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HOW TO MAKE A RAINBOW

And now for three fun home science demonstrations that will have you seeing colors.

OPTICAL ILLUSIONS

Light is a form of energy made up of different wavelengths; the wavelengths that are visible to the human eye are referred to as "the colors of the spectrum." When all these visible wavelengths of color are combined, the result is pure white light. But wait a minute—if that's the case, then how come when you combine all the colors of paint, it turns black? Because of light's *additive* and *subtractive* qualities. Confused? The following demonstrations will shed a little light on the matter (literally).

Note: If you're a kid, you'll need an adult to assist you with these experiments. If you're an adult, these might be more fun with a kid around.

Experiment #1: A Tall Glass of Rainbow

OBJECTIVE: To split direct sunlight into the colors of the spectrum

WHAT YOU'LL NEED:

- A glass of water (preferably a clear, smooth glass)
- Sunlight or a bright, white flashlight
- A white surface or a white piece of paper to make the rainbow appear brighter

WHAT TO DO: You'll have to time this experiment for when the Sun is shining in through a window onto a horizontal surface like a table or countertop. When the light is just right...

1. Place the glass of water in the sunlight. You might have to move it around until the rainbow appears next to it on the table. Use the piece of paper if necessary.
2. Carefully position the glass half off the table, and the rainbow will appear on the floor.
3. If you're using a flashlight, place the glass on a white surface. Aim the flashlight at the glass from a few inches away, moving it around until a rainbow appears.

THE SCIENCE EXPLAINED: *Additive light* refers to all colors of the spectrum combining into white light. This activity shows that process in reverse. When the white sunlight passes through the glass, the wavelengths split into colors of the spectrum (also known as Roy G. Biv, an acronym for "red, orange, yellow, green, blue, indigo, violet"). The glass acts as a prism—which can be any transparent object that disperses light rays.

Three factors are at work here: refraction, dispersion, and reflection. When light rays move from one density to another—in this case, from air to water—they are refracted, or bent. Different wavelengths bend at different angles, dispersing the light rays into the aforementioned Roy G. Biv. That's how it works with any prism. In the case of a rainbow, the prisms are all the water droplets in the air. The dispersed light rays are reflected off the sides of the water droplets, and that appears to us as a rainbow arc with red on the outside and violet on the inside. In order to see a rainbow, the Sun must be directly behind you, shining unencumbered onto raindrops directly in front of you. That's why every rainbow is unique to the person viewing it...and why it seems to follow you in the car.

Experiment #2: Walking Water

OBJECTIVE: To utilize capillary action and color blending to make a liquid rainbow on your table

WHAT YOU'LL NEED:

- 7 clear plastic cups. You can also use drinking glasses or Mason jars—anything you can see through. They should all be the same size.
- Paper towels; the more absorbent, the better.
- Liquid food coloring—red, yellow, and blue—that dissolves in water
- Scissors (which you will most likely need to cut the paper towels)
- A spoon or a stirring stick

WHAT TO DO:

1. Do this experiment on a surface that can stay undisturbed for several hours.
2. Place the 7 cups right next to each other in a semicircle.
3. Fill every other cup with water, nearly to the top, and all to the same level. Cups 1, 3, 5, and 7 should have water; cups 2, 4, and 6 should be empty.
4. Put a few drops of red food coloring in the two outside cups (1 and 7), blue food coloring in cup 3, and yellow food coloring in cup 5. Stir each one gently until the color is even, making sure to wipe off the stirrer between stirrings to keep the primary colors intact.
5. Fold 6 paper towels into long strips less than 1 inch wide. Now bend

each strip in half, forming a V shape. Each "leg" should be about the height of the cup. If they're much longer than that, use the scissors to cut them down to size.

6. Carefully place one end of a paper towel strip into the first cup with the red water, and the other end into the empty cup next to it. Take the second paper towel, and place one end into the same empty cup and the other into the third cup with the blue water. Put the next paper towel into the third cup, making a "bridge" to the fourth, and so on until you've used all 6 paper towels.
7. Wait. It can take several hours for this reaction to be completed, depending on the paper towel's absorption power. If you're so inclined, record a time-lapse video on your phone. You *should* have seven cups half-full of water. The three primary colors—red, yellow, and blue—are still in their cups, but they've combined to create secondary colors between them—orange, green, and purple.

THE SCIENCE EXPLAINED: How does the clear water become colored? A chemical reaction is taking place between the water molecules and the polarized ions in the food coloring. Simply put, the food coloring is made of tiny solids called *pigments.* Upon entering the water, the pigments begin to dissolve and break up; the free-floating color molecules bond with oppositely charged water molecules until a new equilibrium is reached and the water in the cup is a solid color—in this case red, yellow, and blue.

How did the water seemingly defy gravity to get from one cup to another? By *capillary action,* that's how. Within the paper towel are tiny cellulose fibers that have tiny openings. Water molecules are polar—they have both positive and negative ions—which means they are attracted to polarized molecules in the cellulose. That's what pulls the water molecules up. Those water molecules are also attracted to each other—it's called *cohesion*—which is why raindrops form little globules. This creates *surface tension* that bonds the water molecules together as they are drawn through the paper towel. (Capillary action is also how plants and trees are able to "drink" water from the ground.)

This is considered subtractive color blending because we're dealing with matter, not light. Light waves are a type of energy, and when they enter a molecule, most of those light rays are absorbed as energy. The light rays that aren't absorbed reflect the color that we can see. So that red water only appears red because all the other colors were absorbed. The more colors you add, the more colors get absorbed—or subtracted—and the fewer get reflected back. When all the colors are absorbed, the water turns black.

Experiment #3: The Psychedelic Plate

OBJECTIVE: To demonstrate surface tension and color blending, and learn how soap works

WHAT YOU'LL NEED:

- A deep, white plate. A saucer or Frisbee will also do.
- 2-percent or whole milk. Skim milk or a nondairy substitute won't work.
- Liquid food coloring. The more, the better.
- Liquid dish soap (like Dawn)
- Cotton swabs or toothpicks

WHAT TO DO:

1. Carefully pour some milk onto the plate so it covers the entire surface less than ¼ inch deep.
2. Once the surface is calm, add one drop of each food coloring no farther than one inch from the center. Try not to let the drops touch each other.
3. Use the toothpick or cotton swab to collect a very small glob of dish soap.
4. Slowly place the glob of soap into the center of the plate and hold it there.
5. Try not to freak out as the solution erupts into a maelstrom of psychedelic swirling.

THE SCIENCE EXPLAINED: Whole milk is a solution of mostly water with trace amounts of proteins and vitamins, along with tiny globules of oils, collectively referred to as fat. Fat molecules are *nonpolar,* meaning they have no charge and are therefore not attracted to polar molecules in water, so they don't dissolve. That's why oil and water don't mix. Fat molecules do, however, cling to surfaces. That's why washing with water alone doesn't always remove the oils. The soap's molecules are nonpolar, and they're attracted to the nonpolar fat molecules, so much so that they twist and contort them and even break them up in order to make new bonds. On a dirty plate or dirty hands, the soap molecules bond with and then break up fatty deposits so they can be washed away in the water. This reaction would still take place without the food coloring—it just makes it easy to see. Once the soap has bonded with all the fat molecules, a new equilibrium has been reached and the swirling stops. (Too bad there's no chemical reaction that will magically clean up the mess.)