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National Science Education Standard:

Students in grades 9-12 should be able to identify questions and concepts that guide scientific investigations.

2 of the 13 standards listed by the National Board for Professional Teaching Standards:

Accomplished science teachers select and adapt instructional resources, including technology and laboratory and community resources, and create their own to support active student explorations of science.

Accomplished science teachers stimulate interest in science and technology and elicit all their students' sustained participation in learning activities.

Can It! taken from "Games Magazine presents the Giant Book of Games"
ed. by Will Shortz ISBN 0-8129-1951-3 \$15 available at Books-a-Million

After students guess the answers ask them how they were able to do so. Ask them which items they would have difficulty guessing if that item appeared alone, without the others with which they could compare.

Now show them various plant materials and ask them what they might infer from the shapes and sizes. What other information might they need? Encourage good questions and consider making assignments based on those.

How to Create a Botanical Plate

This could be used to generate interest in shapes, sizes, and colors of plant material, or as part of a long-term study on the plants around your campus, or use your imagination (Mother's Day gifts?). I had 12th grade students make them with favorite flowers and plants on campus and it was their favorite "lab".

The Amateur Scientist

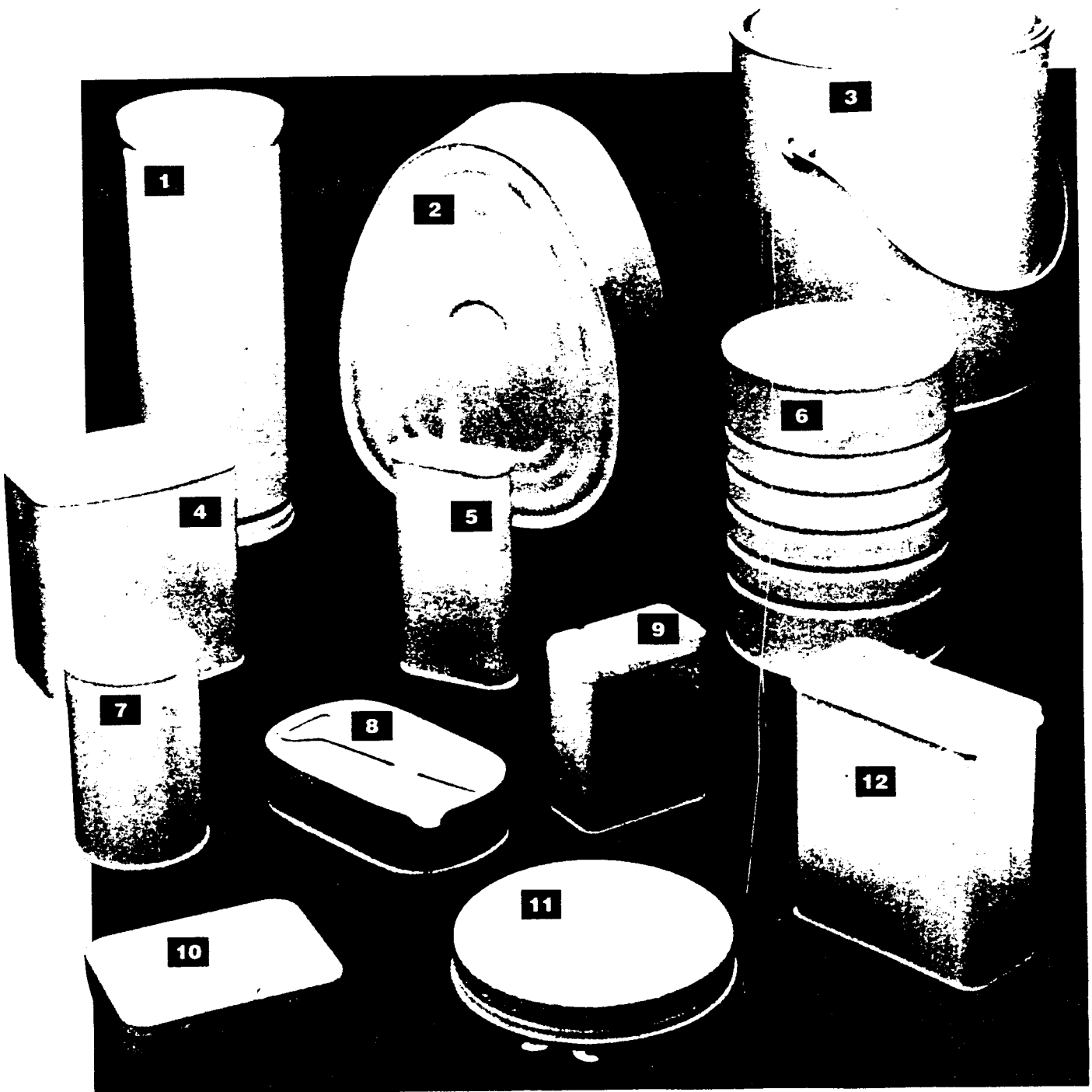
Friends say this really works. I will try it for the first time this fall. My students are intimidated by lab equipment so this may be the way to go before using the "good stuff". If you do so, let me know how it went.

