Get Wet

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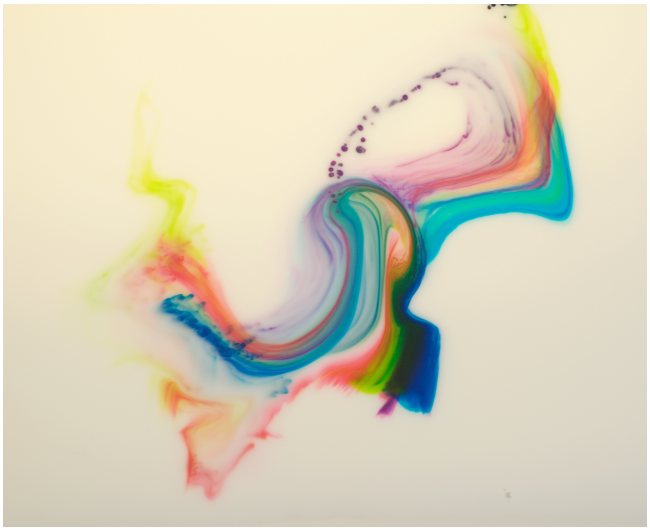

The purpose of this project is to get sense of how to take aesthetically pleasing photos and how to turn fluid flows into art. The image captured for this project was made to illustrate the Marangoni effect using milk, food coloring, and soap.

This image is easy to recreate and entertaining to do as well. All it requires is food coloring, soap, milk, and a Q-tip. The food coloring is used to visualize this flow movement, the soap is the acting agent that causes a surface tension gradient, and the milk is the fluid that reacts with the soap. To recreate the image shown, start with a plate with a thin layer of milk. The plate should be large enough to allow for the fluid to flow without boundaries interfering with the movements (about a 6”x6” area of milk will work. Then place a drop of each food coloring color (red, yellow, blue, and purple for this image) in the middle. Next, put a drop or two of dish soap on the end of a Q-tip and insert it into the milk. For the image shown, the Q-tip was place about half an inch above and the left of the food coloring. For this particular image, Figure 1 shows the placement of all of the materials relative to each other.

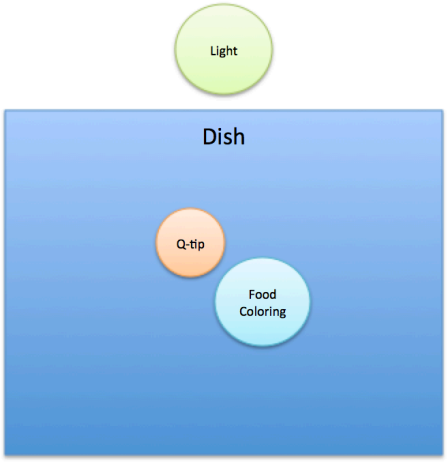

Figure 1: Placement of Q-tip, Food Coloring, and Light

This fluid flow, known as the Marangani effect, is induced by a surface tension gradient in the liquid. Regions with high surface tension will pull more on the fluid than regions with low surface tension. This causes a flow to move away from areas of low surface tension. When the Q-tip covered in soap is inserted in the milk it lowers the surface tension around where the Q-tip is inserted and the milk will begin to flow away from that point. The figure to the right shows the forces acting on the fluid caused by the soap. Because the Q-tip is round the forces from it will decrease the farther away from it the fluid is. This causes the rounding pattern seen in the figure.

The Reynolds number can be calculated using the following equation:

$$Re = \frac{\rho V R_H}{\mu}$$

ρ is the density of the fluid, V is the velocity, μ is the dynamic viscosity, and R_H is the hydraulic radius and can be calculated using:

$$R_H = \frac{A}{P}$$

The density of milk is 1.003 kg/m^3, V is 1 m/s, R_H is calculated to be .0045 m, using dimensions from the plate, and μ is .003 Pa*s. This gives a final Reynolds number of 1520. This also gives some insight as to why the fluid begins to curl around.

All of the items needed to perform this experiment can be bought at any grocery store. The food coloring can be interchanged depending on what colors are wanted in the image. The milk used was 2%. Changing the percentage of milk impacts the surface tension gradient because of the different fat contents. The lighting used was natural lighting let in from windows and a lamp placed nearby to brighten the image. The lamp was placed right next to the plate without actually being in the photo and used a 15-watt compact florescent light bulb.

The camera used was a digital Nikon D5000 with a macro lens attached. The lens has a 60 mm focal length. The aperture used was f/3.5, the shutter speed was 1/80 of a second, and the ISO was set to 250. When the Q-tip is removed, the flow does not noticeably diffuse, so a low shutter speed could be used. The camera was

held about a foot and a half above the experiment to take the image. The raw image had the pixel dimensions of 4288x2848, while the final image had dimensions of 3504x2848. In post-processing, the main change was the contrast of the colors. The background was brightened as much as possible before over exposure using the curves tool. The colors were also slightly adjusted in the curves tool to give them more of a pop (dark ones darkened and bright ones brightened). And finally, cropping was used on the image to get rid of some extra white space on the sides. The photo before using post-processing software is shown below.

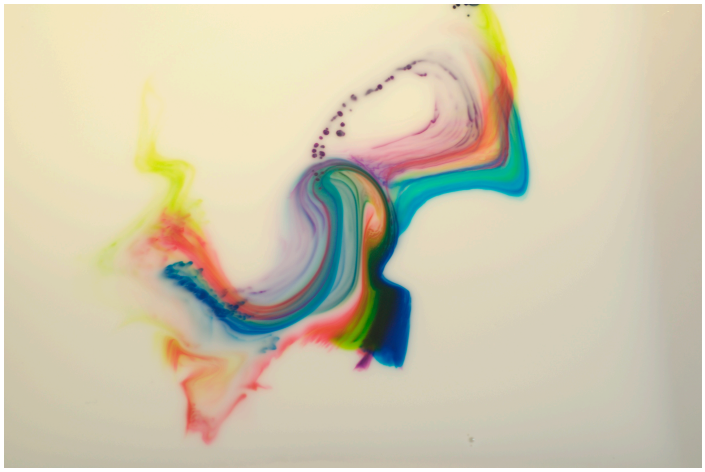

Figure 2: Original Image

This image illustrates a basic example of the Marangoni effect. Personally I like the way the image turned out. The color layering and the slight change in patterns of color are very appealing to me. The one thing that image could use is a better light source. The nearby lamp was not the best at lighting up the whole image and caused inconsistent lighting in the photo that was hard to change in post editing. For the future, trying varieties of food coloring drop locations and Q-tip insertion locations could expand upon this effect. It would be interesting to see the different patterns created by just moving these things relative to each other. Also, the type of milk or temperature of milk could be changed to see the effect that has on the fluid flow.

References

Tadmor, Rafael. “Marangoni Flow Revisited.” *Journal of Colloid and Interface Science* 332.2 (2009): 451–454. Web. 30 Sept. 2014.