NanoDays™

COLLECTION

A Compendium of NanoDays Activities and Resources
from the Nanoscale Informal Science Education Network

USB ARCHIVE
INCLUDES ALL
DIGITAL RESOURCES
plus
SPANISH TRANSLATIONS
for all educational materials

Over 50 Hands-on Activities
to engage the public in nanoscale science, technology, and engineering

Includes materials from NanoDays Kits 2008–2015

The Biggest Event for the Smallest Science!

NanoDays COLLECTION

Over 50 Hands-on Activities
to engage the public in nanoscale science, technology, and engineering

NISE network
NANOSCALE INFORMAL SCIENCE EDUCATION

This book was supported by the National Science Foundation
under Award Numbers 0532536 and 0940143.

nisenet.org

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COLLECTION

USB ARCHIVE

INCLUDES ALL **DIGITAL RESOURCES** *plus* **SPANISH TRANSLATIONS** *for all educational materials*

The included USB drive contains digital files for all the activities, graphic resources, and planning and training materials in this book. The files are formatted so they can easily be printed or, in the case of presentations, shared on a screen or projector.

Some of the graphic resources require specialty or large-format printing.

These and many other nano-related educational resources and professional development materials are also available at nisenet.org.

Tierney Farrell

This book was supported by the National Science Foundation under Award Numbers 0532536 and 0940143. Any opinions, findings, and conclusions or recommendations expressed in this book are those of the authors and do not necessarily reflect the views of the Foundation.

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Gary Hodges

This book is dedicated to all the NISE Network partner organizations, staff, and volunteers who have used and improved our educational materials throughout the years to engage their audiences in learning about nano!

Acknowledgments

The NanoDays printed materials and digital resources in this collection represent the creativity and hard work of many people over many years. In particular, the NanoDays and programs groups contributed to the development of these activities in all their many versions and iterations. The content steering, evaluation, research, inclusive audiences, online brown-bags, and team-based inquiry teams, and our expert advisors all provided invaluable guidance and feedback. The success of these materials at local events is due to the strong relationships cultivated by the RISE and community workgroups and the regional hubs structure of the network. Thank you to all of you for your hard work and for sharing your expertise. Many thanks also to the many others who have supported and contributed to these activities and to this book project, including the reviewers and the network leadership group.

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A Compendium of NanoDays Activities and Resources
from the Nanoscale Informal Science Education Network

Over 50 Hands-on Activities

to engage the public in nanoscale science, technology, and engineering

Includes materials from NanoDays Kits 2008–2015

Gary Hodges

The NISE Network

The Nanoscale Informal Science Education Network (NISE Net) is a national community of researchers and informal science educators dedicated to fostering public awareness, engagement, and understanding of nanoscale science, engineering, and technology (nano). The goals of NISE Net are to create a national community of partners to engage the public in nano, to develop and distribute educational experiences that raise public awareness and understanding of nano, and to generate knowledge about public and professional learning through evaluation and research.

NISE Net includes over 500 museums, universities, and other organizations. The Network is organized into regions, each with a regional hub leader that serves as primary point of contact and provides advice, encouragement, and support to partners. Network partners work together to engage the public in new topics related to science, engineering, and technology. Collectively, our efforts give the Network broad reach to diverse public audiences across the United States.

Tierney Farrell

Gary Hodges

NanoDays COLLECTION

A Compendium of NanoDays Activities and Resources

NanoDays is the flagship event of the Nanoscale Informal Science Education Network (NISE Network). NanoDays is both an annual event celebrating nanoscale science, engineering, and technology and a suite of programming resources that NISE Network partners use year-round to provide hands-on activities for multiple and diverse audiences, from families and school groups who visit the museum to outreach to underserved communities.

The annual celebration mobilizes hundreds of organizations across the country to engage staff, volunteers, and members of the public in learning about nanoscale science, engineering, and technology. While several communities conducted NanoDays events in prior years, the first nationwide week of events took place in 2008 with more than 100 institutions participating. Over the course of the NISE Network project, this has grown to more than 250 events organized at science museums, research centers, and universities across the country from Puerto Rico to Hawaii. This is the biggest event for the smallest science!