CAN IT!

By David Pope

No, this isn't the generic goods section at the supermarket. We've simply removed the labels from 12 cans of familiar products found at the grocery, pharmacy, hardware store, etc. Try to identify—just from

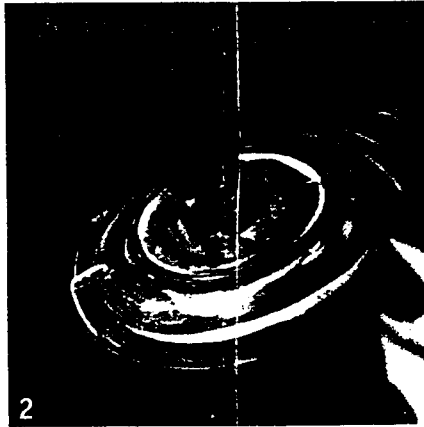
the shape—the type of product or brand name associated with each. Can do? *Answers, page 173*



- | | | |
|----------|----------|-----------|
| 1. _____ | 5. _____ | 9. _____ |
| 2. _____ | 6. _____ | 10. _____ |
| 3. _____ | 7. _____ | 11. _____ |
| 4. _____ | 8. _____ | 12. _____ |

HOW TO Create a Botanical Plate

1. In a small bowl, dilute glue with water until it's quite runny. Using the sponge brush, spread the mixture over the underside of the plate.
2. Press the flowers into the glue wash on the plate.
3. Using either the sponge or paintbrush, dab the flowers with more glue wash.
4. Brush the glue wash over one side of the paper and then carefully lay the moistened side down on the wet flowers and plate.
5. Gently dab the paper with the glue wash again.
6. After the glue dries, use the small paintbrush to apply a fine line of gold



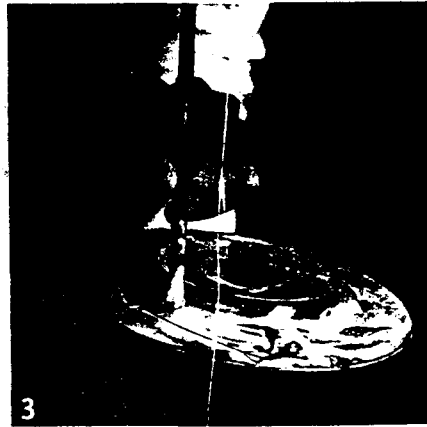
acrylic paint along the rim of the plate, on the underside.

7. When the plate is dry, spray the bottom with the acrylic aerosol coating. (Work in a well-ventilated room or outdoors so that you don't inhale toxic fumes.) Apply 10 to 12 coats, each at 10-minute intervals.

Martha creates votive candles the same way, cutting rice paper to fit and applying it just to the outside of the glass so it doesn't burn.

