

Lotus Leaf Effect



Organization: University of Wisconsin-Madison Materials Research, Science and Engineering Center (MRSEC) Interdisciplinary Education Group

Contact person: Greta M. Zenner, Kim Duncan

Contact information: gmzenner@wisc.edu,
kaducan@wisc.edu, 608-263-7128

General Description

Cart demo

This activity explores how nature has inspired nanotechnology. We demonstrate the self-cleaning ability of the lotus plant and the principles behind it. Visitors see nano-properties at work in nature and learn that these properties are also used in advanced consumer products.

Program Objectives

Big idea: Nanoscale features of materials can alter macroscale behavior

Learning objectives:

As a result of participating in this program, visitors will be:

Exposed how nanotechnology can improve materials in our everyday lives. Visitors will learn that scientists copied a surface in nature that protects leaves and used it to improve paint.

NISE Network Main Messages:

- 1. Nanoscale effects occur in many places. Some are natural, everyday occurrences; others are the result of cutting-edge research.
- 2. Many materials exhibit startling properties at the nanoscale.
- 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.
- 6. How will nano affect you?

Program/Demo Title

Table of Contents

General Description	1
Program Objectives	1
Time Required	Error! Bookmark not defined.
Table of Contents	2
Background Information	3
Materials	4
Set Up	5
Step 1:.....	Error! Bookmark not defined.
Program Delivery	5
Safety:	5
Procedure and Discussion:	5
Tips and Troubleshooting:.....	6
Common Visitor Questions	6
Going Further... ..	6
Clean Up	7

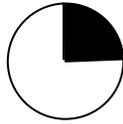
Time Required

Set-up



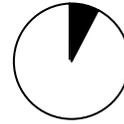
5 minutes

Program



10 minutes

Clean Up



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

Engineers have begun applying nanotechnology to products that we use in everyday life, mostly in the form of surface treatments. Visitors may already be aware of stain-resistant Nano-Tex fabric, which exhibits *hydrophobic* (water-

repellant or, literally, “water-fearing”) properties. This activity explores the nanoscience behind the lotus leaf--nature’s precursor to Lotusan[®] paint.

The *lotus effect*, first noticed in the leaves of the lotus, is a self-cleaning, water-repellant property found in some plants. Remarkably, despite constant exposure to dust, dirt, rain and other elements, the leaves of the lotus plant remain clean and dry. Scientists have discovered that this is because the surface of each leaf contains nanometer-sized waxy bumps that prevent dirt and water from adhering. Because the valleys between the bumps are too small for dirt particles to get into, the dirt stays suspended on the tops of the bumps. When a water droplet falls on the leaf, it is also suspended on top of the waxy bumps, creating a lot of *surface tension*.

Water is a polar molecule, meaning it likes to stick to, or pull on, other water molecules. This attraction causes water to bead up on a surface. Inside a drop of water, each molecule is being pulled in every direction by all the other water molecules that surround it. But at the surface the water molecules are only pulled one way – back into the drop. This pull back inwards toward the center of the drop creates surface tension. Tension around the entire outside of a bead of water makes the drop round instead of flat.

Normally, surface tension affects only the top of a water drop—the bottom sticks to whatever material the water is sitting on. But when the material is a lotus leaf, something very different happens. Nanoscale bumps on the surface of the leaf prop the drop up, so it is almost entirely surrounded by air. This creates surface tension on all sides, making the water bead up even more and stick to the leaf even less. In fact, the water adheres so loosely to the leaf that the tiniest movement causes the beads of water to roll smoothly off, taking any dirt particles with them. This makes the leaves self-cleaning.

Engineers have duplicated this “nano-mountain” structure in a product called Lotusan[®] paint. Buildings painted with Lotusan[®] self-clean every time it rains. The surface of the building always stays dry due to the lotus effect, preventing leaks. Through new advances in nanotechnology, scientists are also discovering ways to create other materials with microscopically bumpy surfaces that mimic the lotus leaf. They hope to make all kinds of self-cleaning and super-non-stick materials, such as self-cleaning windows, non-stick medical devices that will prevent blood clots, and kitchenware that can simply be rinsed and reused because food and other contamination can’t stick to it.

Materials

Lettuce leaves (grocery store)

Leaves from plants that exhibit the lotus effect (kale, turnip greens, collard greens, water lily leaves. Available at grocery stores and most plant nurseries)

Water

Cup for water
Water dropper
Tray to catch water
Towels (paper or cloth)
Poster (provided for download)

Set Up

Time: (5 minutes)

Place leaves in tray.
Fill cup with water.

Program Delivery

Time: (10 minutes)

Safety:

Very safe.

Procedure and Discussion:

Explain that the Lotus effect is a property of lotus leaves that keeps dirt and water from settling on them. Even if the visitor has never seen a lotus leaf, many other common plants exhibit this property. (This script uses kale, but collard greens, water lilies and other plants also work.)

On the table, point out the two different leaves and tell visitors which leaf is which. If necessary, explain that the kale leaf is not a lotus leaf, but behaves similarly due to the nanoscale features on its surface. Ask the visitor to list any differences they see between the two leaves. Invite them to touch the two leaves and explain any differences or similarities between them.

