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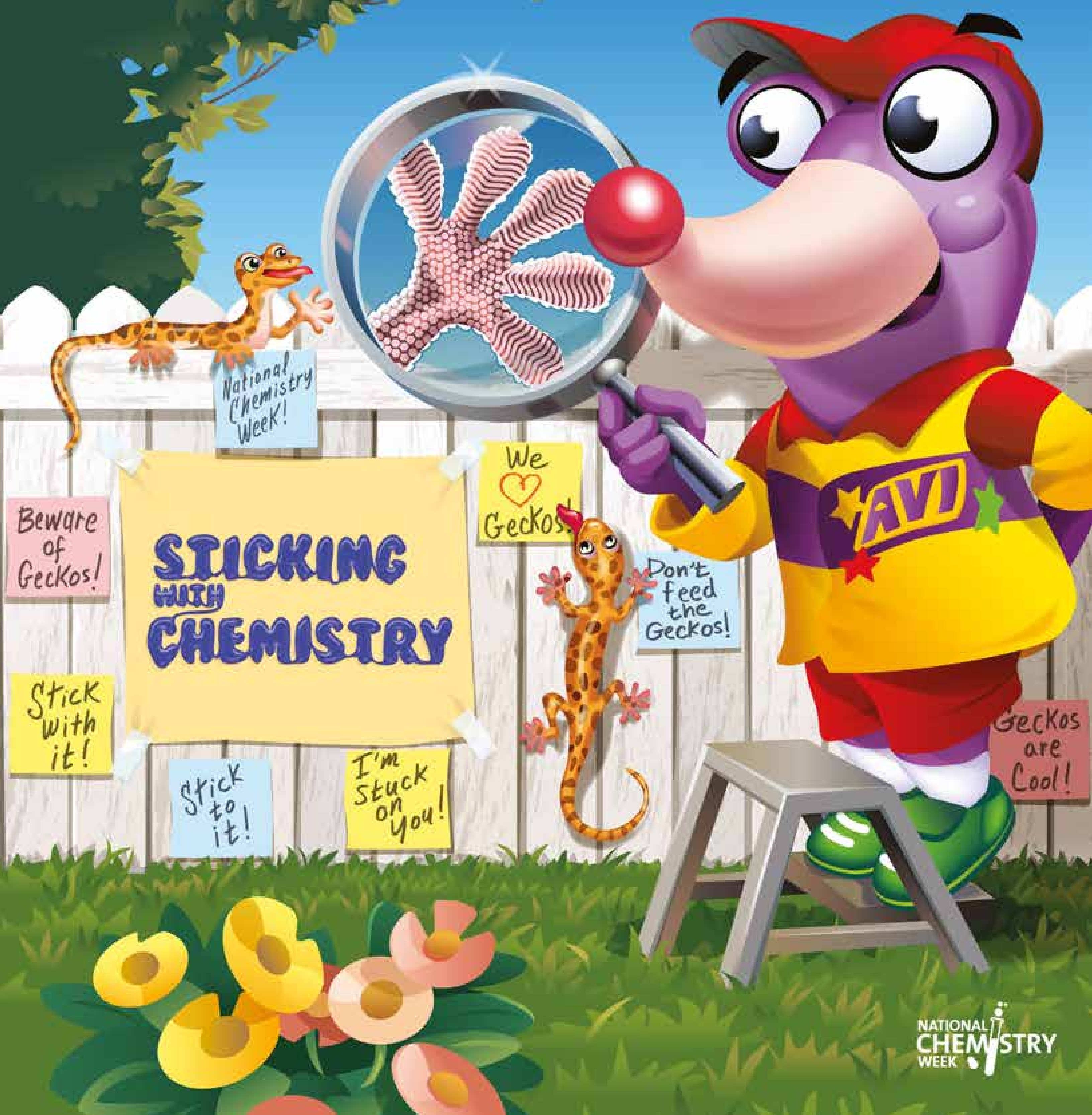
NATIONAL CHEMISTRY WEEK

AMERICAN CHEMICAL SOCIETY



Sticking with Chemistry

By Dave S. Heroux

Welcome to the sticky chemistry of glues and adhesives!

An **adhesive** is something used to stick things together. Adhesives are all around us, although sometimes hidden from our sight … or so obvious we don't notice them. For example, look around your kitchen. You may see bottles, jars, and cans with informative labels stuck to them, or food packages like cereal boxes that are sealed tight with **glue**. If you look down, you'll see your shoes, which are probably held together partly with adhesive chemicals. There are all sorts of adhesives for different uses and they stick in many different ways.

So, what makes something stick? Two basic forces involved in sticking one thing to another are **adhesion** and **cohesion**. Adhesion is a force that causes *different* things to stick together, while cohesion is the force that causes *similar* things to stick together.

You can see both of these forces at work when you look at a water droplet. If you dip your finger in a glass of water and then pull it out, several drops will fall into the glass. But the last one will stick to the end of your finger. This is an example of adhesion. The water also sticks to itself, forming the round drops due to cohesion. But both the adhesion and cohesion in water are very weak, so it's not a very good adhesive.