NanoDays kits are the NISE Network's most widely used set of resources, reaching over a million visitors throughout the year. From 2008–2015, the Network developed and fabricated kits of hands-on activities and programs for dissemination to our partners. These NanoDays kits include everything needed to host an event or to provide nano-related programming throughout the year. In addition to NanoDays materials, the project offers hundreds of open-source educational resources that suit different educational contexts, engage diverse target audiences, and convey a range of content. These materials can be downloaded from nisenet.org.

Like all of the NISE Network's educational materials, the NanoDays activities, programs, and resources you will find in this book, on the USB archive, and online are designed to engage a wide range of audiences in learning about complex scientific content—in ways that are fun and easy to understand. Going forward, we hope you will continue to use these materials to engage people of all ages in learning about this emerging field of research!

Gary Hodges

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150 ml
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50
200 ml

Emily Maletz

Gary Hodges

SECTION 1

Intro to nano

Nanoscale science, technology, and engineering is a large, exciting, and relatively new field of study.

What is nano?

Nanoscale science, engineering, and technology (or "nano," for short) is a relatively new, interdisciplinary field of research. Just within the past couple of decades, scientists have developed methods and tools that allow them to explore some of the most fundamental aspects of our natural world, and to develop new materials and technologies. Some experts think that nanotechnology may transform our lives, similar to the way that the automobile and personal computer changed how we live and work.

The great potential of nano comes from its tiny size. Nano research and development happens at the scale of atoms and molecules. Some things have different properties at the nanoscale, which allows scientists and engineers to create new materials and devices.

Nanotechnology isn't just in the lab—we can already find examples in our homes, stores, and hospitals. In the next 10 years or so, nanotechnology will become even more present in our lives. We'll find it in everyday products like computers, food, cosmetics, and clothing. Nanotechnology might also be part of solutions to big problems, helping address needs such as clean energy, pure water, and cancer treatments.

It's important for everyone to be informed about nanotechnology, because it will be a significant part of our future. Like all technologies, any given nanotechnology has costs, risks, and benefits. Since nanotechnologies are still developing, we can influence what they are and how they're used. We all have a role in determining how these new technologies will play out in our future.

Nano is a large and exciting field of study and there's a lot to know. Learning more about nano will help us understand our natural world, the process of science and engineering, and the ways that society and technology are interconnected.

To begin to understand nano, we can explore four main concepts:

1.

Nano is small and different

Nanoscale things are very small, and often behave differently than larger things do.

2.

Nano is studying and making tiny things

Scientists and engineers have formed the interdisciplinary field of nanotechnology by investigating properties and manipulating matter at the nanoscale.

3.

Nano is new technologies

Nanoscale science, engineering, and technology lead to new knowledge and innovations that weren't possible before.

4.

Nano is part of our society and our future

Nanotechnologies have costs, risks, and benefits that affect our lives in ways we cannot always predict.

PROGRAM

Nanotechnology:

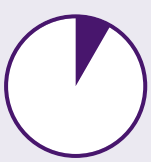
Small Science, Big Deal!

Cart Demo

This cart demonstration reviews the basics of nanoscale science, engineering, and technology (nano) through a number of hands-on activities. Visitors learn that nanometer-sized things are small and often behave differently than larger things do, and that work in this emerging field leads to new knowledge and innovations. Visitors also consider the potential costs, risks, and benefits associated with nanotechnologies.

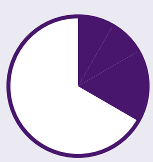
Time Required

Setup



5 min

Program



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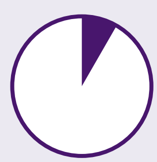
Cleanup



