**Q: What causes surface tension?**

*By Bill Robertson*

**A:** Before I answer that question, it would help if you try a few things that you might or might not have tried before. First, get an eyedropper, a penny, and some water. Using the eyedropper, start dropping individual drops of water onto the penny. How many drops do you think the penny will hold before the water falls off the side of the penny? If you’ve never done this before, prepare to be just a bit surprised at how many drops of water you can get onto a penny. Next, fill a glass to the very brim with water. Then take a metal paper clip and slide it onto the top surface of the water from the side. See Figure 1, and do this slowly and gently. Keep trying until you get the paper clip to float on top of the water. Last, put “water strider photos” into an internet search engine, and notice that these little bugs can float on top of water, with little indentations in the water where the ends of their legs are.

All of the above examples show that water seems to have a “skin” on which things can float or which tends to hold water drops together. This “skin” is due to something called surface tension. To better understand surface tension, I’ll ask you to do one more thing. Get a sheet of waxed paper and an eyedropper. Fill the dropper with water and then place drops of water onto the waxed paper. Notice the almost spherical shape of the drops. Next get a sharp, dry object and poke one of the water drops slightly and then remove the sharp object. What happens? Next, just touch the sharp object to the top of one of the drops and slowly move the object along the surface of the droplet. Figure 2 shows what happens.

Last, make a small pile of flour, sugar, or salt, and poke the surface of the pile with your dry, sharp object and remove it. Try dragging the object along the surface. Do you get the same results you did with the water droplet? Nah.

**Water Whys**

Water molecules are composed of two hydrogen atoms and one oxygen atom. They look a bit like the head of a famous mouse. The hydrogen atoms in water share electrons with the oxygen atom in water. This is called a **covalent bond**. When two atoms share electrons in a covalent bond, the overall energy of the atoms is lower, so the bonded version is more stable than the separate atoms. It turns out that oxygen atoms “like” electrons more than hydrogen atoms (the technical name for this is electron affinity), so the shared electrons in the hydrogen-oxygen bond spend more time near the oxygen atom than they do the hydrogen atoms. Electrons are negatively charged, so that means the oxygen side of a water molecule tends to be negatively charged, leaving the hydrogen side of the water molecule positively charged. See Figure 3.

When you get a bunch of water molecules together, as you have in liquid water, the individual molecules have an electric attraction for one another, as shown in Figure 4. The positive sides of a water molecule are attracted to the negative sides of a different water molecule, and vice versa.

This attraction is the source of surface tension in the water. Each water molecule attracts other water molecules. So let’s look at what happens...
at the surface (the part exposed to the air) of a water drop or any other glob of water. The molecules at the surface are not attracted by the air above (at least not significantly), but they are attracted to the molecules on either side of them and to the molecules within the water. Check out Figure 5, p. 74.

So there’s an overall force “inward” on the water molecules at the surface. It’s a lot like the forces acting on the surface molecules of a rubber ball. This causes water drops to tend to form into spheres. Now, what happens when you push on the surface of an elastic rubber ball? It indents and then bounces back. Same thing with a water drop, as shown in Figure 2. This kind of thing doesn’t happen when you poke a pile of flour or sugar, because the forces between the separate flour or sugar molecules are insignificant. No surface tension exists for those substances.

What’s also shown in Figure 2 is the surface molecules of a water droplet “latching onto” a sharp object and getting pulled along with it. That doesn’t happen with rubber balls! This is because, although the surface water molecules are attracted to the other water molecules in the drop, they are also attracted (because of their polar nature) to other objects. For another example of this, place two Cheerios near each other on the surface of some water. They’ll be attracted to each other because the water in between is attracted to both the other water molecules and the Cheerios. Take a look at Figure 6, p. 74.

Before moving on, I should note that all liquids exhibit surface tension to
some degree. Mercury, for example, has a much stronger surface tension than water. That’s why mercury “beads up” in a more dramatic fashion than water does. [For the record, don’t do what I did as a child and play with mercury. Lots of fun but definitely a health hazard, even in small amounts.] Alcohol has a surface tension that’s about a third that of water, small enough that if you put a drop of rubbing alcohol on a sheet of waxed paper, it will just spread out instead of forming a sphere. Soap solution has a lower overall surface tension than water, but it’s still large enough that soap bubbles will hold together in a more-or-less spherical shape.

Okay, so let’s see if we can explain why you can float a metal paper clip on the surface of water in a glass. If you slide the paper clip gently onto the water surface, you can avoid breaking apart the bonds between the water molecules, and those bonds are strong enough to support the paper clip. It’s a lot like the paper clip is resting on a very delicate mattress. See Figure 7. Water striders are light enough that the surface tension of the water beneath them is enough to support them, also.

**Figure 5a.**

A water molecule surrounded by other water molecules is pulled in all directions.

A water molecule on the edge is pulled back toward the rest of the water.

**Figure 5b.**

A water molecule on the edge is pulled back toward the rest of the water, counteracting the force of gravity.

**Figure 6a.**

Water molecules are attracted to both the object and the rest of the water molecules.

**Figure 6b.**

The attraction of the water molecules to the Cheerios and to one another results in the Cheerios coming together.
Water Ways

Let’s see if we can disrupt the surface tension of water. Go back to your water drops on the sheet of waxed paper. Get the tiniest amount of liquid soap on the end of your sharp object and then touch the sharp object to a water drop. The water drop should collapse. That’s fun, but there are better things to do with soap and water. Put some water in a shallow pan or cup and then sprinkle pepper on top of the water. The pepper stays on top of the water (Why?). Then again put a small bit of liquid soap on your sharp object and touch it to the surface of the water. Neat, huh? Now get a fresh pan of water (rinsed of all soap). Cut a small paper “boat” out of an index card and cut a small notch in it, as shown in Figure 8. Float the boat on the surface of the water. Then touch your sharp object, with soap on the end, to the notch in the boat. Wheeeee!

Soap molecules have one end that is attracted to water molecules and another end that isn’t attracted to water molecules. So, when you add soap to water, the soap molecules tend to “get between” the water molecules. That reduces the surface tension of the water. In the case of the water droplets, a reduced surface tension causes the droplets to collapse. In the case of the pepper on the water, the surface tension of the water is reduced where it comes in contact with the soap. The rest of the water still has surface tension, so that pulls the nonsoapy water away from the soapy water. The soap boat works in much the same way (see Figure 9).

One last related item. Adding soap to water helps get dishes and clothes clean, right? There’s a reason for that. One end of the soap molecule is attracted to water molecules, and the other end is attracted to oil and grease and such. Therefore, the soap molecules connect the water with the oil or grease and thus remove those two nasty things from dishes and clothes.

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