

Temperature Effects on Surface Tension

Objective:

- To investigate the effects of temperature on the surface tension of a thin liquid.

Science Standards:

- Science as Inquiry
 Physical Science
 - position and motion of objects
 - properties of objects and materials
 Unifying Concepts and Processes
 Change, Constancy, & Measurement

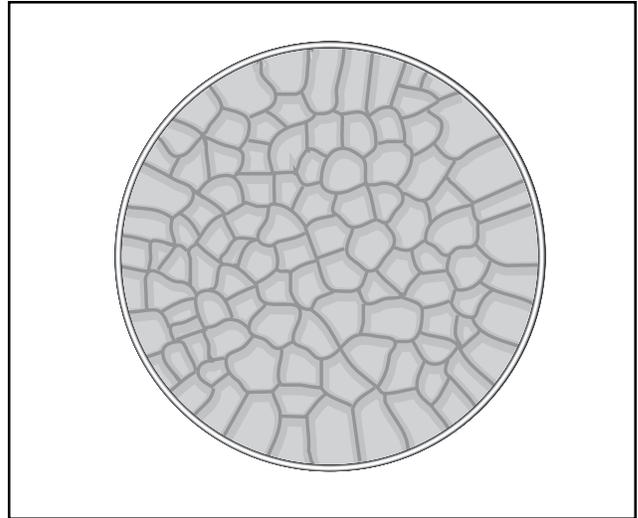
Science Process Skills:

- Observing
 Communicating
 Measuring
 Collecting Data
 Inferring
 Predicting
 Interpreting Data
 Controlling Variables
 Investigating

Activity Management:

This experiment can be done as a student activity or a classroom demonstration for small groups of students. If done as a demonstration, it can be set up while students are conducting the Surface Tension-Driven Flows activity. Rotate small groups through the demonstration.

Be sure to use Pyrex® petri dishes for the demonstration. Also provide eye protection for yourself and the students. It is important that the heating surface of the hot plate be



A thin pool of liquid heated from below exhibits polygonal cell structure due to surface tension-driven flows.

MATERIALS AND TOOLS	<p>Cooking oil Powdered cinnamon Two Pyrex® petri dishes and covers Laboratory hot plate Heat-resistant gloves, hotpad, or tongs Ice cubes Eye protection</p>
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level. Otherwise, it will be necessary to add more oil to cover the bottom of the petri dish. A thin layer of oil is essential to the success of the experiment. Thin layers, on the order of 1 or 2 millimeter, do not exhibit significant convection currents as do layers that are much thicker. There simply is not enough room for convection currents to develop in thin layers. Heat is conducted through the thin layer to the surface very quickly. Since the lower and upper parts of



the liquid are at nearly the same temperature, no convection currents develop.

The demonstration is conducted with two petri dishes. Use the lids of both dishes for holding the oil and spice. To see the surface tension effects, sprinkle the cinnamon from a height of 20 or 30 centimeters to help it spread out evenly on the surface of the oil.

Place the first dish on the hot plate and observe that patterns are produced by the cinnamon. Before placing the second dish lid on the hot plate, invert and insert the bottom of the second dish into the lid. This will effectively place all the oil in contact with glass so there is not any exposed oil surface. The reason for the two different runs of the demonstration is to verify whether or not buoyancy-driven convection currents are involved in moving the cinnamon markers. If these currents are at work, the cinnamon will spread out and swirl through the oil. In other words, the second part of the demonstration is a control for the first part.

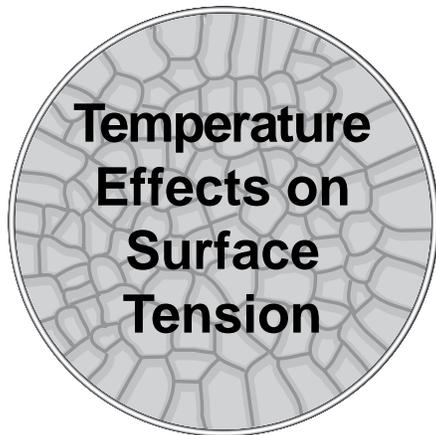
Assessment:

Conduct a class discussion on why it is important for microgravity scientists to understand about surface tension. Collect the student pages.

Extensions:

1. Experiment with other fluid and marker combinations. Several microgravity experiments in space have used 10 centistoke silicone oil (dimethylpolysiloxane) with powdered aluminum as a marker. Both chemicals are available from chemical supply catalogs. The demonstration works best if the aluminum is more flaky than powder. Aluminum flakes will provide reflective surfaces that intensify the optical effect. You can make your own aluminum flakes by obtaining flat enamel hobby paint and allowing the aluminum flakes to settle to the bottom of the bottle. Pour off the fluid and wash the sediment several times with nail polish remover and let dry.
2. Videotape the convective flow patterns and play them back at different speeds to see more details on how surface tension-driven flows develop.
3. Look for patterns in nature, such as mud cracks, that are similar to the patterns seen in this activity. Are nature's patterns produced in the same way or by some different mechanism?





