Wikki-Stix®. It must be small enough to fit into the petri dish.
- Press the design onto a plastic petri dish and anchor with double stick tape. Press gently to make sure there are no bubbles between the tape and the device.
- Mix PDMS (polydimethylsiloxane) according to instructions noted above in method 2. Degas as noted above.
- Pour the mixture over the Wikki-Stix® design. Degas again as noted in method 2 above. Allow the PDMS to cure at room temperature for 48 hours or bake at 60^{o}C for 2-3 hours or overnight.
- Wear gloves. Using scalpel or razor blade cut the mold and gently remove it from the petri dish. The PDMS should show a negative imprint of the pattern after removing Wikki-Stix®.
- Using double sided tape, adhere the mold to a glass plate.
- You may leave ends of the Wikki-Stix® exposed for holes and pull the Wikki-Stix carefully through the imprint in a snake-like fashion. If needed, holes can be punched into the PDMS for inlets and outlets. A blunt needle, probe, or biopsy punch will work.

Experimental variables:

You teacher will assign which fabrication method to use and what experimental variables are to be tested. Below is some of the variables that you might be asked to test. Can you think of other chemistry concepts you would like your device to perform?

- Test the viscosity of the devices using baby oil for a thick fluid compared to fruit juice.
- Use food coloring to demonstrate laminar flow. Requires two inlets. Use two syringes each containing a different color dye.
- Use glitter of various sizes to demonstrate particle size versus speed of flow. Put glitter into water and inject the fluid into an inlet.
- Mix two of more solutions to neutralize an acid or a base.

Record in your lab notebook:

- Variables to be tested
- Design of your device
  - Including how it will be able to test your variables
- Your results
  - What was the outcome of your experiment?
- Ideas for improving your device

Analyze the Results:

1. What is laminar flow?
2. What is turbulent flow?
3. How do pressure changes in a system affect velocity of flow?
4. What advantage is gained by the patient by faster response times in medicine?
5. What advantage is gained by the patient by using smaller sample sizes?
6. What is meant by the term viscosity?
7. What is the effect of the viscosity of a fluid on flow velocity?
8. How is nanotechnology impacting microfluidics?

Draw Conclusions:

- Discuss the scientific principles you learned with this activity.
- How did your experiment work? If it didn't work, why not?
- What were the independent and dependent variables of your experiment? What changes occurred and why?
- What were the benefits or limitations of the method you used?
- Do you think a different fabrication method would have improved your results?
- What are the real life applications of your experiment?

Cleanup: Gelatin, Wikki Stix, and Shrinky Dinks can be disposed in the lab waste cans. PDMS is a non volatile polymer and should be safe to dispose in lab waste, however, check with your school safety procedures. Sharps also should be disposed on according to school rules. All non-consumable lab supplies should be returned to the appropriate storage area.

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