Another key part of something sticking is **wetting**, which is how much the adhesive flows and gets into the tiny parts (rough surface) of what you are trying to stick it to. When you press a Band-Aid bandage to your skin, you make the sticky **molecules** flow a tiny bit into the rough surface of your skin, and the whole thing sticks to you!

The interesting past of paste

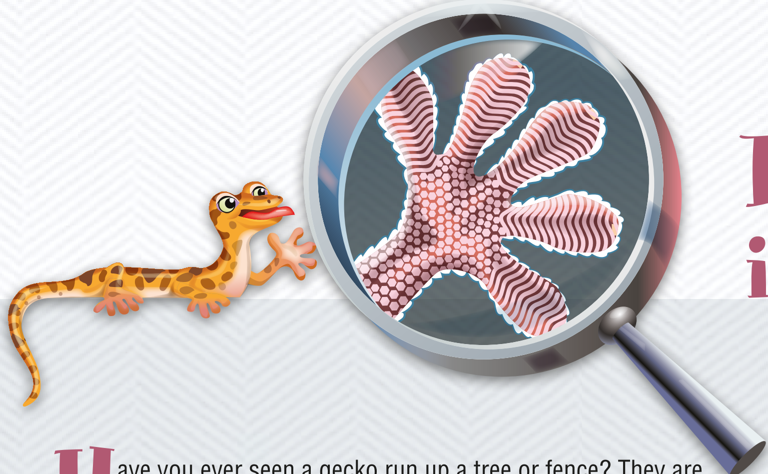
Humans have been using adhesives for a long time. Natural adhesives made from sticky tree sap and animal products, such as skin and cartilage, have been used since ancient times. Adhesives have even been found in the tombs of the ancient pharaohs in Egypt!

Over the last 100 years, chemists have developed stronger synthetic adhesives for all sorts of applications. Scientists need to design adhesives with different stickiness, depending on their use. For example, think about a Band-Aid. The adhesive needs to be able to stick to both the plastic of the Band-Aid, and also to you! It can't stick too much, or you wouldn't get it off!

Today we have a big variety of stickiness, from very strong adhesives like "superglue" to special, not-so-sticky adhesives used for Post-It notes or painter's **tape**. Today, chemists are working to develop adhesives that work to replace stitches when you get cut, as well as adhesives that work underwater, in very hot environments, and even in outer space!

Stick with this edition of *Celebrating Chemistry* and learn about the development of the Post-It note, how chemists are being inspired by nature to make even better adhesives, how to make homemade glue, and how to test just how sticky tape is. Celebrate National Chemistry Week 2020 with the theme, "Sticking with Chemistry." We hope that after reading through this edition of *Celebrating Chemistry,* you'll be stuck on chemistry!

***Dr. David Heroux** is Associate Professor of Chemistry at Saint Michael's College in Colchester, VT.*



Being a Gecko is Sticky Business!

By Lori R. Stepan

Have you ever seen a gecko run up a tree or fence? They are very fast, and they seem to stick to just about anything! Wouldn't it be fun if you could hang upside down from the ceiling or a branch like a gecko?

Geckos belong to the lizard family, and they can be anywhere from 2 to 24 inches long. They help us by eating insects, and they are found in many warm climates throughout the southeastern and southwestern parts of the US, and around the world. However, their most amazing feature is the ability of their feet to stick to almost anything.

Stickiness happens when two substances are attracted to each other. If you have ever felt the pull of two magnets toward each other, you have felt one example of an attractive force. So how does a gecko stick? Is it a sticky goo, tiny suction cups, or even tiny hooks? No, it's none of those things. The answer has to do with chemistry!

The gecko sticks with temporary attractive forces between molecules called *Van der Waals* forces. They are easily formed and broken again, and only occur over short distances, like when the molecules on the gecko's feet are very close to the molecules of the wall. The distance between the molecules has to be very tiny. The molecules are approximately 0.3 – 0.6 nanometers apart. Nanometers measure very small lengths. If one of your hairs were a mile wide, a nanometer would only take up one inch of it!

A gecko's attraction to surfaces like walls, ceilings and branches depends on thousands of tiny hair-like structures called *setae* on the bottom of the lizard's toes. The setae have even smaller divisions on their ends called *spatulae*, which are like tiny versions of the kitchen spatulas that chefs use to flip pancakes. The spatulae are like the tiny bristles at the end of a brush. The molecules that make up the spatulae are attracted to the molecules of the wall, so the gecko's feet stick to the wall.

Close-up image of a gecko foot

The gecko can break that interaction by bending its toes just right. Then, lifting its foot quickly, the gecko sticks it to the wall in a different spot. Because there are so many spatulae, the interaction is very strong. Scientists have estimated that gecko feet would be able to support up to 290 pounds if every one of the spatulae were interacting with the surface at once! That would be one huge gecko!

The gecko can't stick to everything, though. The non-stick coating used in many cooking pans is made of a substance called Teflon, which geckos cannot stick to. Teflon has a surface rich with fluorine atoms, which do not have an attraction to the spatulae of a gecko. Geckos also have trouble on wet surfaces because the water disrupts the Van der Waals interactions between their feet and the surface.

