DIY Microfluidics Lab

Instructors Note: There is a balance between teaching and allowing the students to discover microfluidic phenomena. We encourage an approach in which the instructors allow the students to make mistakes and learn. This can be facilitated by having extra devices that are a) complete (if they can not assemble them) and b) additional kits in case there is an error (since tape is not always reversible). Students should be informed that it's okay to try and fail.

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Background: Nearly all translational microsystems interact with biofluids in some way, shape, or form. In Lecture 2, we discussed scaling laws and how miniaturization can both be beneficial and detrimental to making measurements, depending on the system. One challenge to designing systems that leverage scaling laws is that many of our normal intuitions can be incorrect as they are based on our own interactions with the macro-sized world.

Goals: I designed this lab to be a fun way to gain concrete experience with a miniature system, ideally to inform your later work with microfluidics. By the end of this exercise, my goal is for you to be able to:

1. Describe laminar flow & how fluids behave in a microfluidic
2. Describe the importance of alignment tolerances when assembling a microsystem
3. Describe the operation of several common microfluidic components (mixer, valve, droplet generator)
4. Draw cross sections and top down views for several common microfluidic components
5. Describe how bubbles influence microfluidic operation
6. Describe how dust affects microsystems
7. Be able to design your own microfluidics using double sided tape, silicone, and a craft cutter

Note: All of the objectives are focused on learning not on perfectly working devices. (i.e. if your device doesn't work, it's okay!). But regardless of whether your device operates, let's all work together to learn about microsystems.

Microfluidic Materials: All the microfluidics are made from these materials

3M 96042 Double Sided Tape: This tape has been designed for adhesion to silicones, and is a layer of silicone adhesive with a thickness of 0.05 mm, a clear PET carrier that is 0.025 mm, and another layer of silicone adhesive with a thickness of 0.05mm.

Rogers HT6240-0.01": This commercially available clear silicone is available in large rolls and has good optical clarity combined with a nominal thickness of 0.01" (250 µm) and a tolerance of +/- 0.002" (50 µm)

Sylgard 184 (Precast): Sylgard 184 has already been mixed in a 10:1 ratio of base to curing agent and heat cured at 60ºC in a Petri dish and cut into a square. You'll punch holes in this material to create fluidic ports

Glass Slides (): Standard microscopy slides form the base of the device for easy handling and can easily be replaced with cover slips for high resolution imaging

Ancillary Materials: We'll use these to test your fluidic devices

10 mL syringe with Luer Lock (): Many microfluidic systems use syringe pumps, which can range in price from several hundred to several thousand USD. However, fluid flow can also be achieved with gravity flow from a reservoir, here made with a 10 mL syringe.

Pink needle tip (Techon TE Needle 20 Gauge ½" Pink, TE720050PK): These blunt tip needles are a handy tool to interface the syringe with Tygon tubing

Tygon tubing (Cole-parmer EW-06419): You'll use this to connect everything together. It's the larger, short section of tubing and will join the pink needle tip and PTFE tubing.

PTFE tubing (VWR, 0.012x0.030"): This tubing connects to your microfluidic and the Tygon tubing

Water & food coloring: Food coloring and water work great to visualize fluid

Mineral Oil: Hydrophobic fluid for the bubble experiment

Waste tube & Holder: Made from extra Styrofoam holders for the conical tube holders, used conical tubes for waste (need pic)

Sharps disposal box – small envelopes which can be used for sharps disposal

Puppy pads / towels – Use to keep desks clean and grab water

Tools:

Duck billed tweezers (TDI)*: Duck billed tweezers have a flat surface that can assist with inserting Tygon tubing into the precast PDMS lid.

Smartphone (Record pictures): If you have a smartphone, please feel free to use the imaging capabilities and timers to assist with the exercises. If you do not have a smartphone available, Dr. Myers will be circling the room and will be able to assist.

