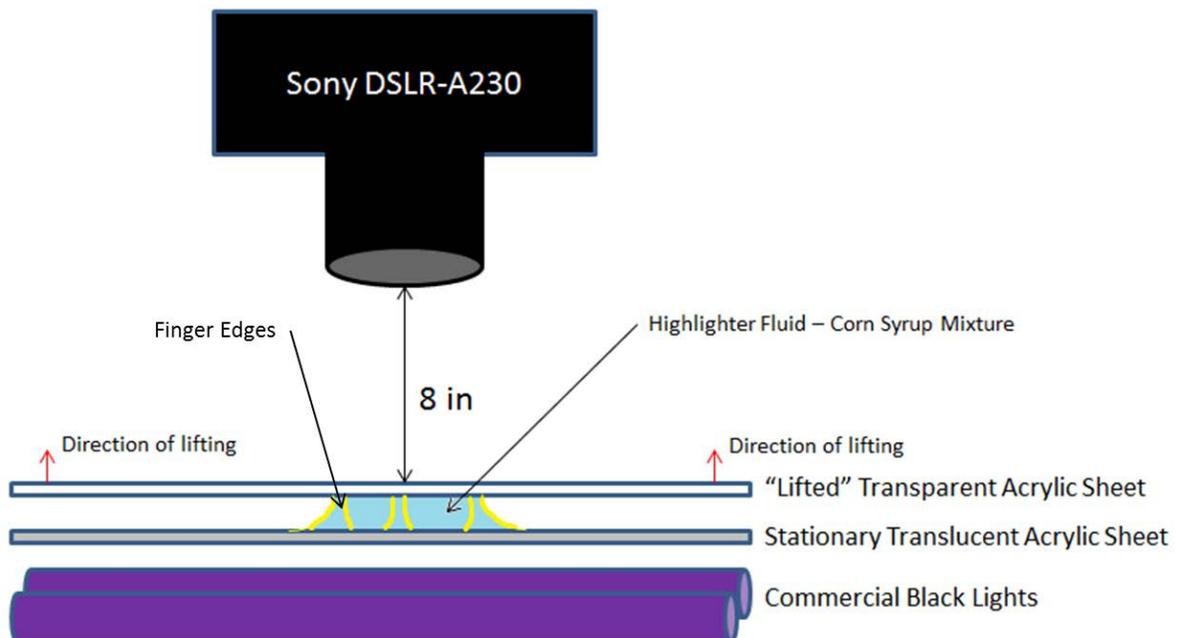


Team Project #2: Viscous Fingering

This image was created to fulfill the requirements of the second team project in an undergraduate flow visualization class at the University of Colorado. The raw image was created in the flow visualization room in the basement of the ITLL with assistance from Aaron Coady and Anthony Johnson from Group Alpha, as well as from Alyssa Frank. The intent of the image was to capture and effectively present the phenomenon of viscous fingering.

The experimental set up consisted of two ¼ inch thick pieces of acrylic – one of which was transparent while the other was a translucent white. The translucent sheet was on top of two commercial black lights in a dark room. About four fluid ounces of Karo brand corn syrup was first puddled on top of the translucent sheet, and approximately one teaspoon of highlighter fluid was dropped on top of the corn syrup. The transparent acrylic was then pressed against the translucent sheet, flattening the suspension of fluids. The transparent sheet was then lifted slowly while air fingered into the highlighter fluid – corn syrup mixture. When the plates were approximately ¼ of an inch apart, as depicted below, the Sony DSLR-A230 was used to capture the raw image of the flow.