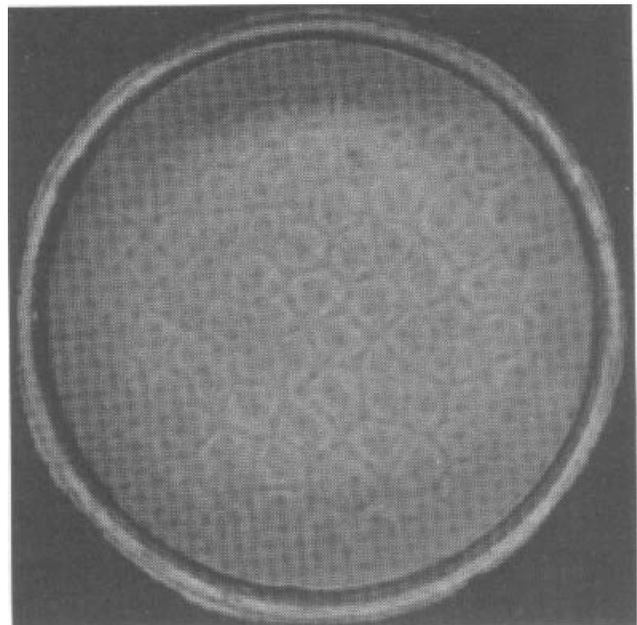
Around the turn of this century, physicist Henri Benard discovered that liquid in thin pools heated from below quickly forms flow patterns consisting of polygonal cells. He made this discovery by placing tiny markers in the fluid that showed how the fluid moved. The cells resembled those that form due to convection currents when a pot of soup is heated. The interesting thing about Benard's discovery is that buoyancy-driven convection currents were not responsible for the flow that was produced.

When a thick pool of liquid is heated from below, liquid at the bottom expands and becomes less dense. Because of buoyancy, the less dense liquid rises to the top of the pool where it spreads out. Cooler surrounding liquid moves in to take the place of the warmer fluid that rose to the top. This liquid heats up, becomes less dense, and also rises to the top to create a cycle that continues as long as heat is applied. This cycling is called a buoyancy-driven convection current.

The problem with studying fluid flows in a heating pot of soup is that convection currents appear to be the only force at work. Actually, surface tension flows are also present but, because they are of lower intensity, they are masked by the more violent buoyancy-driven convection currents. By creating a very thin liquid pool (about 1 mm or thinner), Bénard was able to

eliminate buoyancy-driven convection. In very thin liquids there just is not enough vertical distance for significant buoyancy-driven convection currents to get started. The fluid flow Benard observed was produced by changes in surface tension.

In the cooking oil experiment, you observed two petri dishes with a thin layer of oil and powdered cinnamon markers. The uncovered dish, when heated from below, began forming circular cells that eventually grew into each other to produce polygonal cells. Heat from hot spots in the hot plate was quickly conducted to the surface of the oil. The increase in temperature of the oil reduced the surface tension in those locations. This reduction was apparent because the oil flowed from the center of the hot spots in all directions to the outside. Compare this action to what happened when a drop of liquid soap was touched to the surface of a tray of water in the previous activity. In the second petri dish, a layer of glass was placed over the thin oil layer so the oil did not have an exposed surface. In this manner, surface tension effects were eliminated. No fluid flows were observed, meaning that



Polygonal cells produced in a thin pool of liquid heated from below.

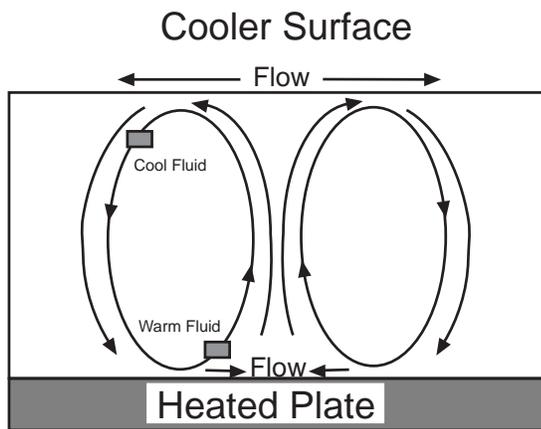


buoyancy-driven convection was not at work. This demonstration served as a scientific control for the first experiment.

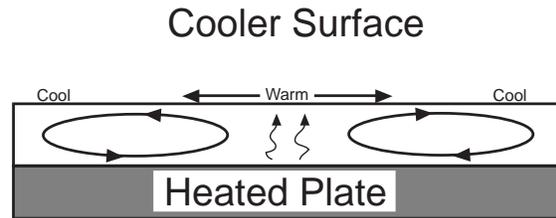
In fluid physics experiments aboard the Space Shuttle and the International Space Station, buoyancy is practically eliminated because of microgravity. Surface tension, however, becomes an important force because it is not a gravity

dependent phenomenon. In crystal growing and other fluid physics experiments, surface tension-driven flows can affect the outcome. For this reason, scientists are trying to understand the mechanics of surface tension-driven flows in microgravity.