MATERIALS

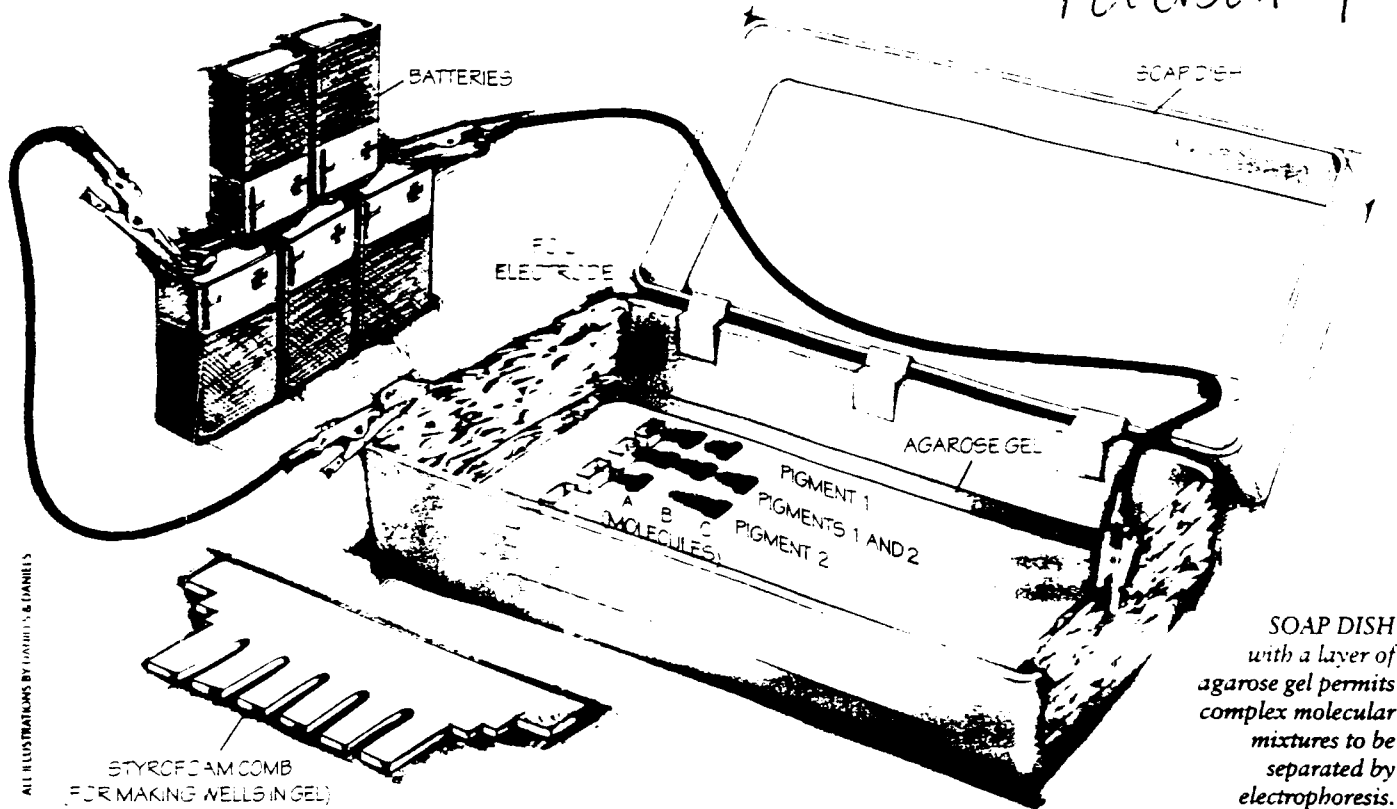
- White household glue
- Craft sponge brush
- Clear glass plate
- Pressed dried flowers
- Small paintbrush
- Rice paper or ordinary tissue paper, cut to plate size
- Gold acrylic paint
- Acrylic aerosol coating



THE AMATEUR SCIENTIST

by Shawn Carlson

Peterson 4



ALL ILLUSTRATIONS BY LORETTA & DANIELS

STYROFOAM COMB
(FOR MAKING WELLS IN GEL)

SOAP DISH
with a layer of
agarose gel permits
complex molecular
mixtures to be
separated by
electrophoresis.

Sorting Molecules with Electricity

The most wonderful private garden I have ever seen is tucked away behind a modest house in La Jolla, Calif., not far from where I live. The gardener is a British-born psychology professor and dear friend who sends me home with fruit and flowers each time I visit. Recently I noticed that two of his plants, though very different in shape, produced flowers of the exact same shade of purple. This observation made me wonder whether the two species might be related.