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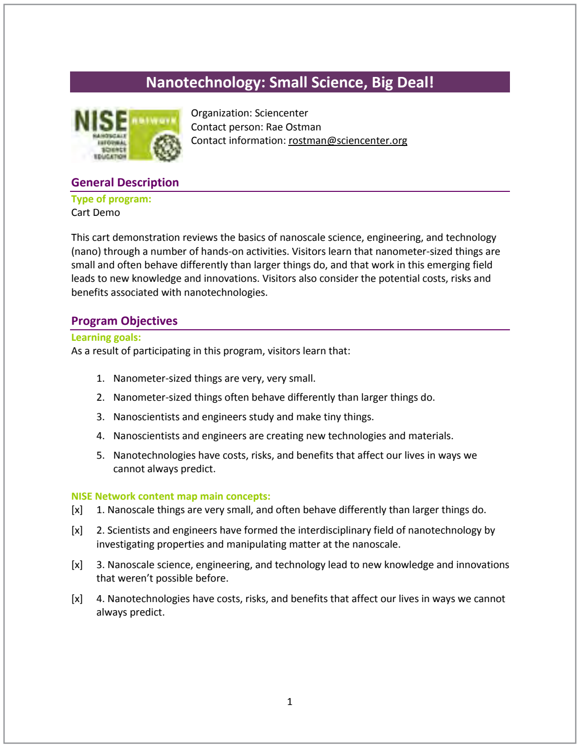
Program Resources



Nanotechnology: Small Science, Big Deal!

Organization: Sciencenter
Contact person: Rae Ostman
Contact information: rostman@sciencenter.org

General Description

Type of program:
Cart Demo

This cart demonstration reviews the basics of nanoscale science, engineering, and technology (nano) through a number of hands-on activities. Visitors learn that nanometer-sized things are small and often behave differently than larger things do, and that work in this emerging field leads to new knowledge and innovations. Visitors also consider the potential costs, risks and benefits associated with nanotechnologies.

Program Objectives

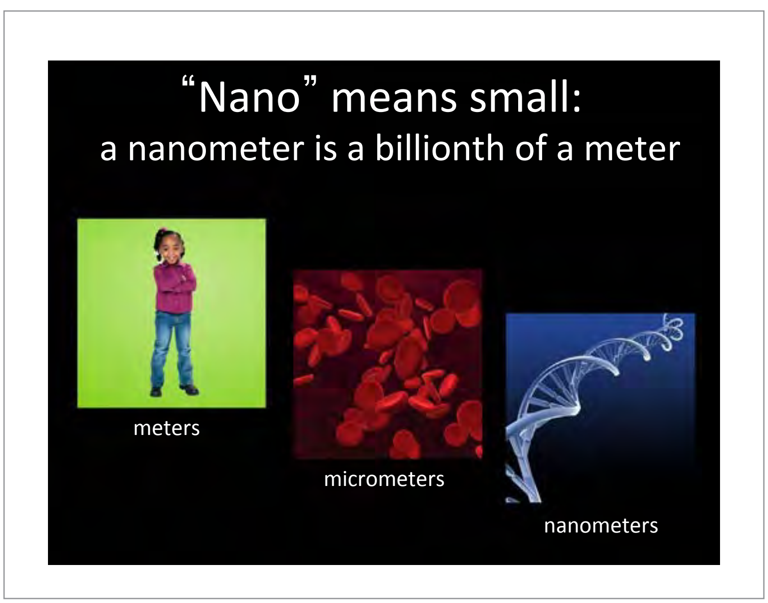
Learning goals:
As a result of participating in this program, visitors learn that:

1. Nanometer-sized things are very, very small.
2. Nanometer-sized things often behave differently than larger things do.
3. Nanoscientists and engineers study and make tiny things.
4. Nanoscientists and engineers are creating new technologies and materials.
5. Nanotechnologies have costs, risks, and benefits that affect our lives in ways we cannot always predict.

NISE Network content map main concepts:
[x] 1. Nanoscale things are very small, and often behave differently than larger things do.
[x] 2. Scientists and engineers have formed the interdisciplinary field of nanotechnology by investigating properties and manipulating matter at the nanoscale.
[x] 3. Nanoscale science, engineering, and technology lead to new knowledge and innovations that weren't possible before.
[x] 4. Nanotechnologies have costs, risks, and benefits that affect our lives in ways we cannot always predict.

1

"Small Science, Big Deal!" lesson plan
15 pages



"Small Science, Big Deal!" presentation
24 slides

PROGRAM

Nanotechnology:

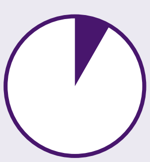
Spin-a-Prize!

