Biomimicry: Synthetic Gecko Tape by Nanomolding

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General Description

Facilitated Activity, Classroom Activity

"Biomimicry: Making Gecko Tape" is a hands-on activity in which audiences use a material similar to one that scientists are researching to mimic the ability of gecko toes to adhere to vertical surfaces.

Program Objectives

Big idea: The toes of a gecko are divided into nanoscale hair-like structures. When a gecko places its foot on the wall and curls its toes, these nanoscale structures interact with the wall on the atomic level. The forces (van-der-waals forces) between the nano-structured hairs of the gecko foot and the atoms of the wall are strong enough to hold up the gecko. Scientists are working to make materials that use gecko-like nano-structures for adhesion.

Learning goals:
As a result of participating in this program, visitors will be able to:
1. Define biomimicry: Imitating nature's best ideas to solve human problems
2. Recognize that gecko feet have structures small enough to be measured in nanometers or billionths of a meter, that allow them to climb vertical surfaces as well as hang upside down on ceilings.
3. Understand that nanoscale hairs are able to interact with the atoms of the surface the gecko is climbing on.
4. Understand that scientists are researching man-made materials that mimic the properties of the gecko foot.

NISE Network Main Messages:
- [x] 1. Nanoscale effects occur in many places. Some are natural, everyday occurrences; others are the result of cutting-edge research.
- [x] 2. Many materials exhibit startling properties at the nanoscale.
- [x] 3. Nanotechnology means working at small size scales, manipulating materials to exhibit new properties.
- [ ] 4. Nanoscale research is a people story.

[ ] 5. No one knows what nanoscale research may discover, or how it may be applied.
[x] 6. How will nano affect you?

Biomimicry: Making Gecko Tape

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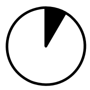
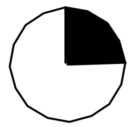
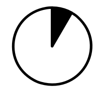
Time Required

Set-up	Program	Clean Up
		
10 minutes	15 minutes	5 minutes

Background Information

Definition of terms

Nano is the scientific term meaning one-billionth (1/1,000,000,000) It comes from a Greek word meaning “dwarf.”

A *nanometer* is one one-billionth of a meter. One inch equals 25.4 million nanometers. A sheet of paper is about 100,000 nanometers thick. A human hair measures roughly 50,000 to 100,000 nanometers across. Your fingernails grow one nanometer every second.

(Other units can also be divided by one billion. A single blink of an eye is about one-billionth of a year. An eyeblink is to a year what a nanometer is to a yardstick.)

Nanoscale refers to measurements of 1 – 100 nanometers. A virus is about 70 nm long. A cell membrane is about 9 nm thick. Ten hydrogen atoms are about 1 nm.

At the nanoscale, many common materials exhibit unusual properties, such as remarkably lower resistance to electricity, or faster chemical reactions.

Nanotechnology is the manipulation of material at the nanoscale to take advantage of these properties. This often means working with individual molecules.

Nanoscience, nanoengineering and other such terms refer to those activities applied to the nanoscale. “Nano,” by itself, is often used as short-hand to refer to any or all of these activities.

Program-specific background

Geckos are able to climb on walls—even walk on ceilings—but they don't use glue, a chemical adhesive, or suction. If you touch a gecko toe it feels soft and smooth, and not sticky, at all. In fact, nanoscale structures on the underside of their feet give geckos the amazing ability to attach to a wide variety of surfaces.

Gecko toes actually have very fine hairs (setae) packed 5,000 per mm^2 (three million per square inch) into the ridges (or lamellae) found on their underside. A single seta of the Tokay gecko (Gekko gecko) is roughly 110 micrometers long and 4.2 micrometers wide. The end of each seta has about 400–1,000 branches ending in a spatula-like structure about 0.2–0.5 µm long. When a gecko places its foot on a wall or other surface and curls its toes, these nanoscale spatulae get so close to the nooks and crannies of the wall's surface that their atoms interact with the atoms of the wall.

If toes were sticky like tape or relied on strong suction, it would be difficult for a gecko to walk or run, as it would be too hard to pull its feet from the surface. The forces between the atoms of the gecko foot and the atoms of the wall (called Van der Waal's forces) are relatively weak forces when compared to normal bonding forces. The contact area between foot and surface must big enough so that these individual weak forces can add up to a very strong force, strong enough to hold up the Gecko.

Researchers at University of California, Berkeley, as well as in other labs around the world have been inspired by the gecko foot's natural properties. They are currently trying to create a new kind of "tape" by mimicking the behavior of the gecko foot.