** Please return these tools, as they were **donated** to help with the educational mission of this class*

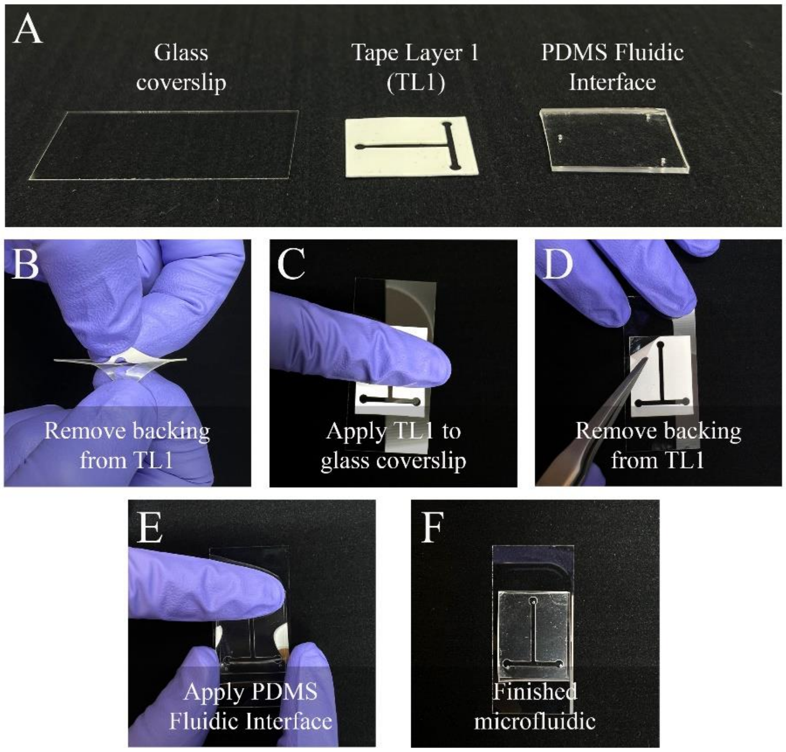
Class Tools

Scissors: For cutting the tubing (if needed)

Scotch tape: To clean dirty PDMS

Extra paper towels: For your worksurface

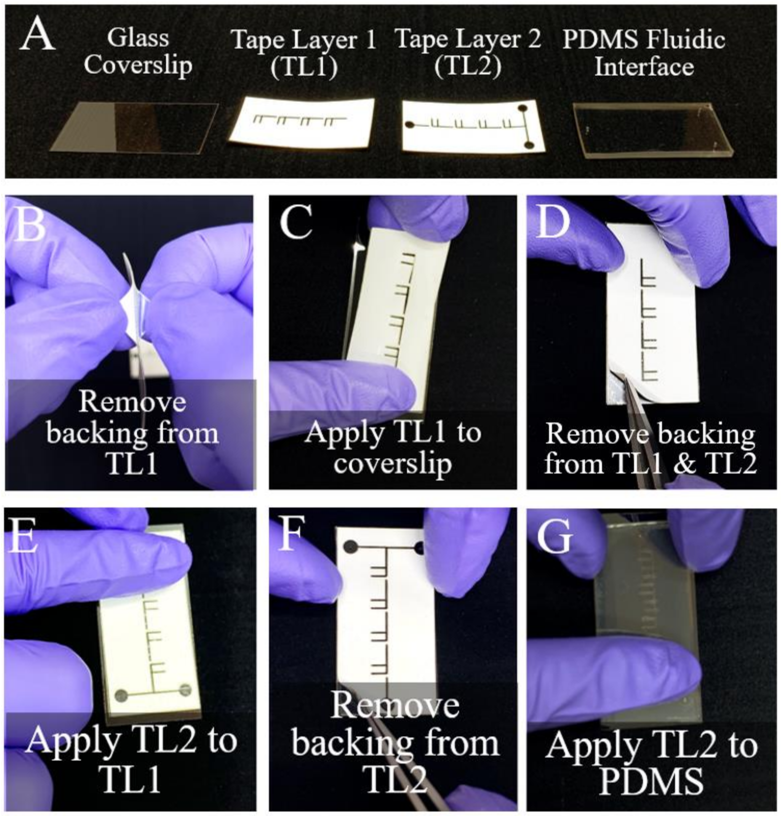
Device Assembly: Each team of 2 will receive a kit that contains the key components to build each of the following devices: 1) Standard Flat Mixer; 2) F-mixer 3) Droplet Generator 4) Quake Valve. You'll also receive a set of syringes and tubing. Here's an example of how to assemble the standard flat mixer:



Pro Tip 1: Work on one microfluidic device at a time, and lay out each layer before assembling. When you assemble your device, start with a glass slide on the bottom (layer 0).

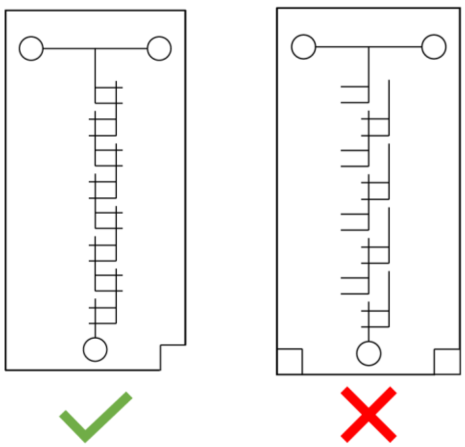
Pro Tip 2: Assemble the devices in the order given above as these will sequentially increase the complexity. There is a sequence of questions to answer with each device, I also recommend answering these questions before moving to the next device.

