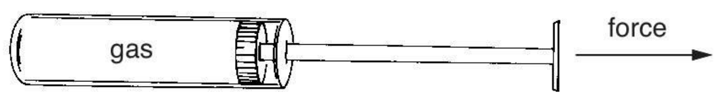
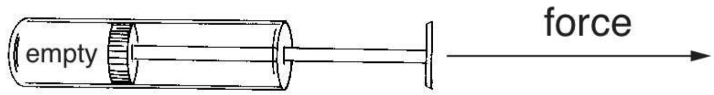
Classroom Demonstrations for
The Life of a Leaf
by Steven Vogel

(Numbers refer to pages in the book.)

No-slip Condition (Page 60):
The no-slip condition can be demonstrated reasonably well in a large, cylindrical, transparent container of water. One allows the water to rest for a few minutes and then gently introduces (through a capillary tube, catheter tube, or pipette) a bit of colorant (rhodamine, Evans blue, food color, etc.) up against the side wall. Very gentle stirring will cause the colorant to form a streak, with the glass at the original location still marked for quite a while. The whole thing is more persuasive if a very viscous liquid such as corn syrup is used, with the dye (from powder) made up in corn syrup or replaced with dark molasses.

Pressure Differences (Page 94):
An ordinary hypodermic syringe can be used to show that air inside a cylinder is not being pulled on but simply reduces the pressure difference with the external atmosphere—air inside makes it easier to pull the piston outward. One can feel that it takes a lot more force to pull it outward from a plugged cylinder with nothing inside than one initially a quarter or half filled with air, as below.

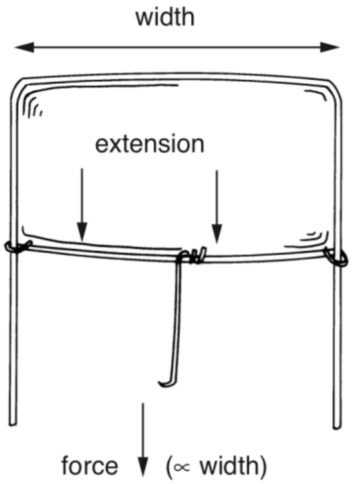




But don't use a big glass cylinder—sudden release of the piston is all too easy, and if the cylinder was initially empty, the piston will collide with the cylinder's end and leave the operator with a (bloody) handful of shards of sharp glass.

Laplace's Law (Page 120):
A collection of sections of plastic pipe from the local hardware store, all rated at the same pressure (say, 40 psi) will have wall thicknesses that increase linearly with their diameters—a decent demonstration of the commercial recognition of Laplace's law. An alternative to laying out hard cash is a trip to the appropriate emporium with a hand-held caliper. One might go further, plotting, from some catalog or website, overall diameter versus price (or weight) per foot or per ten-foot length. Either ought to increase with the square of diameter.

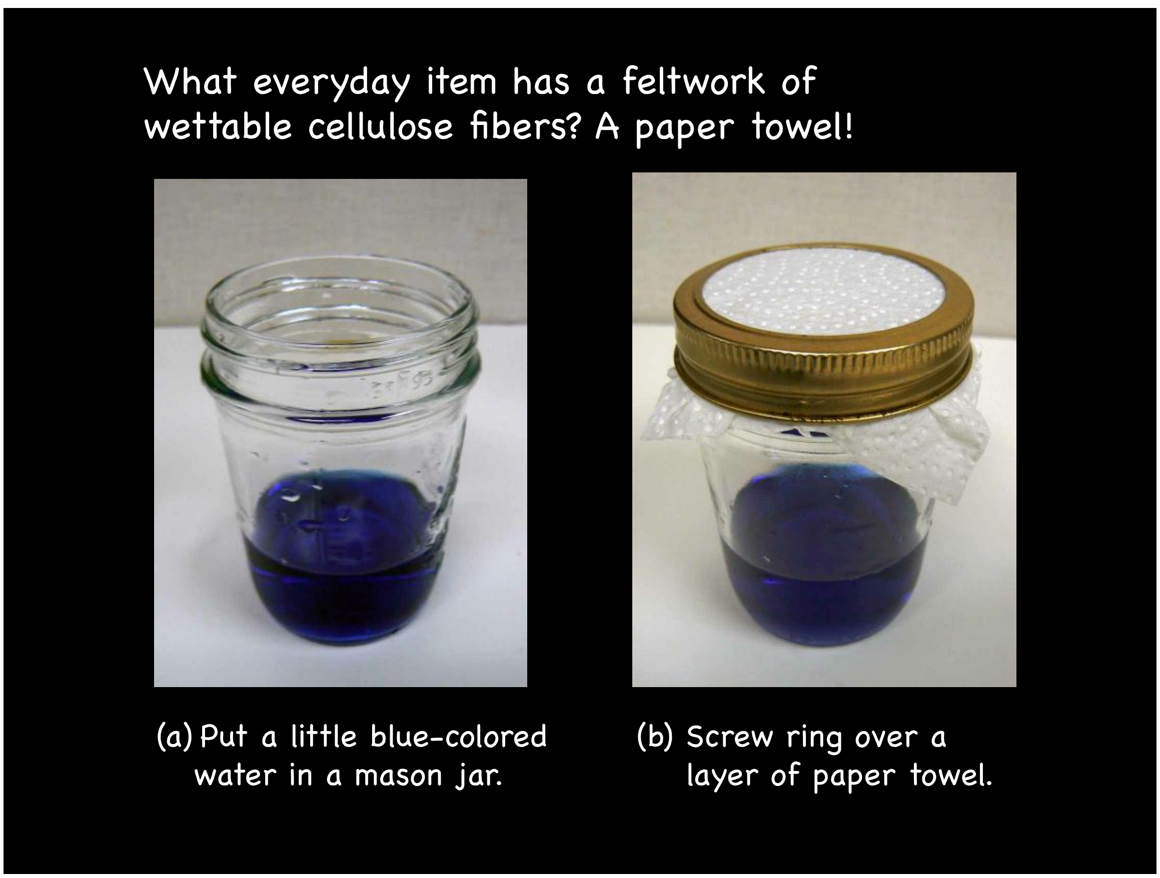
The Force of Surface Tension (Page 122):
A device for illustrating the force of surface tension can be made by bending and looping a few bare, unstranded wires—it can be surprisingly crude and still work.