In a branch of science called biological-inspired design, many scientists and engineers are learning from the gecko by creating new materials that can stick to other materials as efficiently as the gecko foot. Bio-inspired researchers are also currently working on making robots that can climb vertical surfaces, sticky pads for soldiers to use when climbing, and wound-sealing substances that would not require stitching. Wouldn't it be fantastic if in the future a scientist discovered a substance that lets people hang upside down like a gecko? Maybe that future scientist will be *you*!

Dr. Lori Stepan *is an Associate Teaching Professor of Chemistry at Penn State University in State College, PA.*

Milli's Safety Tips Safety First!

ALWAYS:

- Work with an adult.
- Read and follow all directions for the activity.
- Read all warning labels on all materials being used.
- Wear eye protection.
- Follow safety warnings or precautions, such as wearing gloves or tying back long hair.
- Use all materials carefully, following the directions given.
- Be sure to clean up and dispose of materials properly when you are finished with an activity.
- Wash your hands well after every activity.

Making Glue at Home

By Alexsa Silva and
Miranda J. Gallagher

SAFETY SUGGESTIONS

- Safety goggles required
- Protective clothing suggested
- Caution: hot liquids!
- Do not eat or drink any of the materials used in this activity
- Gloves should be used if you are allergic to casein or other milk proteins
- Thoroughly wash hands after this activity
- Have a parent or adult help you

Disposal: There are no hazardous materials used in this activity, and everything can be disposed of in the trash. Containers should be cleaned for reuse.

Note: Follow Milli's Safety Tips found in this issue of *Celebrating Chemistry*.

Introduction

In this activity, you will be able to make glue out of milk! The main ingredient is a protein in milk called casein that you will turn into your own glue, and then test against a commercial glue.

Materials

- ½ cup (118 mL) of skim (or non-fat) milk
- 1 tbsp. (15 mL) of vinegar (acetic acid solution)
- 1½ tsp. (7 mL) of baking soda (sodium bicarbonate)
- 1 tbsp. (15 mL) of water
- stirring spoon
- plastic funnel
- paper coffee filter, cheesecloth, or paper towels
- 1-cup (236 mL) microwave-safe dish
- small plastic cup
- 16-oz. (473 mL) disposable plastic cup
- potholder or insulated kitchen glove
- Popsicle sticks
- single-hole punch
- binder clip
- 12-inch (30 cm) piece of string
- 3–4 lbs. (1.4–1.8 kg) of dry sand
- store-bought glue for comparison
- thermometer

Procedure

1. With the supervision of an adult, warm up (30 seconds in the microwave works!) ½ cup (118 mL) of skim milk in the dish. The temperature should be about 165° F (74° C). Do not overheat the milk. Using a potholder or insulated kitchen glove, remove the dish of milk from the microwave.
2. Stirring constantly, add the vinegar to the milk. Continue stirring until no more lumps form.
3. Let it settle for 5 minutes. You should observe the separation of the solids (which sink to the bottom) from the liquid (which stays on top).
4. Put a paper coffee filter (or cheesecloth or paper towel) in the funnel. Place a plastic cup under the funnel. Pour the liquid first, and then the solids into the funnel. Pour the filtered liquid down the drain, and save the solid in the filter paper.
5. Using the spoon, gently squeeze off any excess liquid left in the solid. Transfer the solid from the paper filter into a plastic cup.
6. Add one tbsp. (15 mL) of fresh water to the solid in the plastic cup. Mix it well with a spoon.
7. Slowly add the baking soda, mixing it well. Repeat the process until no more gas bubbles are formed. (Slightly more than ¼ tsp. (1.2 mL) of baking soda may be needed — but don't use too much.)
8. Your glue is ready! This glue will be usable for about one day, and will then spoil. The spoiled glue can be disposed of in the trash.

Where's the chemistry?

This experiment uses vinegar to make the protein casein clump together and separate from the liquid part of the milk. The protein solids are also called 'curds' and the liquid part is called 'whey.' Just like Little Miss Muffet, we are working with curds and whey!

The **chemical reaction** between the milk and vinegar promotes the linkage of many molecules of casein. These links form tangled chains, and these tangled chains are what make glue sticky! It is important to use milk without fat in it; fat gets in the way of the reaction and prevents the chains of the polymer from sticking together. The baking soda (sodium bicarbonate) neutralizes the excess of vinegar (acetic acid solution); the bubbles produced in the reaction are made of carbon dioxide gas.

How good is your glue?

Now, let's compare the strength of your glue with store-bought glue.

1. Use the glue you made to stick together two Popsicle sticks. Place them so that only one inch (2.5 cm) of the sticks overlap each other and stick together. Make a couple of these test samples.
2. Repeat the same procedure using the commercial glue. Label the Popsicle sticks clearly.
3. Wait several hours for the glue to dry.

Before testing, which glue do you think will be stronger? Why do you think that? To get a general idea of how strong the glues are, try to separate the sticks in one of the samples by hand. What do you observe? How much force does it take to break them apart? Was each one easy or hard? Next, we will test them more carefully.

Single-Lap-Joint Shear Test for Popsicle Sticks

In the chemical industry, chemists and chemical engineers agree on standard testing methods. That way, everyone around the world can do the same test on products. The Single-Lap-Joint Shear Test measures the strength of glue to hold together two pieces of metal as they are pulled apart. We'll do a version using two Popsicle sticks instead of metal.