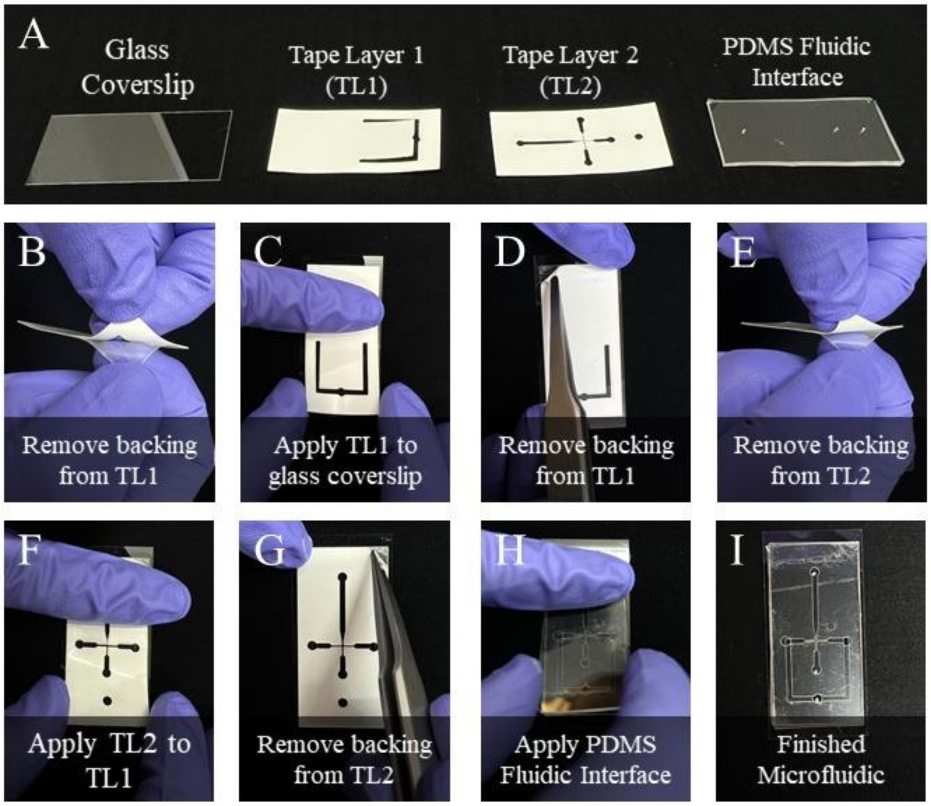
Assembly of other devices:



F-mixer Assembly

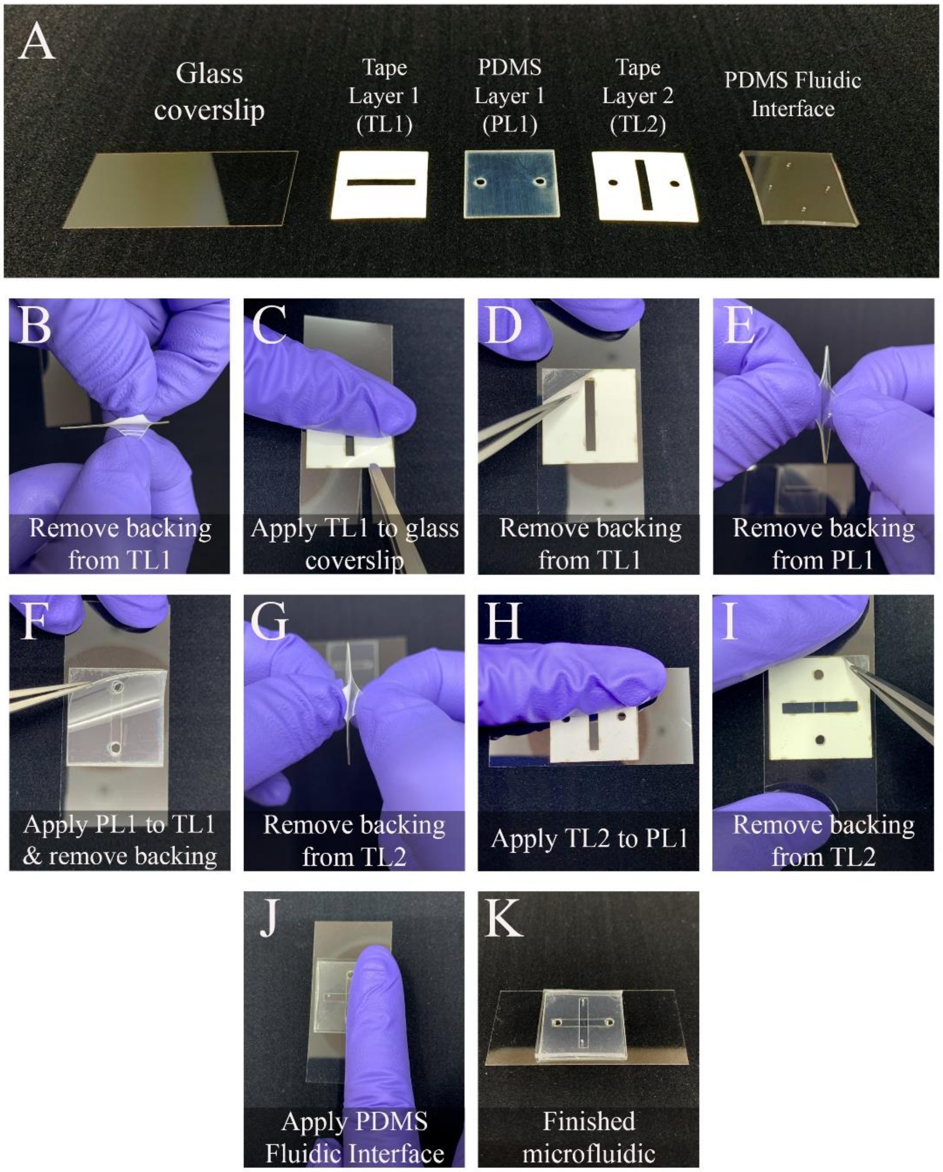
Pro Tip 3: Some of the complex multilayer devices have an alignment square cutout in the corner of the layer. Be sure to line up the squares to ensure that the device layers are properly oriented.





Droplet Generator Assembly

Assembly of other devices:

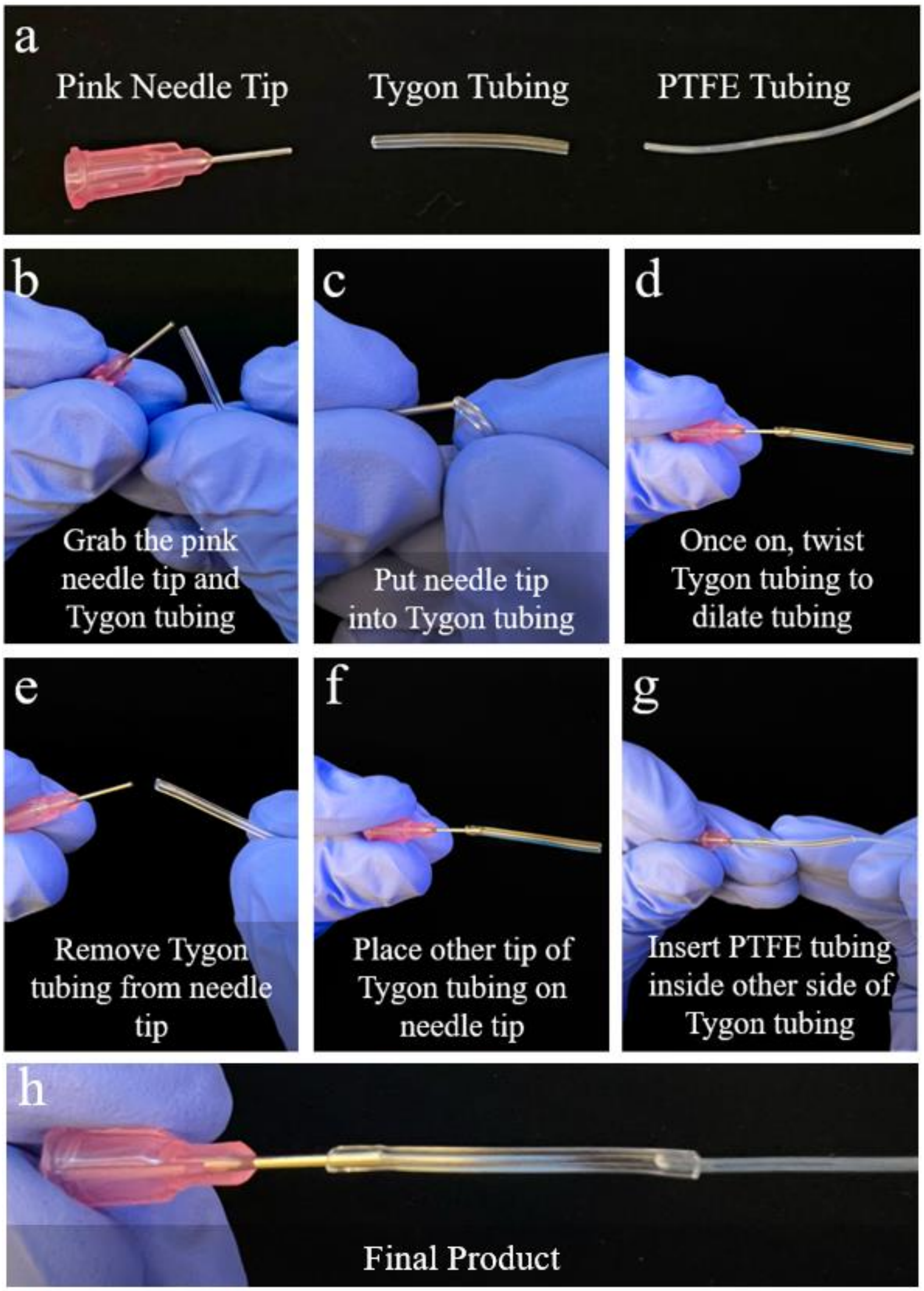


Valve Assembly

Testing your fluidic:

1. Please make sure that you have received 4 syringes:
    a. One with blue water
    b. One with yellow water
    c. One "empty" syringe (filled with air)
    d. One syringe filled with clear mineral oil

2. Now it's time to connect all your tubing to your syringes, here's how to do it:



Pro tip 4: When inserting the PTFE tubing into the microfluidic inlet/outlet ports, confirm that the tubing is placed correctly by lifting the microfluidic using the tubing. If the tubing comes off, that means that the tubing needed to be placed further into the inlet/outlet for proper securement. If the tubing keeps coming off cut the tubing flat rather than at an angle if it isn't already cut flat.

3. When you are ready to test your fluidics, you'll use the following combinations:
    a. **T-Mixer**: Blue and Yellow water.
    b. **F-mixer**: Blue and Yellow water You should be able to see "green" mixing when it occurs.
    c. **Droplet generator**: Blue water and canola oil. Try to setup the device to create blue droplets surrounded by oil
    d. **Valve**: Blue water and an air actuated (place 1mL of air in the syringe)

4. Please look carefully at each device and in light of the device name and what you've observed while assembling it, consider where each syringe should be attached. It's okay to experiment as connections are reversible and interchangeable.
    a. Syringes can be reused. For example you can fill two with the blue and yellow food dye first, then empty the yellow syringe to fill with air for the valve and later fill with oil for the droplet generator.

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T-Mixer Questions:

1. Using the list of materials above, draw a *cross section* and *top view* of the standard flat mixer, be sure to label approximate dimensions and thicknesses. Be sure to make them large enough to make subsequent annotations.

2. Using the dimensions you have estimated or know, estimate of the total volume of fluid in the mixer.

3. Once you have established a steady state fluid flow condition, observe how the fluids look in the mixer. Lightly sketch what you see on top of your top view/. How does the fluid near the entrance look in comparison to the end?

4. IF TIME ALLOWS: Can you think of a way to estimate the flow rate of your system?

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F-mixer Questions:

1. Using the list of materials above, draw a *cross section* and *top view* of the droplet generator, be sure to label approximate dimensions and thicknesses.

2. How was your alignment? Make a brief sketch of the top view of the device if the layers were: 1) Misaligned in the x & y 2) Had a rotational misalignment

3. Did your device mix the fluids? If not, can you comment on what may have happened? If so, where was the mixing point (Mark in your sketch above)

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Droplet Generator Questions:

1. Using the list of materials above, draw a *cross section* and *top view* of the droplet generator, be sure to label approximate dimensions and thicknesses.

2. What would happen in this device if the oil was replaced with water? Make a sketch of what this might look like.

3. How does changing the pressure applied to the syringes change the operation of the device?

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Valve Questions:

1. Using the list of materials above, draw a *cross section* and *top view* of the Quake valve, be sure to label approximate dimensions and thicknesses.

2. Your air channel has an inlet and outlet hole, what happens when you seal the outlet hole with your finger and actuate the air syringe?

3. What happens to the fluid flow when the valve is actuated down? What happens to the fluid flow when a negative pressure is applied to the valve?

4. How much deformation can you see in the valve? Is this surprising to you?

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General questions:

1. Did you have any trapped bubbles? Did they change the performance of your device relative to what you expected or relative to the other groups?

2. Did you notice any dust particles on your device? How might dust affect the operation of your device?