



## Nanotechnology Workshop – Teacher Resources

### OBJECTIVES:

- Participants will explore examples of nanotechnology in everyday life in addition to explaining the basics of nanotechnology research and design.

### ACADEMIC CONTENT STANDARDS:

- Science and Technology 3-5 A: Describe how technology affects human life
  - 3.1: Describe how technology can extend human abilities (e.g., to move things, to extend senses).
  - 3.2: Describe ways that using technology can have helpful and/or harmful results.
  - 4.1: Explain how technology from different areas (e.g., transportation, communication, nutrition, healthcare, agriculture, entertainment, manufacturing) has improved human lives
  - 4.2: Investigate how technology and inventions change to meet peoples' needs and wants.
- Science and Technology 6-8 A: Give examples of how technological advances, influenced by scientific knowledge, affect the quality of life.
  - 6.1: Explain how technology influences the quality of life.
- Physical Science 6-8 A: Relate uses, properties and chemical processes to the behavior and/or arrangement of the small particles that compose matter.
- Physical Science 9-10 A: Describe that matter is made of minute particles called atoms and atoms are comprised of even smaller components. Explain the structure and properties of atoms.

### VOCABULARY WORDS:

**Atom** – A basic unit of matter that consists of a dense central nucleus surrounded by a cloud of negatively charged electrons.

**Graphene** – A one-atom-thick planar sheet of carbon that is densely packed in a honeycomb shape.

**Lotus Effect** – Refers to the very high water repellency (superhydrophobicity) exhibited by the leaves of the lotus flower.

**Micron** – One millionth of a meter.

**Molecule** – A group of atoms bonded together.

**Nano** – The scientific term meaning one-billionth ( $1/1,000,000,000$ ). It comes from a Greek word meaning “dwarf.” How small is one-billionth? One blink of your eye is about one-billionth of a year. A marble is about one-billionth the size of the Earth.

**Nanometer** – One billionth of a meter. Nanometers are used to measure things that are too small to see, like atoms and molecules. A nanometer is about the length of 10 hydrogen atoms, laid end-to-end.

**Nanoparticle** – A nanoscale particle.

**Nanoscale** – Of a size measurable in nanometers or microns. At the nanoscale, many common materials exhibit unusual properties, such as remarkably lower resistance to electricity, or faster chemical reactions.

**Nanotechnology** – The manipulation of materials at the nanoscale to take advantage of the unusual properties matter at these tiny scales. This often means working with individual molecules.

**Static Electricity** – The build-up of electric charge on the surface of objects.

**Surface Area** – The term used to describe the area of an object that is exposed.

## EXTENSIONS AT COSI:

Innovation Showcase

- Visit the Innovation Showcase to learn more about the latest technologies and innovations.

## SAMPLE TEST QUESTIONS:

1. What is graphene?
  - a. A new material made from carbon nanotubes.
  - b. A one-atom thick sheet of carbon.
  - c. Thin film made from water.
  - d. None of the above.
2. Gravity plays:
  - a. Plays a strong role in nanoscale.
  - b. Do not play a strong role in nanoscale.
  - c. Is as important as other forces in nanoscale.
  - d. None of the above.
3. Surface area per unit volume for nanoparticles is:
  - a. Same as macro-size particles.
  - b. Higher than macro-sized particles.
  - c. Lower than macro-sized particles.
  - d. None of the above.

#### ADDITIONAL RESOURCES:

[www.cosi.org](http://www.cosi.org)

[http://pbskids.org/dragonflytv/games/game\\_nano.html](http://pbskids.org/dragonflytv/games/game_nano.html)

<http://www.guardian.co.uk/nanotechnology-world/nanotechnology-in-everyday-life>

<http://www.21-tech.org/blog/2012/05/09/diy-nano/>

## Nanotechnology Workshop Pre Visit Activities

### Paper Cutting

**INTRODUCTION:** What is the smallest unit of matter? An atom. During this next activity, you'll study how big an atom is and relate that size to

### **OBJECTIVES:**

- Students will begin thinking about nanoscale by exploring the size of an atom.

**KEYWORDS:** Atom, nanoscale, nanotechnology.

### **MATERIALS:**

- 1 strip of paper 28 centimeters long (11" inches)
- 1 pair of scissors

### **INSTRUCTIONS:**

- Take your strip of paper and cut it into equal halves.
- Cut one of the remaining pieces of paper into equal halves.
- Continue to cut the strip into equal halves as many times as you can.
- Make all cuts parallel to the first one. When the width gets longer than the length, you may cut off the excess, but that does not count as a cut.

