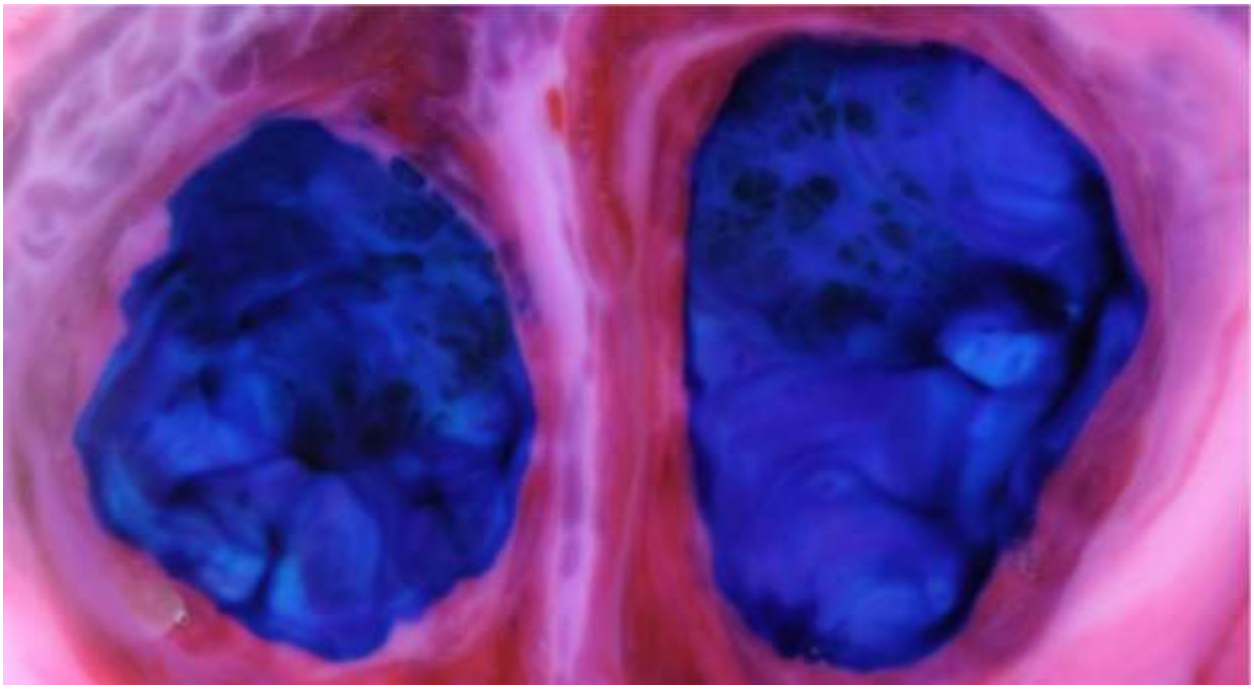
Lungs



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Flow Visualization

Team Image #2

March, 2011

The goal of this flow visualization was to capture the colorful fluid motion of food dye on top of milk created by the addition of a soap surfactant. This idea originated from a demonstration seen on the F-Yeah Fluid Dynamics website (HouseholdHacker, 2011). I created an image from a similar setup for my Get Wet assignment but sought to improve upon this idea for the Team Image #2. The flow is driven by a surface tension instability and is further disrupted by a knife which is dragged through the flow.

The schematic in Figure 1 shows the setup of the fluid visualization. This was performed in a circular Pyrex dish approximately 5 inches in diameter and one and half inches deep. Milk was poured into the dish to a depth of a quarter on an inch. Four drops of both red and blue food coloring were added on top of the milk and allowed to settle for several seconds. Next, two drops of soap were added to initiate fluid motion. After about 20 seconds I dragged the tip of knife through the flow and then added a drop of blue dye in each of the vortices.

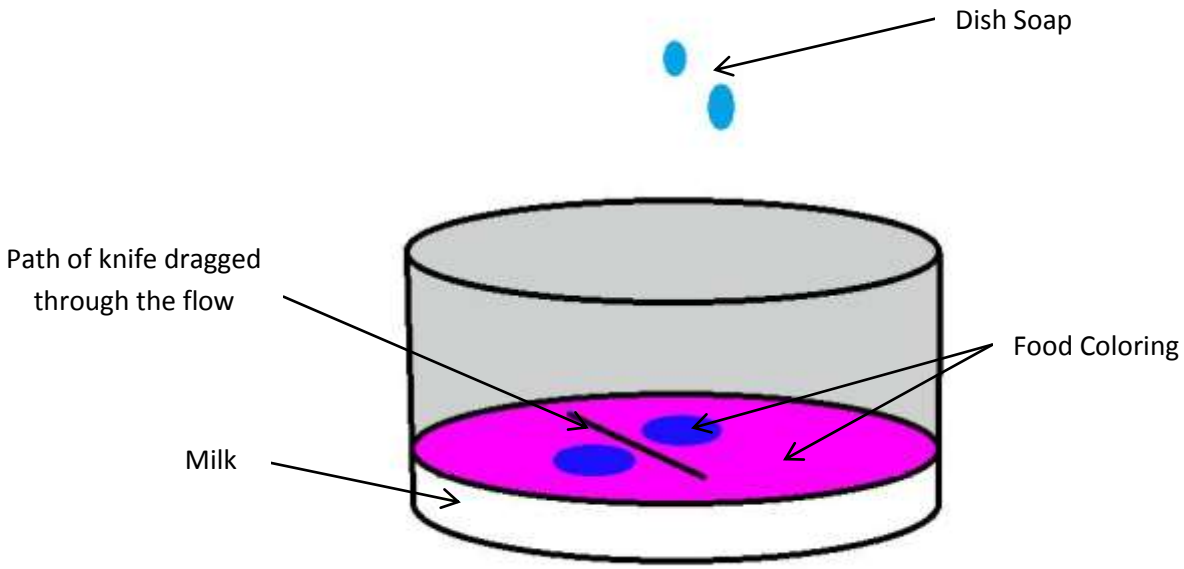

Figure 1: Setup

The photo below shows the progression of the surfactant driven flow after the dish soap was added but before drops of blue dye were added.