1. Have an adult help you use a single-hole punch to make two opposite holes near the top rim of a plastic cup.
2. Loop the string through the binder clip and both holes of the cup. Knot the string at both ends, so the knots are next to the holes in the cup.
3. Pick up the two sticks you glued together with store-bought glue. Attach a binder clip to the bottom stick.
4. Holding the other end of the stick assembly, add sand slowly to the cup until the glue can no longer hold them together. Record the amount of sand used by estimating how full the cup was (such as $^{1}/_{4}$ or $^{1}/_{3}$ full). Repeat with your homemade glue.

Single Lap Shear Test	Amount of Sand Added Before Glue Failed
Homemade Glue	
Commercial Glue	

What do you think would happen if you tested different ingredients? What if you tried a milk with higher fat content (2% milk, for example)?

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***Dr. Miranda J. Gallagher** is a Postdoctoral Research Associate in the Department of Chemistry at Rice University in Houston, TX.*

Patching People Up:
How Wound Adhesives Work

By Verrill M. Norwood III

Have you ever cut or hurt yourself and had to use an adhesive bandage, such as a Band-Aid? If so, then you know that an adhesive bandage is a small piece of sticky adhesive tape with an absorbent pad that you use to cover small cuts or wounds on your body. The absorbent pad is often made of cotton, and there is sometimes a thin coating over the pad, to keep it from sticking to the wound. The adhesive bandage protects the wound and scab from bacteria, damage, or dirt, so that the healing process of the body is less disturbed.

Acrylic acid contains the elements carbon (shown in black), oxygen (red), and hydrogen (blue).

The adhesive used in bandages is commonly an acrylic polymer. What is a polymer? **Polymers** are very big molecules made up of many smaller molecules chemically attached together in a repeating pattern. In fact, the word *polymer* is Greek for 'many parts.'

The smaller molecules that come together to form polymers are called **monomers** — small units that link together over and over to form a large polymer. Think of monomers like paper clips that link together to form a chain, and the chain is a polymer. By changing the type of monomer used, chemists can make polymers with many different characteristics. Acrylate monomers are one type that is especially useful in making glues.

We've all had cuts and scrapes that adults help us take care of at home. But what about more serious wounds — the kinds that involve a trip to the doctor? In selecting a way to close up patients' wounds, today's doctors have many different choices, including sutures (also called "stiches"), staples, adhesive strips, and adhesive glues.

Doctors use adhesive glue — also called "skin adhesive" or "liquid stitches" — to close both major and minor wounds. Skin adhesives have many benefits, such as less pain, antibacterial activity, and less visible scars. They are very effective in closing small, straight wounds on sensitive areas like the face and head.

Most skin adhesive glues used today are made from a type of acrylate polymer known as **cyanoacrylate**. At first, cyanoacrylates were used for non-medical purposes. Have you ever heard of superglue? It was not until 1998 that the U.S. Food and Drug Administration approved a special kind of cyanoacrylate for medical use. Medical cyanoacrylates are less toxic than the regular superglue your parents might use around the house.

What is it that makes acrylates so sticky? The answer is found at the molecular level. The **atoms** in the acrylates tend to have an attraction to other molecules, a force that is similar to what you see in static cling. You can see static cling happening when your clothes stick together as they come out of the dryer, or when you rub a balloon on your head to make it stick to a wall. Stickiness can also come from the glue flowing into the gaps and crevices and holding tight within itself.

One thing for sure is that glues and adhesives can be used in many different ways, as long as we find the right kind of glue for the job!

***Dr. Verrill Norwood** is a Professor of Chemistry at Cleveland State Community College in Cleveland, TN.*

What Kind of Glue?

By Alex Madonik

If you are making something, you probably need to stick stuff together. Chances are, you will use an adhesive or glue of some type. Humans have been using glue for thousands of years, going back to caveman times. Over the years, we have developed an amazing variety of glues, which we use for nearly every purpose.

Why are adhesives sticky? Adhesives are made of molecules, combinations of atoms that may attract other groups of atoms. It's sort of like static electricity, but more permanent. Other types of adhesives flow and mix on a surface, and are so thick (or viscous) that they hold things together. Think about how honey makes your fingers stick together if you get some on them.

Some glues are sticky polymers dissolved in water or another liquid, like common white glue. As the polymers dry, the liquid evaporates and the solid, sticky adhesive stays behind.

Other glues help things stick because of a chemical reaction. **Silicone** and cyanoacrylate glues, like Krazy Glue and Gorilla Glue, react with water vapor in the air and harden through a chemical reaction.

Because water helps them harden, cyanoacrylates can be used to close wounds without stitches. Be sure to read the other article in this issue of *Celebrating Chemistry* about wound adhesives!

Epoxy glues have two parts that start the chemical reaction when mixed together. Special epoxy glues used by dentists harden when exposed to ultraviolet light. The bonds made by epoxy glues are waterproof and strong.

There are so many differences in the kinds of materials you may want to stick together that we have practically zillions of types to choose from.

Here are some common kinds of glue you may have used.