### **WHAT'S GOING ON?**

|  |         |       |   |
|--|---------|-------|---|
| How far did you get? Here are some comparisons to think about! |         |       |   |
| Cut 1  | 14.0 cm | 5.5"  | Child's hand, pockets                       |
| Cut 2  | 7.0 cm  | 2.75" | Fingers, ears, toes                         |
| Cut 3  | 3.5 cm  | 1.38" | Watch, mushroom, eye                        |
| Cut 4  | 1.75 cm | .69"  | Keyboard keys, rings, insects               |
| Cut 6  | .44 cm  | .17"  | Poppy seeds                                 |
| Cut 8  | 1 mm    | .04"  | Thread. Congratulations if you're still in! |

|        |              |              |                                       |
|--------|--------------|--------------|---------------------------------------|
| Cut 10 | .25 mm       | .01"         | Still cutting? Most have quit by now  |
| Cut 12 | .06 mm       | .002"        | Microscopic range, human hair         |
| Cut 14 | .015 mm      | .006"        | Width of paper, microchip components  |
| Cut 18 | 1 micron     | .0004"       | Water purification openings, bacteria |
| Cut 19 | .5 micron    | .000018"     | Visible light waves                   |
| Cut 24 | .015 micron  | .0000006"    | Electron microscope range, membranes  |
| Cut 31 | .0001 micron | .0000000045" | The size of an Atom!                  |

Is there anything smaller? Yes, the size of an atom nucleus would take about 41 cuts! Scientists use advanced technology to explore the world of electrons and quarks that are at least 9,000 times smaller than a nucleus.

We can not see anything smaller than an atom with our eyes, even with the electron microscope. Physicists study much smaller things without seeing them directly.

Is there an end to the quest for the smallest and most basic elements in our world? The search began with the Greeks and continues as scientists search for the Building Blocks of the universe. These things are far beyond the range of sensory perception but not beyond the range of human understanding.

### How is this nano?

Although a metre is defined by the International Standards Organization as 'the length of the path travelled by light in vacuum during a time interval of  $1/299\,792\,458$  of a second' and a nanometre is by definition  $10^{-9}$  of a metre, this does not help scientists to communicate the nanoscale to non-scientists. It is in human nature to relate sizes by reference to everyday objects, and the commonest definition of nanotechnology is in relation to the width of a human hair.

Unfortunately, human hairs are highly variable, ranging from tens to hundreds of microns in diameter ( $10^{-6}$  of a metre), depending on the colour, type and the part of the body from which they are taken, so what is needed is a standard to which we can relate the nanoscale. Rather than asking anyone to imagine a millionth or a billionth of something, which few sane people can accomplish with ease, relating nanotechnology to atoms often makes the nanometre easier to imagine. While few non-scientists have a clear idea of how large an atom is, defining a nanometre as the size of 10 hydrogen, or 5 silicon atoms in a line is within the power of the human mind to grasp. The exact size of the atoms is less important than communicating the fact that nanotechnology is dealing with the smallest parts of matter that we can manipulate.

Source: <http://iopscience.iop.org/0957-4484/14/1/001>

**CONTENT STANDARDS:**

- Physical Science 6-8 A: Relate uses, properties and chemical processes to the behavior and/or arrangement of the small particles that compose matter.
- Physical Science 9-10 A: Describe that matter is made of minute particles called atoms and atoms are comprised of even smaller components. Explain the structure and properties of atoms.

**ACTIVITY SOURCE:** <http://www.miamisci.org/af/sln/phantom/papercutting.html>

## Atom Exploration

**INTRODUCTION:** Just how did scientists discover the atom, considering they couldn't see it? This next activity will demonstrate how difficult this process might have been.

### **OBJECTIVES:**

- Students will be challenged to figure out what object is inside a piece of clay, without seeing it. They will relate the process they went through to what Ernest Rutherford did in order to discover the first atom.

**KEYWORDS:** Atom, nanotechnology

### **MATERIALS:**

- Clay or Play-Doh
- Round toothpicks
- Several small objects such as:
- Penny, marble, rubber band, raisin, marshmallow, paper, clip, bead, etc.