Figure 2: Food coloring on top of milk

The fluid continued to churn for about 40 seconds or more. During this time the food coloring revealed several different shapes and forms. The final image shown below was taken about 30 seconds after the addition of soap.

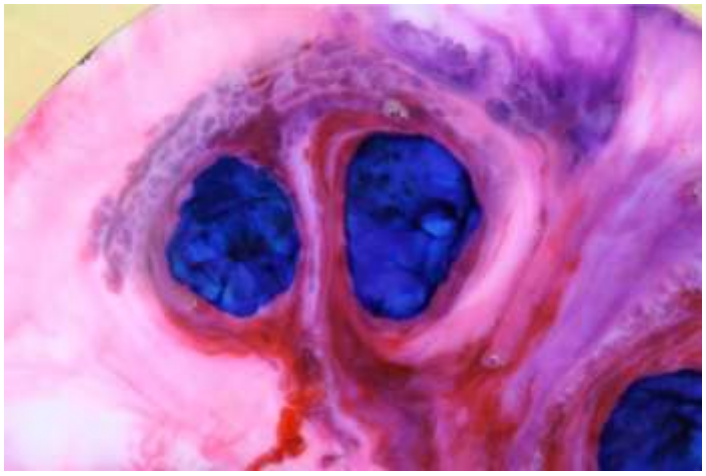

Figure 3: Final image un-cropped

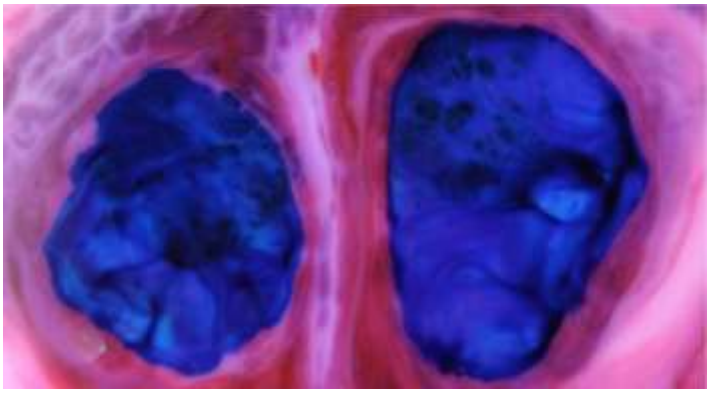

Figure 4: Final image cropped

So what's going on? The soap is acting as a surfactant which is any substance that lowers the surface tension of a liquid. Surface tension is a fluid property that holds a fluid together in the presence of an outside force. This phenomenon is what keeps water from overflowing from a glass when the fluid height is above the rim. When a surfactant is added to the mixture the surface tension of the milk and food coloring is reduced as cohesive bonds are broken (Spangler, 2011). This causes the fluid to move erratically in an attempt to balance the surface tension. This initial motion causes further mixing of the soap, milk, and food coloring which creates more and more motion. The food coloring allows us to see what is happening as the fluids mix turbulently. The soap also breaks down fats in the milk as it mixes adding more randomness to the flow. Eventually, the fluid reaches equilibrium after about 40 sec. After about 20 seconds, while the fluid is still moving slowly, I dragged the tip of knife through the flow and added two drops of blue food coloring in the vortex swirls.

The two tables below show the materials used and fluid properties (www.engineeringtoolbox.com). The maximum speed of the fluids was assumed to be 5 in. per second.

Table 1: Materials

Materials
King Scoopers 2% milk
Pyrex Dish 5in. Diameter
Kroger Neon Food Coloring
Seventh Generation Natural Dish Soap

Table 2: Fluid Properties

Material	Density (kg/m$^{3)}$	Kinematic Viscosity (m^2/s)	Surface Tension (N/m)	Re #
Milk	1030	1.12E-06	7.34E-02	5357.14
Food Coloring	1000	1.12E-06	7.34E-02	5357.14
Dish Soap	960	1.19E-03	6.33E-02	5.04

All photos shown were taken on March 26th, 2011 in sunlight from an overcast sky. The following photographic settings were used on a Canon EOS Digital Rebel XS (Lens EF-S 18-55 mm 1:3.5-5.6 IS):

- No flash
- Shutter Priority
- Distance from lens to object: 45 mm
- Focal length: 55 mm
- Original image dimensions: 3888 X 2592 pixels
- Cropped image dimensions: 2053 X 1119 pixels
- Exposure: 1/100 sec.
- Aperture: f/7.1
- ISO: 200
- White balance: Auto

The image was cropped but no other adjustments were made to the original image.

The image reveals the randomness associated with turbulent flow and powerful forces that a surface tension instability can impose on a fluid. The physics of this flow are well demonstrated, however they provide only qualitative evidence of certain instances of fluid motion. I really like the organic feel of the image and the cell-like structures that can be seen in the blue pools. I wish I could have sharpened the focus a bit more and I think a circular copping may have looked better.

References

HouseholdHacker: *Scientific Tuesdays (2011),* http://fuckyeahfluiddynamics.tumblr.com/post/2531217529/in-this-video-the-householdhacker-heads-to-the

Steve Spangler Science: *Color Changing Milk* (2011), http://www,stevespanglerscience.com/experiment/00000066