Materials

For making the gecko "tape"

- Silicone RTV Mold-Making System (http://www.tapplastics.com/) -
  - Side A 1 lb, $20.50
  - Side B Fast Catalyst (Blue) 0.1 lb, $3.95
- Polycarbonate Millipore Track etched Isopore membrane filter (http://www.millipore.com/) TMTP04700, 5µm pore size, 47 mm diameter $84.00 for pack of 100 filters
- Wide double sided sticky tape
- Disposable mixing container (any smooth glass/plastic wide mouth container)
- Petri dishes (1 for each piece of tape)
- Stirrer sticks or plastic disposable knives
- Weighing scale

Program Presentation

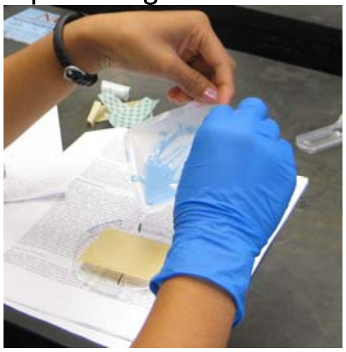
- Small plastic fruit basket or plastic cup
- String
- Paper clips
- Weight (i.e., pennies or loose bolts and nuts)
- Live Gecko in transparent holding tank
- Hand held magnifying glasses

Set Up

Time: (5 minutes)
(one time: 45 minutes to make the gecko tape)

Making the gecko "tape" (24 hours in advance)

1. Tape the filter paper onto the back of the Petri dish with two-sided tape. The filters are made of a transparent material and are separated by blue colored paper. Always handle the filter paper with forceps and clean gloves. There are two purposes for the double-sided tape. It holds the filter in place. It also seals the filter on one side, so that the silicon does not flow through. The tape must be at least as large as the filter itself. If you use two pieces of sticky tape they must not overlap or have a gap between them. Smooth down the filter paper with a clean, gloved finger to eliminate any air bubbles.
2. Mix the two components of the silicone in a disposable container. The ratio is 1 part Side B to 10 parts Side A **by weight**. 0.5 gm of Side B to 5gm of Side A is sufficient to cover one filter completely.
3. Stir the two components very well. The silicone is ready when there are no streaks and the color is a uniform blue (hint: look from the bottom of the container for any spots that have been missed). You only have 30 minutes of working time once you start mixing before the mixture starts to set.
4. Carefully pour the mixture onto the filter from a height of 4-6 inches; this helps in expelling the air bubbles. Make sure that a uniform layer is covering the filter. You can tilt and shake the Petri dish to ensure that the silicone covers the entire filter, do not use fingers or any kind of tool to spread. Once the silicon is on the filter paper, visible air bubbles on the top surface are unimportant. In the photo shown below, the transparent filter is on top of the double sided yellow sticky tape. The tape is larger than the diameter of the filter.



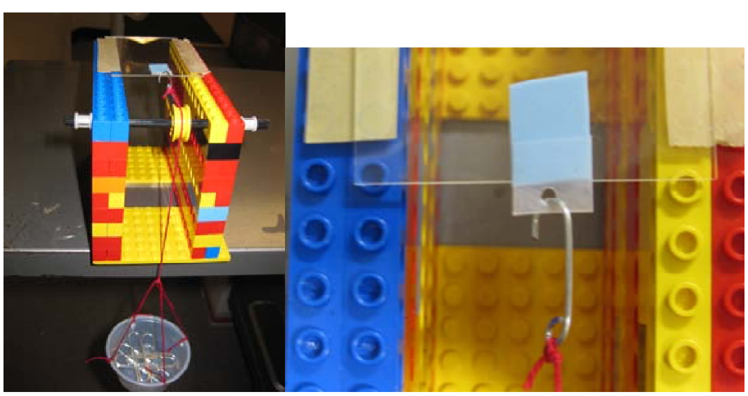
5. Set the Petri dish aside to cure overnight, it will be ready for use in about 24 hrs. After 24hrs it can be very easily peeled of the Petri dish. The photo here shows a dry tape before being peeled off the filter (the filter is transparent and is taped on a double sided yellow stick tape).

For testing the gecko "tape"

1. Attach string to the small plastic fruit basket or other container so that it can be hung.
2. Attach a paper clip to the other end of the string.
3. Attach the paper clip to the gecko tape by carefully piercing or clipping onto one end of the tape.

Notes to the Presenter: During testing it is important the tape is completely flat on the surface that you want it to "stick" to. The gecko as well as the gecko tape 'stick' only under shear forces (forces parallel to the surface), when there are no forces acting on them, i.e. under no-loading condition the tape is in a 'non-adhesive state'. It is similar to the behavior of a refrigerator magnet, as you pull down on a magnet it sticks harder.