- **Elmer's School Glue** — This glue is not runny, and is washable, safe, and nontoxic, so it's good for everyone to use and is easy to clean up. It works for joining lots of materials for school crafts projects.
- **School Paste** — This comes in a tub with a brush attached to the lid. It is very useful for making posters or papier-mâché models.
- **Glue Stick** — Has the advantage of being very easy to use for joining paper, as it can be applied directly to the pieces to be joined.
- **Wood Glue** — Is used for making furniture and cabinets. It has to be strong and resistant to moisture and humidity. The glue has to be good at filling in gaps and imperfections in the wood surface.
- **Spray Glue** — Comes in aerosol cans and can be used for gluing big projects, like mounting a poster or photo enlargement.
- **Fabric Glue** — The small fibers in fabric need a special glue. Fabric glue can be used to attach patches or repair seams.
- **Hot Glue** — Uses a special 'heat gun' to melt a stick of glue. The glue melts, and when it cools it makes a strong, flexible joint. It is very useful for arts and crafts.

And here are a couple of uncommon glues.

- **Hide Glue** — Has been used to make cellos and violins for hundreds of years and is still used today. It comes from animal skins, bones, tendons, and other tissues, similar to gelatin. It is applied warm and forms a strong bond when set.
- **Dental Glue** — If you have braces, you know they were glued onto your teeth using a special orthodontic glue. This glue is a special resin that hardens when exposed to a special light source. Dental glues are non-toxic and unaffected by the saliva and moisture in a mouth.
- **Shellfish Glue** — Mussels, barnacles, and oysters attach to rocks using an adhesive protein they make themselves. Now scientists have created a manmade version of this natural glue that can be applied and cured under water. It could be used for repairing boats or securing piers or buoys. They may also be used for surgery.

No matter how big or small, chemistry has the right glue for the job! Chemists work in the lab to develop glues and adhesives before they are produced in a factory and then sold in the store. See if you can spot at least 6 places in the illustration below where you can use glues, tapes, or adhesives around your home. Can you think of other situations where the types of glue mentioned in this article could be used? You might find adhesives in surprising places!

***Dr. Alex Madonik** is a Chemistry Instructor at Peralta Community College in Oakland, CA.*

By Bill Doria

Preserving Beautiful Works of Art with Glues and Adhesives

Glues and adhesives are everywhere — even in places you might not expect!

If you've ever taken a trip to an art museum, you may have seen beautiful paintings and sculptures that are hundreds of years old. Imagine how much dust and dirt might collect on the artwork in that long a time, and imagine how much the sun and heat might dry them out! But all those paintings still look great after such a long time — and chances are that glues and adhesives help to keep them that way!

Glues and adhesives are especially useful in taking care of works of art. "It's amazing — I take them for granted," says Claire Taggart, an art historian and art conservator at the Nasher Sculpture Center in Dallas, Texas. She repairs sculptures and paintings that have been damaged, and helps keep them looking beautiful and new — and she uses adhesives every day! "We use adhesives to repair flaking paint, for structural repair, and much more. I'm almost always thinking about adhesives and how they can be used."

Glues can come from unexpected places. Take isinglass, for example. Isinglass is one of the most useful glues for repairing ancient parchments that have been torn or damaged. Isinglass is made from the swim bladders of a kind of fish called a sturgeon. It's a form of collagen, the same protein that's found in your skin, tendons, and cartilage. Isinglass is especially useful for repairing paper, because it doesn't have to be mixed with water, which would weaken the paper. Water could also make the paper tear more easily, since the water disrupts the forces that hold the paper fibers together.

A torn piece of parchment is treated with isinglass.

Consolidants are another type of adhesive useful for works of art. Consolidants are used to treat the edges of broken objects so that they can be joined together by glues. For example, suppose you're a brave archaeologist with a bullwhip and floppy hat! You've just discovered an ancient terracotta vase, but it's broken into a hundred pieces, and some of them are very tiny. It won't be possible to join the pieces together just by applying glue to each tiny piece, because some of them will be too fragile and crumble into powder.

A 19th-century luminaria (candle holder) from Guatemala. The edges of the shards will be coated with a consolidant to protect them from damage, and then they'll be glued together.

That's where consolidants come in. As Taggart says, "To join together materials that are soft or porous, we use a consolidant to harden the edges so that the pieces can adhere better to each other." Consolidants are also used on damaged paintings to prevent paint on canvas or other surfaces from flaking off. Consolidants such as polyvinyl acetate or polyvinyl alcohol are commonly used.

The repaired luminaria. As good as new!

As useful as adhesives are in helping us repair artwork, they also have a dark side — often, adhesives are part of the problem in damaged works of art! "There are situations where the repair has been done by a well-meaning professional or owner, but the repair was made using the wrong type of adhesive, like superglue," says Taggart. Nothing will reliably dissolve superglue! "Sometimes it's not possible to remove it without damaging the artwork.

So, adhesives and glues can rescue your favorite sculpture or painting — or cause permanent damage to it! It takes experts who love both art and chemistry to take care of artworks so that they can be enjoyed for hundreds more years. Maybe that could be a job for *you!*

Dr. William Doria *is an Associate Professor of Chemistry at Rockford University in Rockford, IL.*

How Many Times Can You Stick a Post-It Note?