For scale, the thing ought to be about two inches (5 cm) across. For the downward slider use a cross-wise piece of wire with loops at its ends and a vertical extension (twisted on) below to pull on. Pulling on the latter, you (or a student with a steady hand) notices that the force to move the slider doesn't depend on the slider's position. Alternatively, you can tip the whole rig slowly up from a horizontal position, unlike what would happen with a rubber membrane. Any elevation sufficient to move the slider ought to be enough to move it all the way downward. The solutions sold in toy stores for blowing bubbles seem to be a little better than diluted dishwashing detergent.

Interface as Pressure Barrier (Page 125):

A paper towel (I've used the least expensive from Costco) is a proper cellulose feltwork, deliberately make hydrophilic. So it ought to serve as a model of the cell walls of the air-exposed cells within leaves. A tighter mesh would probably support still more liquid, but I haven't done a lot of exploring—part of the message is the ordinariness of what's needed. An 8-ounce Mason jelly jar with the top ring but no disk provides the container; in the pictures the water has been colored with a tiny bit of Evans blue. Food coloring would undoubtedly work as well. The brown towels in my lab do not work.



(a) Put a little blue-colored water in a mason jar.

(b) Screw ring over a layer of paper towel.

Invert jar and let
it drip a while.

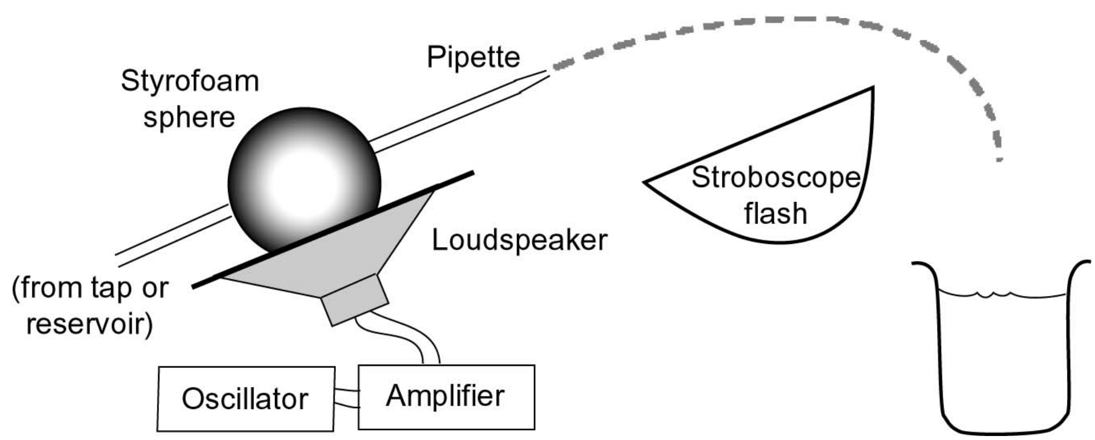
Dripping stops with
most of water still
in the jar.

Water is held up
by lower pressure
in the air above it,
and those little
interfaces between
the cellulose fibers.

