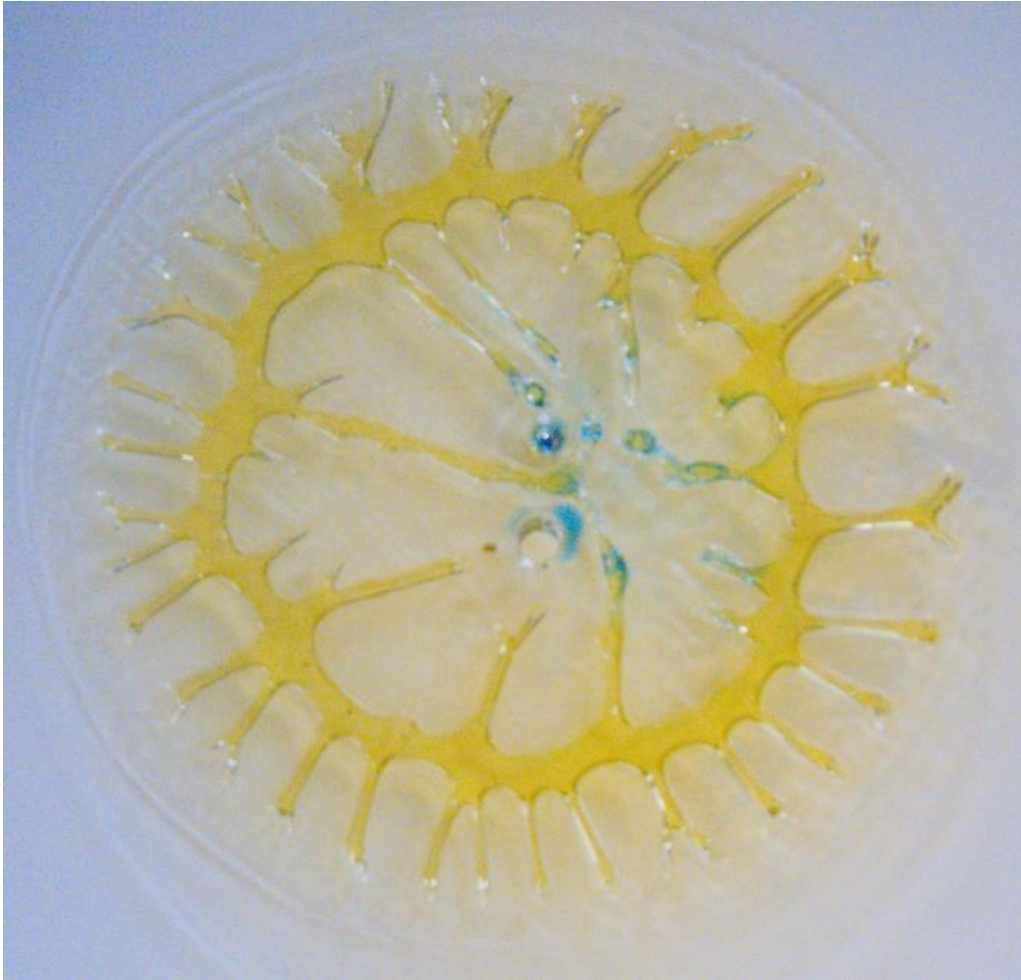




Sweet Instability

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CVEN 5153: Flow Visualization

Team First Assignment

October 5, 2026

1. Introduction

This image was taken for the “Team First” assignment as part of the Flow Visualization course at CU Boulder. The objective of this assignment was to take a compelling picture or video that captures a flow phenomenon, with the added help of a team. By working in teams, we were able to attempt more complex and time-consuming experiments. For this assignment, we were interested in attempting to create the Saffman-Taylor instability with a Hele-Shaw cell. I was inspired by the interesting and somewhat abstract look of the Saffman-Taylor instability. I wanted to create an image that was interesting to look at and allowed viewers to see different and unique things in the flow. This experiment was done in collaboration with my teammates, Henry Wojcik and Natalia Nieto-Wire, who helped set up and run the experiment. Additionally, I used Anthropic’s Claude 4.6 Sonnet to review this report for grammar and consistency (Anthropic, 2026).