By Keith Michael Krise

SAFETY SUGGESTIONS

- Safety goggles required
- Do not eat or drink any of the materials used in this activity

Disposal: There are no hazardous materials used in this activity. All materials can be disposed of in the trash after the activity.

Note: Follow Milli's Safety Tips found in this issue of *Celebrating Chemistry*.

Introduction

Post-It Notes are small pieces of paper with a strip of adhesive along the top edge of its back side. Unlike other kinds of tape, the adhesive on Post-It Notes allows the paper to be stuck to surfaces, but also to be easily peeled away, and re-stuck to other surfaces.

A 3M scientist, Dr. Spencer F. Silver, discovered the adhesive on Post-It Notes by accident, but did not have a use for it at first because it was not very sticky. Later, Art Fry, another 3M engineer, was marking pages in a choir songbook using small pieces of paper. The trouble was, the paper would never not stay in place, and would fall out of his book.

Then Fry, who knew about Dr. Silver's new glue, had a great idea: he could use the new adhesive for removable bookmarks! In 1980, after years of hard work, the removable bookmarks with the not-so-sticky adhesive were first sold as the classic yellow Post-It Note that everyone knows today. Post-It Notes have been a success and, 40 years later, they are found in schools, homes, offices, and choir practices (of course!) around the world! Let's investigate the stickiness of Post-It Notes!

Materials

- Post-It Notes
- Sand
- Water
- Smooth, dry, and clean surface (kitchen counter, window glass)
- Rough surface (brick, concrete)
- Glue stick
- Small squares of paper

What did you observe?

What happens to the Post-It Note and the temporary "sticky note" after repeated sticking, unsticking, and re-sticking to different kinds of surfaces? Record your observations in the table below.

Surface Type	Post-It Note	Temporary "sticky note"
Sandy		
Wet		
Rough		
Skin		

Procedures

1. Take a new Post-It Note and stick it to a smooth, dry, and clean surface. Then remove the note and re-stick it to the surface in the same place. Continue to stick and unstick the note until it no long will remain stuck on the surface. Keep track of how many times you do this.
2. Repeat this process with a new Post-It on each of the following:
   a.) a surface covered with a small amount of sand
   b.) a smooth surface made wet with a few drops of water
   c.) a rough surface
   d.) the skin on your hand
   e.) somewhere on your clothing

   For each surface you tested, how many times could you stick, unstick, and re-stick the Post-It Note? What did you observe after repeated sticking and unsticking on each surface?
3. Record your observations for each surface in the "What did you observe?" section.
4. You can also make your own temporary "sticky-note" using a glue stick. On one edge of a small piece of paper, spread a small strip of glue. For your temporary "sticky-note," how many times can you stick, unstick, and re-stick it on the different surfaces you used above? What did you observe after repeated sticking and unsticking on each surface?

Which surface was the *best* for repeated unsticking and re-sticking of the Post-It Note? Why do you think this might be?

Some people use sticky notes on their clothes to help them remember a job or errand they are to do. Does that seem like a good idea?

How did the temporary note work, compared to the Post-It Note?

How does it work?

Unlike more permanent adhesives, the adhesive found on Post-It Notes is made up of a single layer of small spheres connected to the paper of the sticky note, but that do not evenly cover the surface. This layer of spheres has the appearance of the surface of a basketball. Because of the space between these spheres and the soft, stretchy material the spheres are made of, the adhesive does not stick strongly and can be easily stuck, unstuck, and re-struck without tearing when removed!

***Dr. Keith Michael Krise** is an Associate Professor of Chemistry at Gannon University in Erie, PA.*

The Adventures of Meg A. Mole, Future Chemist

Dr. Chelsea Davis

In honor of this year's National Chemistry Week theme, "Sticking with Chemistry," I traveled to the School of Materials Engineering at Purdue University in West Lafayette, Indiana. Here I met Dr. Chelsea Davis, a chemist who studies adhesives and glues. A materials chemist who studies adhesives is also known as a polymer chemist. I know a lot of my friends use glue in their school projects, so I could not wait to learn more about the chemistry behind Dr. Davis' work!

"So, what does a materials chemist do?" I asked Dr. Davis. She replied, "I measure how sticky surfaces are. I try to understand why some surfaces are stickier than others. I have a fancy microscope that uses lasers to see colors in 3D. I use wrinkles and cracks to change how sticky rubber surfaces are. I build my own machines to measure adhesion."

Dr. Davis brought me into her laboratory and continued to tell me more about her work. She explained, "Most of my experiments are really little. It is normal for many of my samples to fit on the tip of your finger. When people come into my lab, they normally see me with my head really close to my work, wearing a jeweler's visor that helps me see little things. The visor makes my eyes look really big and my students laugh when they see me in them." I did laugh when she put the visor on for me! It was very neat to see how something so small could be so helpful in the world.

I really enjoyed my time visiting with students in in Dr. Davis' lab, but she explained that she does most of her work in her office. She explained, "I have several students who work with me on research. We meet together in my office, and then they spend most of their time doing the experiments in the lab. I miss working on experiments myself — but this way, I get to think about many different research projects at the same time. My students bring me new data all the time, and I get to work with them to figure out what it means."