### **INSTRUCTIONS:**

#### Set Up:

Before you begin, prepare several clay balls (about 3" in diameter) and place one small object in the center of each.

1. Children can work alone or in groups. Give them a clay ball and about 20 round toothpicks. (The flat ones are too flimsy for this activity.)

#### Activity:

1. Challenge the kids to figure out what object is hidden inside the clay without seeing it. They can use the toothpicks as tools to probe each ball and then predict what's inside.
2. Have kids share their predictions and how they came to these conclusions before opening the ball to see how close their predictions were. (Kids can get clues to the size and shape of the object by examining the depth the toothpick is inserted. The firmness of the object is revealed when the toothpick actually touches—or goes through—the object.)

### **WHAT'S GOING ON?**

Many times, scientists must investigate things they cannot see. In 1911, Ernest Rutherford conducted a famous experiment in which he shot alpha particles (helium nuclei) at gold atoms. He found that most of the particles went straight through (because atoms are mostly

empty space), but some particles were deflected back as if they hit something very dense. This led to our current model of the atom as a small, dense, positively charged nucleus with circling electrons. Just because scientists cannot see things at the nanoscale doesn't mean they cannot learn about them and make revolutionary discoveries as Rutherford did! Nanoscientists have developed special tools such as scanning probe microscopes that have special probes (similar to the toothpicks in this activity) to "feel" for bumps on the surface and map out the arrangement of atoms.

#### **CONTENT STANDARDS:**

- Physical Science 6-8 A: Relate uses, properties and chemical processes to the behavior and/or arrangement of the small particles that compose matter.
- Physical Science 9-10 A: Describe that matter is made of minute particles called atoms and atoms are comprised of even smaller components. Explain the structure and properties of atoms.

#### **ACTIVITY SOURCE:**

[http://pbskids.org/dragonflytv/web\\_assets/pdf/dftv\\_nanoedguide\\_wheresnano.pdf](http://pbskids.org/dragonflytv/web_assets/pdf/dftv_nanoedguide_wheresnano.pdf)

(Ice breaker, page 2)



## Nanotechnology Workshop Post Visit Activities

### Finding Nano

**INTRODUCTION:** We think of nanotechnology as a science of the future, but there are many products currently on the market today containing nanoparticles.

**OBJECTIVES:**

- Students will research and explore examples of nanotechnology in their everyday lives.

**KEYWORDS:** Nanotechnology, technology applications

**MATERIALS:**

- Library books
- Computer with internet
- Paper
- Pens or pencils

**INSTRUCTIONS:**

The students will create an inventory of “all things nano” around them. They can create this list by visiting discount stores, sporting goods stores and drugstores or by searching books or the internet. Students can take pictures or draw pictures that can be included in their final report. Their final report should detail what items they found that are “nanoproducts” as well as an explanation as to how they determined it was a nanoproduct. The students should also try breaking down their findings into categories, like these: nature, technology and the future. Students can also discuss the use of advertising in promoting a product. Are all these items really nano? Take a vote: nano or not? How would you know? How might you test the product’s claim? Would you want to know if a product was made using nanotechnology? Would it influence whether or not you purchased it? Does the type of product make a difference—e.g., toothpaste versus a baseball bat?

**WHAT’S GOING ON?**

Nanotechnology is all around us. Read this news article to read more!

<http://www.guardian.co.uk/nanotechnology-world/nanotechnology-in-everyday-life>

**CONTENT STANDARDS:**

- Science and Technology 3-5 A: Describe how technology affects human life
  - 3.1: Describe how technology can extend human abilities (e.g., to move things, to extend senses).

- 3.2: Describe ways that using technology can have helpful and/or harmful results.
  - 4.1: Explain how technology from different areas (e.g., transportation, communication, nutrition, healthcare, agriculture, entertainment, manufacturing) has improved human lives
  - 4.2: Investigate how technology and inventions change to meet peoples' needs and wants.
- Science and Technology 6-8 A: Give examples of how technological advances, influenced by scientific knowledge, affect the quality of life.
  - 6.1: Explain how technology influences the quality of life.



## Powers of Ten Game

**INTRODUCTION:** Can you organize the universe based on size?

### **OBJECTIVES:**

- Students will play a game where they are challenged to organize items according to size.

