**The Mysteries of Milk**

**Introduction**

We will start with a class discussion of milk. Who regularly drinks milk?

1. What is milk? How is it similar/dissimilar to water?
2. What is the difference between different types of milk? (whole, 2%, 1%, skim, cream, etc)
3. What products are made from milk? Do you know how they are made? (We will make “cheese” and butter today)

**Activity 1: Exploring surface tension with milk**

**Materials**

* Milk: skim, whole
* Water
* 6 Plates
* Food coloring (a few colors per group, can share)
* Pepper
* 4 small cups (for holding the liquids [and soap] before the tests and to make pouring easier)
* A bunch of toothpicks and q-tips (at least 6 of each)
* Another cup to hold some soap
* Masking tape and pen (to label the different tests)

**Procedure**

1. Lay out butcher paper on the table.
2. Gather up all the materials. Fill up two small cups with each type of milk and one cup with water. Make sure you know which cup has which liquid.
3. Set out the 6 plates on the table and label the butcher paper with numbers 1-6. (1 = whole/dye, 2 = skim/dye, 3 = water/dye, 4 = whole/pepper, 5 = skim/pepper, 6 = water/pepper.)
4. Pour each liquid onto its respective plate (you don’t need that much). Don’t pour any pepper or food dye onto the plates just yet. Note: We will first be varying the type of liquid. Therefore, we want to keep consistent other variables, such as dye placement, liquid amount, soap amount, etc.
5. Wait a bit to let the liquids settle.
6. Drop a few drops of food coloring in the center of the whole milk plate (plate 1).
7. Discuss: What happened when you dropped in the food coloring? What will happen when you poke the center with a clean toothpick?
8. Poke the center with a clean toothpick. (Nothing spectacular should happen.)
9. Discuss: What will happen if you use a soapy toothpick instead?
10. Dip the end of a toothpick in soap (you can put some in another small cup). Poke the center of the liquid again. Record on worksheet.
11. Dip a soap-covered q-tip into the same liquid and hold it there. Record your observations. Use the other end of the q-tip to touch another area with soap. Does the magic effect keep happening? Write down on the worksheet how long the effect lasts, how strong it seems, and any other observations. You can also dump the liquid on the plate and start fresh again if you’d like
12. Repeat with skim milk and water (plates 2-3).
13. Try a similar experiment with pepper instead of the food coloring on both water and milk (plates 4-6). Record your observations.
14. Try discussing some of the questions on the back.
15. Keep exploring! (depending on how much supplies are left)

**Questions to think about**

* Does it happen with water too? *(It should, but it’s not spectacular because the food coloring sinks to the bottom and this is a surface effect.)*
* What does the food coloring have to do with it? *(The food coloring, which is less dense than the milk, floats on the surface. It lets us visualize the effect.)*
* Does the effect happen with pepper instead of food coloring? *(Yes, which leads us to think that it’s not the food coloring causing the magic. The food coloring and pepper simply act as indicators of the milk movement.)*
* How does the effect differ between each type of milk? *(I found that it seemed to be strongest and last the longest with the fattier milk.)*
* Why does it differ with each type of milk? *(This is a great question. In science, the answers are not always clear. What do you think?)*
* Why does the effect happen in the first place? *Surface tension!*
* Why does it stop eventually? *(An equilibrium is reached in the lowered surface tension.)*

**Activity 2: Exploring surface tension**

**Materials**

* Pennies
* Water
* Pipettes
* Dish soap
* 1 Cup

Procedure:

1. Idea: Milk is mostly water (with some fat and calcium--this extra stuff makes the food coloring, which is pretty much just water, float!) and water has high surface tension. We will explore this surface tension.
2. Fill your cup with water. Use a pipette to add water to a penny, drop by drop (each student will do this). How many drops do you think you’ll be able to add to the penny? Record on your sheet. See how high you can make the dome of water without it breaking. Count the number of drops as you go.
3. Question: Why does this happen? Water molecules want to hold on to each other very tightly. They do not want to separate. Inside the water, each water molecule is pulled in all directions by the surrounding molecules. However, for water on the surface, there is no water above it to pull upwards. Thus, water on the surface is pulled inwards tightly. This property is called***surface tension***. If the water molecules didn’t care to be next to each other, your water dome would just be a flat puddle. (Note: this is why raindrops are roundish and why the pepper floats on the surface (it should sink after soap is added though!)) This stickiness property of water can be seen very easily. **Drop a bit of water onto the table and gently touch your finger to the surface. Watch as the water grabs onto your finger.**
4. What do you think will happen when you add soap? Will you be able to get more or less water on the penny? Make a prediction on your sheet.
5. Add some soap to your cup of water and try again. What happened? Were you able to add more drops or less? Why? (Answer: you shouldn’t have been able to add as many drops using soapy water. The soap lowered the surface tension, so the water molecules aren’t holding on to each other as tightly)
6. To understand what happens when you suddenly decrease surface tension, we can do a little demonstration. Stand up and have your group hold hands. Slowly move away from each other, “increasing the tension”. Carefully let go and see what happens. You should feel a backwards force. You are like the water molecules on the milk’s surface. Similar to the way you are launched backwards when you let go of each other, the milk shoots outwards when the surface tension is broken by the soap.

**Activity 3: Proteins in milk**

**Idea:** Scientific explanation: Milk contains a protein called casein, which is negatively charged. Vinegar contains positively charged hydrogen ions. The negative and positive charges attract to one another and form these clumps. The lumps are called curds and the remaining liquid is whey. (Cheese makers don’t use vinegar to make cheese though! They use an enzyme called rennet which has positive ions)

Easier explanation that is also true: Milk contains proteins. A protein’s shape is very important, as it determines the behavior and function of the protein. Different processes cause proteins to unfold (change shape) such as heat or a change in acidity. We will add vinegar to the milk, thereby changing the acidity and affecting the shape of the protein in the milk, making it unfold (picture on worksheet!).

**Materials**

* ½ cup warm milk
* 2 teaspoons vinegar
* Stir stick
* 2 cups
* Cheesecloth
* Rubber band

**Procedure:**

1. Add ½ cup warm milk to a cup.
2. Add 2 teaspoons of vinegar to the warm milk and stir or slosh around, then allow the milk to sit for 5 minutes. The casein will precipitate into heavy white curds.
3. Once you start waiting, have 1 person start shaking your cream for activity 4 depending on the time (we probably need a total of 20 minutes to shake the cream and get to try the butter).
4. While waiting for the protein in the milk to turn into curds, cut out a piece (2-3 layers) of cheesecloth large enough to cover the top and 2 inches down the sides of a new cup. Using a rubber band, fasten the cheesecloth over the top of the cup. (if we somehow run out, you can just use paper towels to separate the solid from the liquid, but do it over the sink!)
5. Pour the curdled milk into the cup, collecting the curds (casein) in the cheesecloth, allowing the vinegar and whey to drain off into the bottom of the cup.
6. Gather up the cheesecloth and twist to dry.
7. Explore the “cheese” (don’t eat it!). How is it different than the milk it started as? What did the vinegar do?

**Activity 4: Making butter!**

We can also use the proteins in milk (well, cream) to make butter! By shaking the cream, the fat molecules get shaken out of position and they stick together.

**Materials**

* Mason Jar (16 oz)
* 1 cup heavy cream

**Procedure:**

1. Pour cream into mason jar, filling it about half way. Screw the lid on tightly!
2. Shake the mason jar for 10-20 minutes. Take turns shaking so that you don’t get too tired! During this process, clean the table up and throw away the butcher paper. Everyone should wash their hands and we can put out paper towels to use as “plates”
3. After some time, you’ll have whipped cream. Keep shaking until you hear that a lump has formed inside, and then shake for an additional 30-60 second after that.
4. Pour out the remaining liquid (its buttermilk now) and try your butter on a cracker. (Note, if you were going to do this at home and store it, you’d want to rinse your butter 3 times. Since we won’t be saving it, we will skip this step)