Dr. Davis told me more about a project she was working on for the roads in Indiana. I was a bit confused about which adhesives would be needed for roads, so she told me about it in more detail. She said, "I designed a new way to test how strong the adhesion was for temporary pavement marking tapes. These are the tapes that road construction workers use to mark traffic lines when they are making new roads. It's important that these tapes are really sticky in different conditions. Sometimes they aren't as sticky when they get cold or wet. Since I live in Indiana, this is really important here as well." Lines on the road are very important for everyone.

Growing up, Dr. Davis really enjoyed math and Spanish, but told me about an experiment she did as a child that she still uses in her classroom as a demonstration today. "I remember making slime with Elmer's Glue and borax in elementary school. That was my first memory of a science experiment," she said. It wasn't until high school that she realized she wanted to be a scientist. She said, "One day when I was about 16 years old, a scientist came to our chemistry class to teach us about polymers. She held up a bowling ball and said, 'This is one molecule.' From that moment on, I was hooked. I attended science camp at her college that summer and haven't stopped learning about science ever since."

I asked Dr. Davis what she liked the most about her job. "I love watching the expression on my students' faces the first time that an experiment really works. Their excitement is contagious and makes me want to do more." I cannot wait to see what Dr. Davis does next!

Personal Profile

Birthday? August 23

Favorite food? Dr. Davis is obsessed with chickpeas!

Favorite pastime/hobby? Crocheting huge blankets

What kind of interesting projects are you working with now?
One of my students is working on a project to invent a new type of sticky surface that changes its stickiness depending on how you attach it to surfaces. She built her own adhesion tester, and is getting some really cool results now.

Word Search

Try to find the words listed below — they can be horizontal, vertical, or diagonal, and read either forward or backward.

R	P	B	R	Y	M	R	Y	E	W	R	O	C	F	W
Q	W	O	W	L	O	K	N	P	I	W	Y	E	N	E
Y	I	F	L	T	C	O	F	S	E	A	T	X	X	F
N	Y	Q	Y	Y	C	I	Y	Y	N	M	N	F	R	C
O	S	S	K	I	M	G	J	O	D	F	P	S	D	F
I	U	X	L	C	I	E	A	P	I	P	P	A	M	B
S	W	I	L	W	A	C	R	K	S	O	L	T	M	C
E	S	R	Y	E	R	T	N	O	I	S	E	H	D	A
H	L	R	U	Y	V	J	K	N	L	X	J	B	T	S
O	K	R	L	W	E	I	M	O	N	O	M	E	R	O
C	I	A	E	P	G	V	S	P	V	Z	U	Q	K	L
Q	T	A	O	V	Q	E	U	E	G	F	O	E	Y	V
E	S	X	I	D	S	P	Z	H	H	I	Y	Z	J	E
X	Y	E	U	L	G	A	V	L	P	D	R	Q	C	N
W	O	Z	G	E	N	T	Q	V	V	L	A	N	M	T

ADHESION	CYANOACRYLATE	MONOMER	SOLVENT
ADHESIVE	EPOXY	POLYMER	TACK
COHESION	GLUE	SILICONE	TAPE

For answers to the word search, please visit the *Celebrating Chemistry* Archive at **www.acs.org/ncw**.

Testing Tape Stickiness

By David Heroux and An-Phong Le

SAFETY SUGGESTIONS

- Do not eat or drink any of the materials used in this activity
- Thoroughly wash hands after this activity

Note: Follow Milli's Safety Tips found in this issue of *Celebrating Chemistry*.

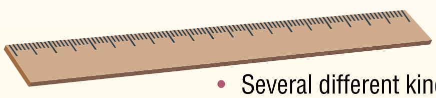
Introduction

How can we measure how sticky an adhesive tape is? This question is more complicated than it seems!

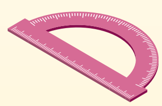
We can describe stickiness in different ways. As you have already learned, adhesion describes how strongly the tape and the surface bond to each other. Cohesion describes how strongly the adhesive molecules on the tape attract and hold on to each other. **Tack** describes how quickly a bond forms between the tape and the surface.

Scientists customize tapes for specific uses by balancing adhesion, cohesion, and tack. For example, high-tack tape sticks quickly to a surface, but it may be difficult to move later. In this activity, you will be a scientist testing the tackiness of different tapes. Adhesive scientists around the world use tests like this!

Materials



- Ruler
- Scissors for cutting tape
- Several ball bearings or large marbles (you'll need separate ones for each test). You can try using balls of different sizes, masses, or materials.
- Book
- Several different kinds/brands of tape, such as duct tape, masking tape, cellophane tape, or packing tape.
- Protractor to measure angle of ramp (optional)
- Wipes to clean the test marbles or balls



Procedures

1. Build the *rolling ball tack tester* following the design illustrated above.
2. The ball bearing or marble needs to roll easily down the incline. Make an incline out of cardboard strips folded into a 'V' shape or a carboard tube from a roll of paper towels. You could also use the middle of an open thin book or magazine.
3. Use books or blocks to support one end of the incline until the slope is about 30 degrees. You can use a protractor or your smartphone to measure the angle. There should be little to no drop between the incline and the test tape surface.
4. Mark the ball's starting point at the top of the incline with a pencil or Post-It note. It is very important to release the ball at the same point for each test.
5. The tape will be sticky-side-up when the ball rolls onto it. Place about 10 inches of tape, sticky-side-up, on your work surface. The sticky surface should begin at the lower end of the incline.
6. Use masking tape to fasten each end of the tape to the flat surface. You will repeat this for each tape to be tested.
7. Hold the ball at the starting point and then carefully release it. Allow it to roll down the incline onto the tape, where it will stick. You may need to adjust the angle of your ramp or starting point until you get good results.
8. Measure the distance from the base of the ramp to the point where the ball or marble stops, and enter this distance into your data table.
9. Do three trials for each type/brand of tape. This is what scientists always do: repeat their measurements to make sure their results are correct.