Now introduce the idea that water will behave differently on the two surfaces because of the nanoscale features on the kale leaf. Slowly place a few droplets of water onto each leaf. Ask visitors to observe the difference. The water flattens out and forms puddles on the lettuce leaf. However, on the kale leaf, the water beads up and easily rolls off if you tip the leaf.

Why does this happen? Explain that the two leaves, even though they don't look too different to our eyes, are very different on the nanoscale. These differences in leaf texture cause water to interact in different ways. The kale (or lotus) leaf has tiny nanometer-sized "fingers" on its surface. These tiny fingers are so small that water and dirt are too big to fit between them. So the water beads up and

rolls off, taking surface dirt particles with it. This is how the kale (and lotus) leaves stay clean and dry.

Commercial products have frequently taken their inspiration from natural phenomena. Explain that the burrs that stick to people and animals after a walk in an open field inspired scientists to create a synthetic mimic—Velcro! After looking at the burr closely, engineer George de Mestral noticed there were special hooks and loops that gave the burr its ‘stickiness’. Scientists and engineers have been similarly inspired by the nanostructure of the Lotus leaf and have developed special coatings and treatments that allow fabrics and paints to act the same way as a lotus leaf. Nano-tex[®] manufactures fabrics that are specially treated so that liquids bead up on their surface and stains don’t set. Also, a company called STO[®] manufactures a special kind of paint, called Lotusan[®], that repels dirt and water.

Tips and Troubleshooting:

Water has potential to be messy--have cleaning materials nearby.

Fresh leaves work best.

Providing a sample surface coated with Lotusan[®] would be interesting. However, attempts to prepare such a surface have been unsuccessful. Lotusan[®] paint requires a 30 day curing period to exhibit the ‘self cleaning’ properties. Even with the cure time, we did not see the self cleaning behavior. It may be possible to contact STO to further troubleshoot this issue.

Common Visitor Questions

Going Further...

Here are some resources you can share with your visitors:

Lotusan[®] website:

<http://www.stocorp.com/allweb.nsf/lotusanpage>

This STO[®] website has a very compelling video demonstration of the self cleaning properties of Lotusan[®] paint.

Lotusan[®] brochure:

[http://www.stocorp.com/webfiles.nsf/htmlmedia/s647+lotusan.pdf/\\$file/s647+lotusan.pdf](http://www.stocorp.com/webfiles.nsf/htmlmedia/s647+lotusan.pdf/$file/s647+lotusan.pdf)

Nanotex[®] (stain resistant fabrics)

<http://www.nanotex.com/index.html>

For other consumer products that utilize nanotechnology:

<http://www.nanotechproject.org/inventories/consumer/>

Clean Up

Time: (5 minutes)

Throw away leaves

Wipe up water

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 overarching main idea is explicitly stated at the beginning of the program, and reinforced by a hands-on activity and subsequent discussion.
 - A graphic poster (available for download) reinforces the overarching main idea for those visitors who prefer to visually digest information.
- [x] 2. Provide multiple entry points and multiple ways of engagement
 - The Kale/Lettuce leaf demonstration provides verbal, visual and tactile entry points into the programs main messages and learning objectives:
 - The presenter provides a verbal explanation of the differences between leaves that exhibit the lotus effect and those that don't.
 - Visitors are invited to feel for and visually observe differences between leaves that exhibit the lotus effect and those that don't.
 - Visitors can also read the relevant information on a poster.
 - Creating the connection to current consumer products provides another path of engagement.
 - This aspect of the program can be further emphasized by providing samples of the Nanotex[®] fabric and regular fabric.
 - Visitors can feel for differences between the two fabrics
 - Visitors can visually observe how the fabrics behave differently when in contact with water.

- [x] 3. Provide physical and sensory access to all aspects of the program
- The presenter verbally describes the differences in texture and appearance between the two different types of leaves.
 - The presenter verbally describes the differences in behavior of water when it comes in contact with the two different leaves.
 - Many different plants exhibit the lotus effect. The presenter should select a leaf that will be familiar to visitors.

To give an inclusive presentation of this program:

1. Examples of leaves being used for the visual display can be passed around the audience to allow visitors to feel for differences between regular lettuce, and leaves of plants exhibiting the lotus effects. Be sure to provide sufficient number of leaves so that visitors can feel the leaves early on in the program.
2. When dropping the water on the two different leaves, be sure that the leaves are visible to all members of the audience. Multiple stations can be used to allow for small groups at each table. Also, a camera can be used to project the 'experiment' onto a larger screen.
3. Some visitors may not be familiar with lotus leaves or lily pads. Select several types of leaves that exhibit the lotus effect to be used during the demonstration.
4. Visually displaying the similarity in behavior of lotus-like leaves and Nanotex fabrics (through a fabric swatch) would reinforce the connection between nanotechnology to everyday life.

This project was supported by the
National Science Foundation under Grant No. ESI-0532536.