Surface Tension in Droplet Formation (Page 163):
A particularly impressive demonstration of surface tension in droplet formation can be arranged if one has access to a stroboscopic flasher whose frequency can be varied. As in the diagram below, one squirts water through a pipette so it takes a short, arcing trajectory and watches the formation of droplets with the stroboscope. Normally, droplet formation is a bit irregular; vibrating the pipette with a barely audible hum at around 80 Hz from a small loudspeaker ensures sufficient regularity. If the strobe frequency is slightly lower than droplet-formation frequency (or slightly lower than half that frequency—our Strobotac makes much brighter flashes at 40 Hz), droplets will appear to form in very slow motion. If the frequency is a little higher then, disconcertingly, the droplets will appear to ascend and enter the pipette.

Laplace’s law comes into play as well—any reduction in radius of the cylinder of water will increase the inward pressure caused by surface tension. So radius reduction leads to further radius reduction and droplet formation. The phenomenon has some direct biological relevance—the reader can guess where.

An alternative to an exposed loudspeaker is one of the little spherical speakers supplied with older I-Mac computers. For that matter, a computer can provide both oscillator and amplifier if equipped with software that makes it generate audio-frequency sine waves. I’ve used a share-ware program for a Macintosh called “Audio Toolbox,” and I’m informed that many analogous programs exist for PC’s.



Properties of a Composite (Page 198):

Another composite you can make and play with consists of fiberglass, as stiff component, and gelatin, as compliant matrix. You might form two troughs of aluminum foil—perhaps 10 x 2 x 1 inch (25 x 5 x 2.5 cm)—and spray their insides with no-stick cooking spray (“Pam”). In one, lay a strip or two of fiberglass batting—sold as pipe or wall insulation—and place the troughs in a baking pan. Dissolve one ounce (28 g) of gelatin in 3 cups of boiling water and nearly fill the troughs. Add enough water outside the troughs to offset the flimsiness of the foil. Chill until set, drain the pan, and fold back the foil molds. Explore the properties of the resulting composite, noting in particular the differences connected with crack propagation.

Compressing Water (Page 199):

That liquid water can resist compressive loads doesn't have the startle-value of water as a tensile material. But we rarely think about it and even less often realize how ordinary is the phenomenon. So-called "hydroskeletons" find use in a wide variety of animals and plants, enough so finding one that doesn't ever do so isn't easy.

Comparing the resistance of filled and empty soda-pop cans to compression ought to lend considerable support to the idea. In practice, one puts cans between two boards or board and floor and climbs up on the resulting platform.

This particular 10-stone (140 lb, 65 kg) human can be supported on four cans; I haven't enlisted my more gravitationally-endowed friends to test the limits. In any case it might be a good idea to hold onto the top of a chair until confident that one will indeed be supported. If support fails, one of course gives new meaning to the term "soda pop."

The chair (or desk) is crucial if you want to crush empty cans as a real-time component of the demonstration. Not only are you going to drop about six inches, but the four cans will not likely collapse in perfect synchrony. Be careful!

How Resistance to Bending Scales (Page 204):

Here's a simple demonstration of how resistance to bending scales that operates at a larger scale and makes a decent classroom demonstration. Obtain a piece of softwood, eight feet long, a "1 x 8" as they're sold, as free of knots as you can find. Rule lines across the board at 1, 2.5, 4, 5.5, and 7 foot points. Lay the board across supports (bricks on their sides, for instance) with 3 feet between supports, add a weight in the middle (I use 140 pounds—10 stones—in the form of myself), and have someone record the downward deflection. Then repeat with six feet between supports. The second trial should give, with luck, about eight times the deflection. But be careful. I once tried the thing with a board that had a knot and ran between two saw horses. It dropped me most embarrassingly (a camera was running). The trouble, of course, is that you want to tickle the edge of breaking to get a good deflection.

A Wind Tunnel (Page 226):
Automobiles and molding don't match wind tunnels for convenience and versatility. One doesn't need (or want!) carefully smoothed flow, but the speeds available with household fans aren't quite adequate to get particularly good leaf reconfiguration. And leaf-blowers have too small a stream to do the job well. So one might contrive a small wind tunnel by making a large box fan blow into a channel that *gradually* decreases its cross-sectional area by about half, thereby doubling speed (or nearly so, depending on the fan's response). Cardboard and duct tape ought to do most of the construction job.

Supportive Systems (Page 228):
Each of the supportive systems illustrated in figures 12.6 and 12.8 can be demonstrated with models two or three feet tall. (a) For compressive buttressing, use a vertical 2 x 2 with four bottom supports nailed on, one on each face. The supports need be no more than simply right triangles of 1/4" plywood. (b) Taprooting takes nothing more than a pointed pole pushed down into a bucket of sand. (c) For tensile buttressing, attach a base plate beneath a 1 x 1 pole with a single nail from below. Instead of each triangles used in the previous model use a diagonal cord between two eye-screws (or, if fancy, wire and turnbuckle) plus triangles of corrugated cardboard, the latter taped on to emphasize the minimal role of all but the outer portion.

These demonstrations are from www.press.uchicago.edu/sites/vogel/
Additional demonstrations are welcome; please write svogel@duke.edu