Notes: The ball bearings or marbles used in this activity need to be washed and dried before they are used again. You also need to use a new piece of tape each time you do the activity.

What did you observe?

Kind of Tape	Distance Traveled		
	Trial 1	Trial 2	Trial 3

How does it work? / Where's the chemistry?

Pressure-sensitive adhesive tapes are coated with an adhesive made of large molecules called *polymers*. Pressing the tape on a surface causes these large polymers to spread out. The spread-out adhesive now interacts and bonds with the surface, causing the tape to stick. The tack of a tape depends on how easily the adhesive can spread out and interact with the surface.

Does a high-tack tape let the ball roll a short distance or a long distance? Based on your measurements, which tape had the highest tack? Did the same tape have the highest tack for all of the different balls you rolled?

Here are some more questions that you might want to explore:

- Try rolling balls with different masses. If you roll a heavy ball and a light ball down the tape, which one do you think exerts more pressure? How did the mass of the ball affect how far it rolled on the tape?
- How does the roughness of the ball affect how quickly a tape will stick?
- What happens to the tack of the tape if you reuse it for several tests? Can you see any differences on the tape surface?

What other questions can you investigate about tapes? Experiment to find the answers!

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Dr. An-Phong Le *is an Associate Professor at Florida Southern College in Lakeland, FL.*

Words to Know

Adhesion – different things sticking together.

Adhesive – stuff used to stick two things together.

Atom – the smallest unit of a chemical element that has the characteristics of the element.

Polymerization – a chemical reaction that starts with a few monomer molecules and keeps going by adding more monomer units to create a long polymer chain.

Chemical reaction – the process of rearranging atoms between substances to make different substances.

Cohesion – bonding that holds one kind of stuff together.

Compound – a pure material that combines two or more elements in a specific, stable form.

Cross-link – a new bond that connects two polymer chains together. Cross-links convert liquid glues into solid polymers.

Cyanoacrylate – a very reactive monomer that hardens by reacting with water from the air. Water starts a "chain-reaction" that causes the cyanoacrylate monomers to link up and work as a glue.

Element – a pure substance, such as copper or oxygen, made from a single type of atom.

Epoxy – a type of glue that comes in two parts that react chemically to form very strong bonds.

Glue – sticky liquid with adhesive dissolved in a solvent.

Molecule – the smallest unit of a chemical compound.

Monomer – small building-block molecules that can link up to make polymers.

Polymer – long molecules built up from many small monomer molecules linked together.

Silicone – flexible polymer containing silicon-oxygen bonds. It hardens by reacting with water from the air. Water activates the ends of the silicone polymer chains to form cross-links.

Solvent – liquid that dissolves a solid.

Tack – how quickly a bond forms between the tape and the surface.

Tape – plastic or paper strip with a solid adhesive on one side.

Wetting – to cover a surface with water or any other liquid.

About the American Chemical Society?

The American Chemical Society (ACS) is the largest scientific organization in the world. ACS members are mostly chemists, chemical engineers, and other professionals who work in chemistry or chemistry-related jobs. The ACS has over 150,000 members. ACS members live in the United States and different countries around the world. Members of the ACS share ideas with each other and learn about important discoveries in chemistry during scientific meetings held around the United States several times a year, through the use of the ACS website, and through the many peer-reviewed scientific journals the ACS publishes. The members of the ACS carry out many programs that help the public learn about chemistry. One of these programs is National Chemistry Week, held annually during the third week in October. ACS members celebrate by holding events in schools, shopping malls, science museums, libraries, and even train stations! Activities at these events include carrying out chemistry investigations and participating in contests and games. If you'd like more information about these programs, please contact us at **outreach@acs.org**.

About Celebrating Chemistry

Celebrating Chemistry is a publication of the ACS Office of Science Outreach in conjunction with the Committee on Community Activities (CCA). The Office of Science Outreach is part of the ACS Division of Education. The National Chemistry Week (NCW) edition of Celebrating Chemistry is published annually and is available free of charge online or in print through your local NCW Coordinator. Learn more about the online educational resources and activities available for this year's National Chemistry Week celebration at **www.acs.org/ncw**.

About the Adhesion Society

The mission of The Adhesion Society is to promote the advancement of the science and technology of adhesion and the dissemination of this knowledge, promote education and training in the science and technology of adhesion, and provide recognition of accomplishments in the international adhesion science and technology community. Find out more at **https://www.adhesionsociety.org/**.

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