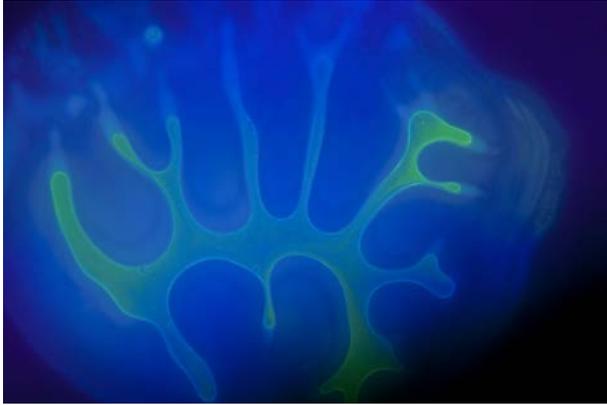


When the plates were pressed together the highlighter fluid and corn syrup mixed slightly but the highlighter fluid remained concentrated at the interface between the air and corn syrup at the edge of the “puddle”. The viscosity of the corn syrup allowed it to adhere to the transparent acrylic sheet when it was lifted. The viscous forces at this interface attempted to maintain the same contact as when the sheets were pressed together, but as the plates were pulled apart these forces then had to compete with the forces induced by the atmosphere and gravity. To satisfy conservation of mass, the pressure of the atmosphere pushed air into the unstable sites on the surface of the corn syrup which then resulted in “viscous fingers”. These fingers are seen as the air cavities in the image. With the plates now separated, the corn syrup adhering to the top plate is pulled downward, where it forms a similar but thicker layer to satisfy conservation of mass, as can be seen in the slightly out of focus purple background to the flow.^[1]

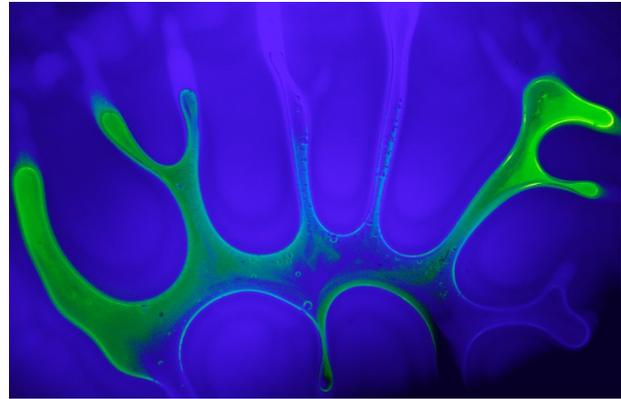
The flow was visualized through the use of highlighter fluid. The highlighter fluid was extracted from a sharpie highlighter by removing the stick within the marker and allowing it to sit in 1 cup of water for a few minutes. When the water-highlighter mixture appeared to be homogenous it was ready to be used to create the image. Black-lights beneath the translucent white acrylic created a diffusely lit surface for creating the flow, in what was otherwise a dark room. The glowing effect of the highlighter fluid mixture placed on top of the corn syrup allowed for effective imaging of the flow.

The raw image was taken with a Sony DSLR-A230 camera. The focal length of the lens during the capture was recorded as 55.0 millimeters. An exposure time of 1/40 second with f/5.6 and an ISO of 400 were used to capture the image. The image was originally 3872 by 2592 pixels and covered a 4 inch by 2.5 inch field of view. The lens was approximately 8 inches from the surface of the ¼ inch thick transparent acrylic top sheet at the time of the exposure.

Edits were made to the raw image in Photoshop CS5.1 to produce the final image. The image was first cropped to 2734 by 1773 pixels to draw focus to the flow and remove some of the darker part of the photo. The color curves of the photo were then adjusted to intensify the blacks and enhance the greens and yellows from the highlighter fluid. The red and green were increased while the blue was decreased in the channel mixer to draw further attention to the brighter colors in the photo. Increasing the vibrance of the photo also helped with this effect. Finally, to draw attention to the depth of field beyond the fluid clinging to the top layer of acrylic, the cyan, green and yellow were enhanced using color balance.



Raw "Before" Image



Post-Photoshop "Final" Image

This image reveals the effects of viscous fingering as a result of atmospheric pressure at a corn syrup – air interface. The crisp edges of the corn syrup, accentuated by the highlighter fluid, create a clear display of these effects. The final product did fulfill the intent of the project, but still had room for improvement. From an artistic standpoint, although the Photoshop manipulations enhanced the edges of the interface, there are regions that became grainy as a result of these alterations. This was not desired but was deemed an acceptable loss to the quality for higher edge resolution. Also, the dark corner to the image lost a significant part of the flow which may have added value to the image.

References:

- ^[1] Saffman, P. G., & Taylor, G. (1958). The penetration of a fluid into a porous medium or hele-shaw cell containing a more viscous liquid. *Proc. R. Scot. Lond. A*, 245(1242), 312-329. doi: 10.1098/rspa.1958.0085