**KEYWORDS:** Nanotechnology, scale.

### **MATERIALS:**

- Powers of Ten instructions (see below)
- Powers of Ten playing cards (Available via COSI's Nanotechnology workshop website.)

### **INSTRUCTIONS:**

1. Each player is dealt five cards.
2. Three cards are placed face up on the table, starting three rows of play.
3. Players take turns adding a card from their hand above or below one of the rows of play.
  - You must place the cards in the correct size order. Smaller objects go at the bottom of the row. Larger objects go at the top.
  - Each card has a number on it that tells you how big or small the object is. Bigger objects have positive numbers. Smaller objects have negative numbers.
  - Cards can't be played if they are identical in rank to the end of the row.
  - You can't sneak a card into the middle of a row—it has to go on the top or bottom.
  - If you can't play a card, pass on your turn.
4. Whoever gets rid of all their cards first wins! (If no one can get rid of every card, then whoever has the fewest cards wins.)

### **WHAT'S GOING ON?**

Things in the universe come in different sizes—and size is important! The objects on the cards are organized according to powers of ten.

Each number on the scale represents a ten-fold change in size. An object marked with a 0, like a pirate, is about a meter tall. An object marked with a +1, like the Statue of Liberty, is around ten times bigger than a pirate. An object marked with a -1, like a chicken, is around ten times smaller.

Really tiny objects, like DNA, are marked with even lower numbers. DNA ( $10^{-9}$ ) is so tiny it's measured in nanometers! A nanometer is a billionth of a meter. In the emerging field of nanotechnology, scientists work with very tiny things measured in nanometers. Nanometers, centimeters, and meters are all part of the metric system. The metric system is a measuring system using units based on powers of ten. Scientists use the metric system because it makes calculations easier.

*How is this nano?*

A nanometer is a billionth of a meter. That's really tiny! Nanometers are used to measure things that are too small to see, like atoms and molecules, the basic building blocks of our world.

Nanoscale science focuses on things that are measured in nanometers. Scientists use special tools and equipment to work with things that have nanometer-sized parts, such as microchips.

In the field of nanotechnology, scientists and engineers make new materials and tiny devices. Nanotechnology allows them to make things like smaller, faster computer chips and new medicines to treat diseases like cancer.

#### CONTENT STANDARDS:

- Science and Technology 3-5 A: Describe how technology affects human life
  - 3.1: Describe how technology can extend human abilities (e.g., to move things, to extend senses).
  - 3.2: Describe ways that using technology can have helpful and/or harmful results.
  - 4.1: Explain how technology from different areas (e.g., transportation, communication, nutrition, healthcare, agriculture, entertainment, manufacturing) has improved human lives
  - 4.2: Investigate how technology and inventions change to meet peoples' needs and wants.
- Science and Technology 6-8 A: Give examples of how technological advances, influenced by scientific knowledge, affect the quality of life.
  - 6.1: Explain how technology influences the quality of life.

#### ACTIVITY SOURCE:

NiseNET: [www.nisenet.org/catalog](http://www.nisenet.org/catalog)



## The Lotus Effect

**INTRODUCTION:** 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.

### **OBJECTIVES:**

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

- Be exposed how nanotechnology can improve materials in our everyday lives.
- Learn that scientists copied a surface in nature that protects leaves and used it to improve paint.

**KEYWORDS:** Nanotechnology, Lotus Effect

### **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)

### **INSTRUCTIONS:**

#### Set Up:

1. Place leaves in tray.
2. Fill cup with water.

#### 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. 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.

## WHAT'S GOING ON?

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.

#### CONTENT STANDARDS:

- Science and Technology 3-5 A: Describe how technology affects human life
  - 3.1: Describe how technology can extend human abilities (e.g., to move things, to extend senses).
  - 3.2: Describe ways that using technology can have helpful and/or harmful results.
  - 4.1: Explain how technology from different areas (e.g., transportation, communication, nutrition, healthcare, agriculture, entertainment, manufacturing) has improved human lives
  - 4.2: Investigate how technology and inventions change to meet peoples' needs and wants.
- Science and Technology 6-8 A: Give examples of how technological advances, influenced by scientific knowledge, affect the quality of life.
  - 6.1: Explain how technology influences the quality of life.

#### FURTHER EXPLORATION:

**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/>

**ACTIVITY SOURCE:**

NiseNET: [www.nisenet.org/catalog](http://www.nisenet.org/catalog)