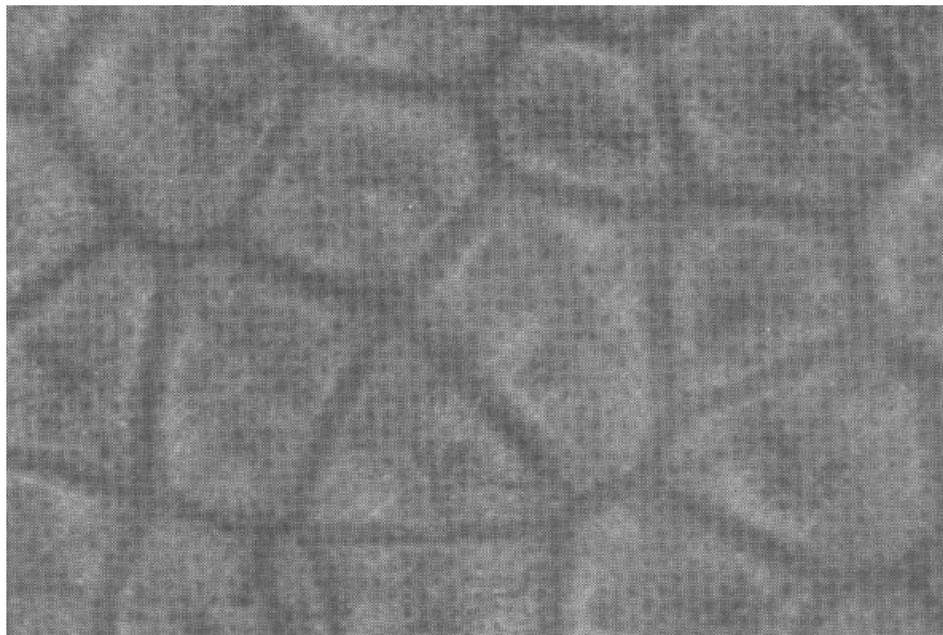
In these two diagrams, the difference between buoyancy-driven convection currents (left) and surface tension-driven convection currents (right) is shown. Flow in the left diagram is produced by changes in fluid density brought about by heating the bottom. Flow in the right diagram is brought about by reducing surface tension above a heated plate.



Thick Liquid Pool



Thin Liquid Pool

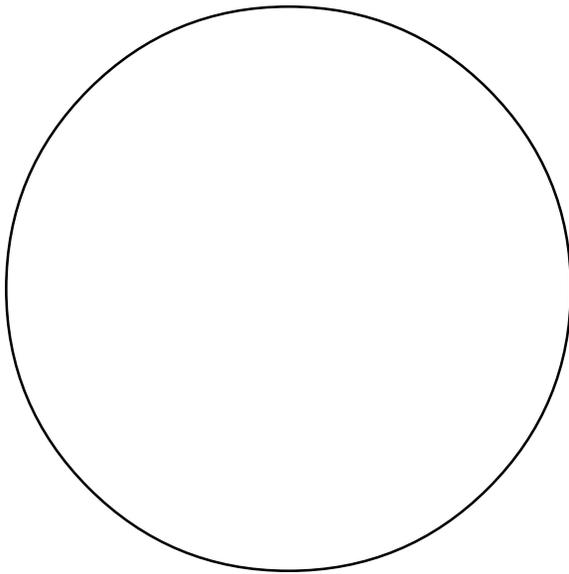


Magnified view of the polygonal cells that are produced by surface tension-driven convection.

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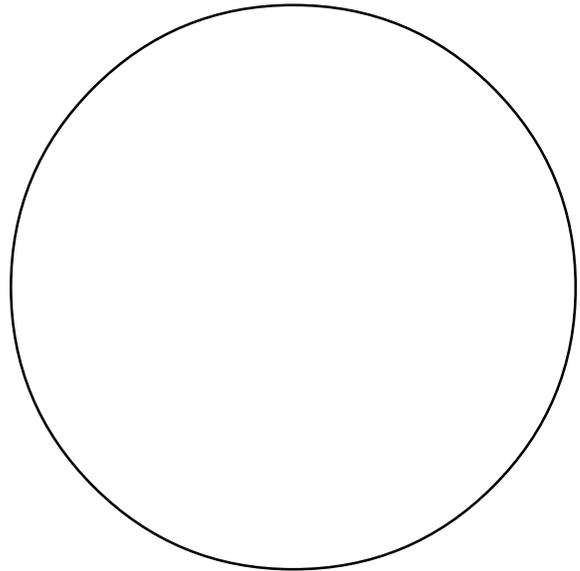
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1. Sketch the fluid flow patterns that appeared in the thin pool of cooking oil when heat was applied to the bottom of the first petri dish. Indicate with arrows which direction(s) the fluid flowed.



What effect did an increase in temperature have on the surface tension of the oil?

2. Sketch the fluid flow patterns that appeared when heat was applied to the bottom of the second petri dish. Indicate with arrows the direction(s) of any fluid flows observed.



Explain what you observed.

Why?

What effect on surface tension do you predict lowering the temperature of the oil would have? How could this be observed?