One normally traces evolutionary connections by identifying physical similarities between species. So I decided to extract and isolate the pigments in the two flowers so that I could compare them in detail. That process is actually much easier than it sounds. In fact, using a simple technique called electrophoresis, I could carry out the experiment in about an hour for very little money.

Most molecules are electrically neutral, but some important biological molecules, including proteins, DNA frag-

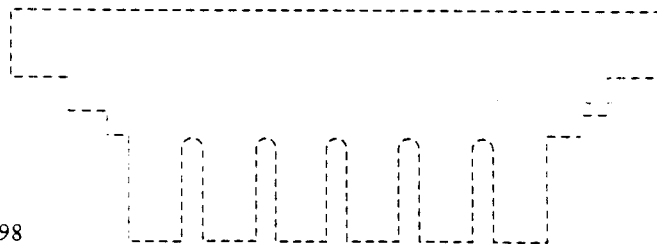
ments and many natural dyes, carry a net negative charge when they are in solution. Electrophoresis cleverly uses a weak electric field to force such charged molecules to drift through a medium that separates them by offering differing amounts of resistance to motion.

You can easily see this phenomenon in action when you place a droplet of dye on a strip of blotting paper that has been wet by a conductive fluid, such as salt water. When the ends of the paper are connected across a battery, a voltage is set up, which drives the charged dye molecules through the paper. Positively charged particles move toward the negative terminal, whereas negative ones move toward the positive terminal. Usually, larger molecules have a more

difficult time than smaller ones in passing through paper fibers, so the smaller molecules drift faster. Thus, over time, the different molecules in a mixture will tend to sort themselves by size.

It takes only a few minutes to set up a basic apparatus. From a large coffee filter cut a rectangular strip of paper that is about one centimeter (about half an inch) wide and about 15 centimeters (six inches) long. Place this paper band inside a flat glass pan or cooking dish. Roll each end of the paper strip around a nail, and use an alligator clip to secure it. Wire the clips to five nine-volt batteries connected in series.

To make the conductive solution, mix about 100 milliliters (four ounces) of distilled or bottled water with 1.5 grams (about a quarter teaspoon) of table salt. Then thoroughly wet the paper, including the nails, with the salt so-



TEMPLATE
allows the "comb"
to be cut from a
Styrofoam meat tray.

The Amateur Scientist

lution, but don't add so much that the paper is submerged in a puddle.

To begin, use a toothpick to place droplets from several different hues of food coloring in a line, then connect the electrodes. The colors will rapidly spread into streaks as the pigment molecules migrate toward the positive electrode. Next, mix two of the dyes, say, red and green, and run a tiny splotch of the combination. After about 20 minutes, the colors should begin to separate. The same technique can be used to separate other molecular mixtures.

So here's how to find out if two plant species use the same molecules as pigments. First, crush the flowers and immerse them in clear isopropyl alcohol, letting the solids settle. Pour off each of the resulting color-tinged liquids into separate containers and then concentrate them by letting the alcohol evaporate. Once the alcohol is nearly gone, dissolve the pigments in a few drops of the salt solution you made earlier.

Next, line up three tiny dots of pigment on a strip of soaked filter paper by placing a pure sample from each plant on the outside and an equal mixture from both in the center. Then connect the batteries. If the outside dots separate into different sets of colored swaths and the center streak appears to be a combination of the outer ones, then you know that different pigments are involved. But if all three dots form the same pattern, then both plants probably rely on the same molecules for color.

Note that the salt ions will also drift toward the electrodes, where they will quickly create a layer of tarnish that impedes the flow of electricity. So after each run, you will have to scrub the electrodes. As all this cleaning rapidly becomes tiresome, you might try to replace the steel nails with another conductive material that does not tarnish as quickly—stainless-steel wire or alu-

minum foil, for example. Small pieces of gold or platinum wire or chain work especially well.