Horizontal setups as described here work best. If you use a vertical setup like a window or wall, the basket must be hanging completely free (not touching the wall). If the basket is touching the wall there will be a horizontal force exerted on the basket, perpendicular to the force of gravity. For the fibers to be engaged only shear forces (parallel to the surface) should be applied. The clip or hook that is used to connect the tape to the basket should not be on the same surface as the tape. Thus it is easiest to make sure that the clip/hook are offset from the surface that the tape is mounted on (see figure) if you use a horizontal setup. In this figure a small piece of adhesive was used to attach the hook, in most cases it better to use small binder clips to avoid damaging the tape.



Program Delivery

Time: (15-20 minutes)

Safety:

1. It is very important that the filters be always handled through gloves, the pores on the filter are so small that dirt can completely block them.

Procedure and Discussion:

Have a gecko in the room, preferably in a clear walled plastic or glass box that can be turned gently upside down. Pass the gecko in the box around. Have visitors make observations. You may want to have visitors use magnifying glasses for this.

Show photographs of a gecko foot at increasing magnifications (images can be downloaded from NISE Network Image Collection http://www.nisenet.org/viz_lab/image-collection). Point out the branching of the hair-like structures on the gecko's foot.

Discussion:

Question: What do you know about the Gecko? What is the most interesting fact that you know about the Gecko? Get all possible answers; give pointers that may lead to their climbing ability.

What mechanism might the Gecko use to climb wall?

Geckos have the extraordinary ability to walk on almost any surface including polished glass. Lets us try to find the mechanism with which a Gecko climbs. -- Have visitors share their observations and suggest possible mechanisms of climbing.

Discussion of different theories that visitors may propose:

There is no residue left behind as the gecko walks, so geckos don't use glue

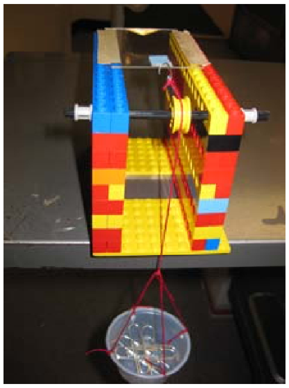
Suction does not work very well on trees, branches and rocks.

Share information: Researchers charged the air around a gecko with X-rays to form charged molecules (ions). This would have caused any electric charge to leak away if the geckos used static electricity. The feet still stuck.

Share information: Gecko feet stick to walls even underwater or in a vacuum.

Procedure:

1. Attach the tape to the surface similar to the one shown in the figure.



2. Slowly and gently add weights (pennies, clips, nuts, bolts etc) to the container. Initially you may need to press on top of the tape to ensure that the structures start to interact with the surface (called a pre-loading force). As you add sufficient weight, this becomes unnecessary as the pull of the basket will exert a shear force parallel to the tape which will cause the tape to hang by itself. The load bearing capability of a sample can be determined by increasing the load until the tape detaches itself from the surface.

Tips and Troubleshooting:

1. Do not allow visitors to bang on the gecko container. Keep a dark cloth nearby and cover the gecko container when it is not being observed.
2. If contamination (like dust or fingerprints) is observed on the surface of the tape, it can be cleaned with ethanol and air-drying.

Common Visitor Questions

1. If sheer forces (forces parallel to the surface) are essentiall, then how does a Gecko stick upside down to the ceiling?

Answer: Upside down on the ceiling, the Gecko foot is still acting under sheer forces, it pulls all of its 4 feet inwards, thus the direction of the force is towards the body of the gecko.

Going Further…

Refer to the pdf file Discussion/classroom format for extensive discussion and further details.

Clean Up

Time: (5 minutes)

"Gecko tape" should be rinsed with ethanol and left to air dry before it is used again.

Universal Design

This program has been designed to be inclusive of visitors, including visitors of different ages, backgrounds, and different physical and cognitive abilities.

The following features of the program's design make it accessible:

[x] 1. Repeat and reinforce main ideas and concepts
The basic idea is repeated multiple times so visitors have several opportunities to grasp the concept.

[ ] 2. Provide multiple entry points and multiple ways of engagement

[x] 3. Provide physical and sensory access to all aspects of the program
Visitors are given the opportunity to actively participate (kinesthetic) as well as listen and watch.

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Any opinions, findings, and conclusions or recommendations expressed in this program are those of the author and do not necessarily reflect the views of the Foundation.