2. Experiment Overview

Figure 1 depicts the experimental setup needed to recreate this image. The base, PVC tray, shut-off valve, leveling screws all came preassembled. Our setup was missing an aluminum frame and required that we arrange the acrylic pane and glass pane. To create the desired flow, we needed to inject a less viscous solution into a more viscous solution. We selected honey and water with dye as these solutions. Approximately two tablespoons of honey was placed onto the acrylic surface and smoothed to create a large circle. A few drops of green and blue food dye were diluted with roughly 100 mL of water. This solution was placed in a syringe and then injected into the honey solution. After injecting this solution, we noticed that it was not creating the flow that we expected. We could see a light fingering with the dye, but it was very subtle. We noticed that our setup was incorrect, as both the acrylic pane and glass panes had holes, which prevented the Hele-Shaw cell from functioning correctly. As we were troubleshooting, we lifted the glass pane, which produced the pattern shown in the final image.



Figure 1. Experimental set up (Flowvis.org)

3. Photographic and Visualization Techniques

To illuminate the flow, a bike light was placed underneath the Hele-Shaw cell. This positioning provided backlighting that allowed the solution to be more visible against the light background without glare from the overhead lights. The overhead lights were turned off, however some ambient daylight from nearby windows was present as the photo was taken in the early afternoon. The camera flash was not used to avoid potential glare or reflection from the glass surface. A relatively fast shutter speed of 1/250 was selected to freeze the flow motion and prevent blur. An aperture of f/8 provided a sufficient depth of field, while an ISO of 1600 allowed for enough exposure given the low light conditions. An overview of the full camera settings used is shown in Table 1.

Table 1. Overview of image characteristics

Camera Setting	Value
Camera model	Canon EOS Rebel T3I DSLR Camera
Lens model	Canon EF-S 18-55mm f/3.5-5.6 IS II Macro Autofocus APS-C Lens
Lens focal length	55 mm
Distance from object to lens	38 cm
Size of the field of view	15 cm x 10 cm
Image size	Original image: 5184 x 3456 pixels Final image: 3530 x 3369 pixels
Aperture	f/8
Shutter speed	1/250 s
ISO	1600

To enhance the image, post processing was completed in darktable, an open-source photo editor. The original image (Figure 2) captured the Saffman-Taylor instability well but was very dark. To lighten the image, I increased the contrast between the light background and the darker flow and adjusted the exposure. I also cropped the image to better focus the flow and increased the saturation to bring out the colors.



Figure 2. Original raw image

4. Fluid Dynamics

The Saffman-Taylor instability occurs when a less viscous fluid interacts with a more viscous fluid in a confined space such as a Hele-Shaw cell (Saffman & Taylor, 1958). This displacement results in a finger-like pattern at the interface between the two fluids. Surface tension ultimately stabilizes this growth, preventing unlimited finger thinning and setting finger spacing.

In this experiment, lifting the glass pane created a reverse pressure gradient, pulling air in from the edges, and creating a lifting Hele-Shaw cell flow (Coutinho & Miranda, 2023). Air, with a viscosity of 1.8×10^{-5} Pas at room temperature (25°C) is far less viscous than honey, which has an average viscosity of 0.421 to 23.405 Pas at the same temperature, with common Coloradan varietals ranging from 3.367 to 12.28 Pas (Yanniotis et al., 2006). This substantial contrast drove the instability, creating the finger-like pattern visible in the final image.

To characterize the flow, the capillary number Ca provides a dimensionless measure of viscous to surface tension forces:

$$Ca = \frac{12(\eta_1 + \eta_2)|b(0)|}{\gamma} \quad (1)$$

Where η_1 is the viscosity of the honey (7.8 Pas), η_2 is the viscosity of air (1.8×10^{-5} Pas), b is the estimated lifting speed (0.00625 m/s), and γ is the surface tension of the honey (0.06 N/m).

$$Ca = \frac{12(7.8 + 1.8 \times 10^{-5})|0.00625|}{0.06} = 9.75$$

In their review of lifting Hele-Shaw cell flows, Coutinho & Miranda (2023) indicate that a typical Ca value for these flows ranges from 10^{-3} to 10, with larger values representing more dramatic and rapid finger-like patterns.

5. Conclusion

The final image successfully captures the flow phenomenon with a compelling and somewhat abstract aesthetic. I appreciate how it asks the viewer to question exactly what they are looking at. I believe that the yellow from the honey contrasts well against the light background, and the subtle spots of blue draw the viewer in. Even though it does not show the Saffman-Taylor instability in the way I originally intended, it shows it in a unique way. If I were to repeat this experiment, I would spend more time investigating possible ways to adjust the Hele-Shaw cell to get a more traditional image. Methods such as using a syringe with a wider nozzle or plugging the extra hole could produce the more classic fingering pattern. I believe it would be interesting to compare this more traditional view to the version I captured.

6. References

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