Although many great discoveries have been made using paper-based electrophoresis, this simple method does have a big drawback: the molecules tend to get caught up in the fibers of the paper. This complication explains why even pure dyes form streaks instead of remaining well-defined dots as they move along. So these days biologists often replace the paper with a more uniform material called agarose—a clear substance with the consistency of stiff gelatin. The DNA "fingerprint" patterns you may have seen are produced by electrophoresis on such a gel. Each of the individual lines in the fingerprint indicates strands of DNA of a certain length. Compared with results with paper, the degree of separation possible with a gel electrophoresis is amazing.

September's *Amateur Scientist* column explained how to extract DNA from living tissues. Unfortunately, the extracted material must be subjected to sophisticated laboratory manipulations using expensive reagents before a fingerprint can be created. But similarly diagnostic patterns can be made using plant pigments. Indeed, complex pigments often separate so cleanly that the results are just as stunning. After about 20 minutes, you can often isolate virtually every molecule involved in such a mixture.

Although ordinary gelatin does not work well, I'm told that a food additive called agar-agar may and that it can be found in Chinese food markets. But I suggest that you spend \$25 and purchase enough agarose gel for about 40 experiments from Edvotek, an educational biotechnology company in West Bethesda, Md. (301-251-5990; www.edvotek.com).

You can quickly fashion a gel-based electrophoresis unit from any small,

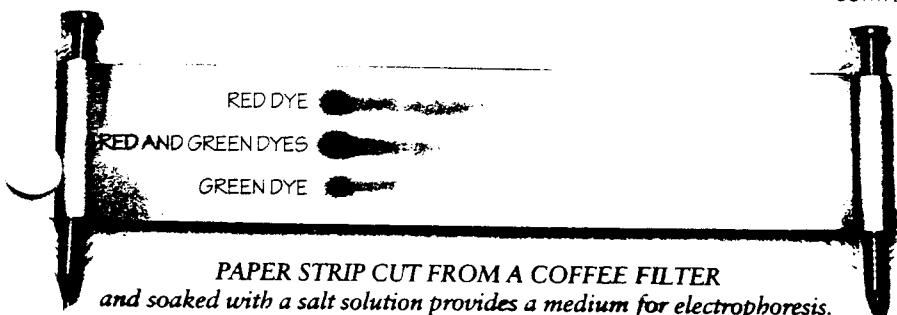
rectangular container that is waterproof. I used the bottom of a plastic soap dish. Bend some aluminum foil over the two shorter sides to serve as electrodes and then pour enough of the hot, liquid agarose into the dish to cover it with a half-centimeter layer. Because your gel must contain reservoirs to hold the concoctions you wish to separate, cut out a comb shape [see *bottom illustration on opposite page*] from a Styrofoam tray—the kind used to pack meat at the grocery store—and suspend it so that the tines penetrate the liquid agarose but don't poke through the bottom. Let the gel set before carefully removing the comb. This maneuver should produce a series of nicely spaced wells for your samples. Now add enough of the salt solution to cover the gel and keep it from drying.

With an eyedropper, place your test substances into the wells, rinsing the dropper thoroughly between samples. To start your experiment, just connect the aluminum foil to your batteries with alligator clips, with the positive terminal attached to the side opposite the wells so that the negatively charged molecules have some room to move. Don't worry if you notice some bubbling along the foil as water molecules are split apart by electrolysis. And don't be concerned if the color of the pigments changes (a common effect of altered pH). Because of its tendency to tarnish, you will have to replace the aluminum foil when you renew the agarose after each run.

Electrophoresis is a cornerstone of molecular biology. Armed with this technique you can isolate the basic stuff of biology for further exploration. There are far too many living systems for professionals to study them all, and so there are many discoveries waiting for the ambitious amateur armed with this technique, a textbook and some perseverance. So why not get to work! SA

NEGATIVE

POSITIVE



PAPER STRIP CUT FROM A COFFEE FILTER
and soaked with a salt solution provides a medium for electrophoresis.

The Society for Amateur Scientists has joined forces with Edvotek to create a complete gel-based electrophoresis unit for kitchens and classroom labs. Send \$55 to SAS, 4735 Clairemont Square, Suite 179, San Diego, CA 92117, or call the society at 619-239-8807. You will find more information about this and other articles from the Amateur Scientist at web2.thesphere.com/SAS/WebX.cgi on the World Wide Web.