Stage presentation

Nanotechnology Spin-a-Prize! introduces visitors to the basics of nanoscale science, engineering, and technology (“nano”) through a game show format. Visitors learn that nanometer-sized things are small and often behave differently than larger things do, and that work in this emerging field leads to new knowledge and innovations. Visitors also consider the ways that nanotechnology will affect our lives.

Time Required

Setup



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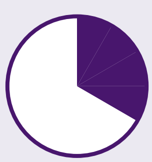
Program



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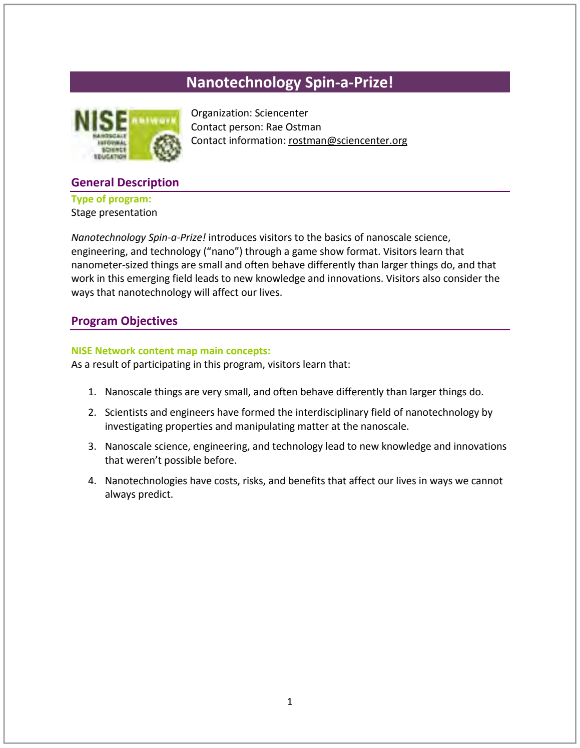
Cleanup

5 min

Program Resources



Nanotechnology Spin-a-Prize!

Organization: Sciencenter
Contact person: Rae Ostman
Contact information: rostman@sciencenter.org

General Description

Type of program:
Stage presentation

Nanotechnology Spin-a-Prize! introduces visitors to the basics of nanoscale science, engineering, and technology ("nano") through a game show format. Visitors learn that nanometer-sized things are small and often behave differently than larger things do, and that work in this emerging field leads to new knowledge and innovations. Visitors also consider the ways that nanotechnology will affect our lives.

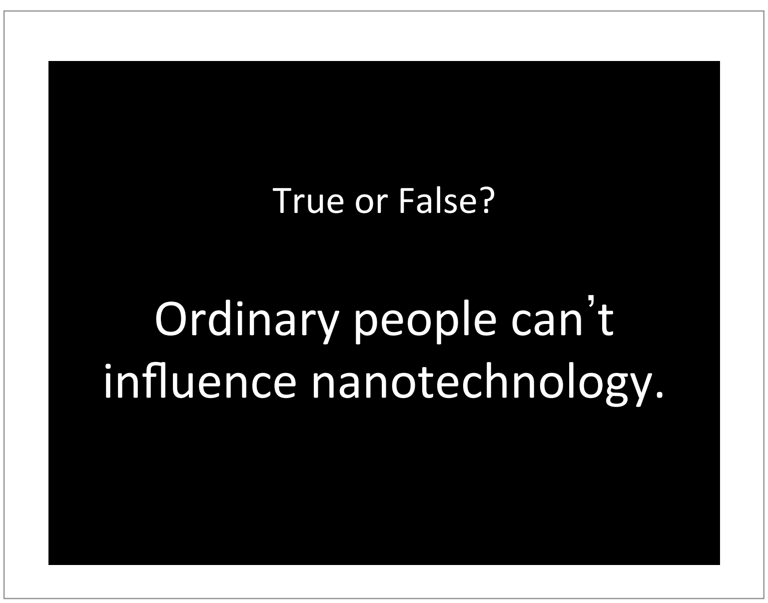
Program Objectives

NISE Network content map main concepts:
As a result of participating in this program, visitors learn that:

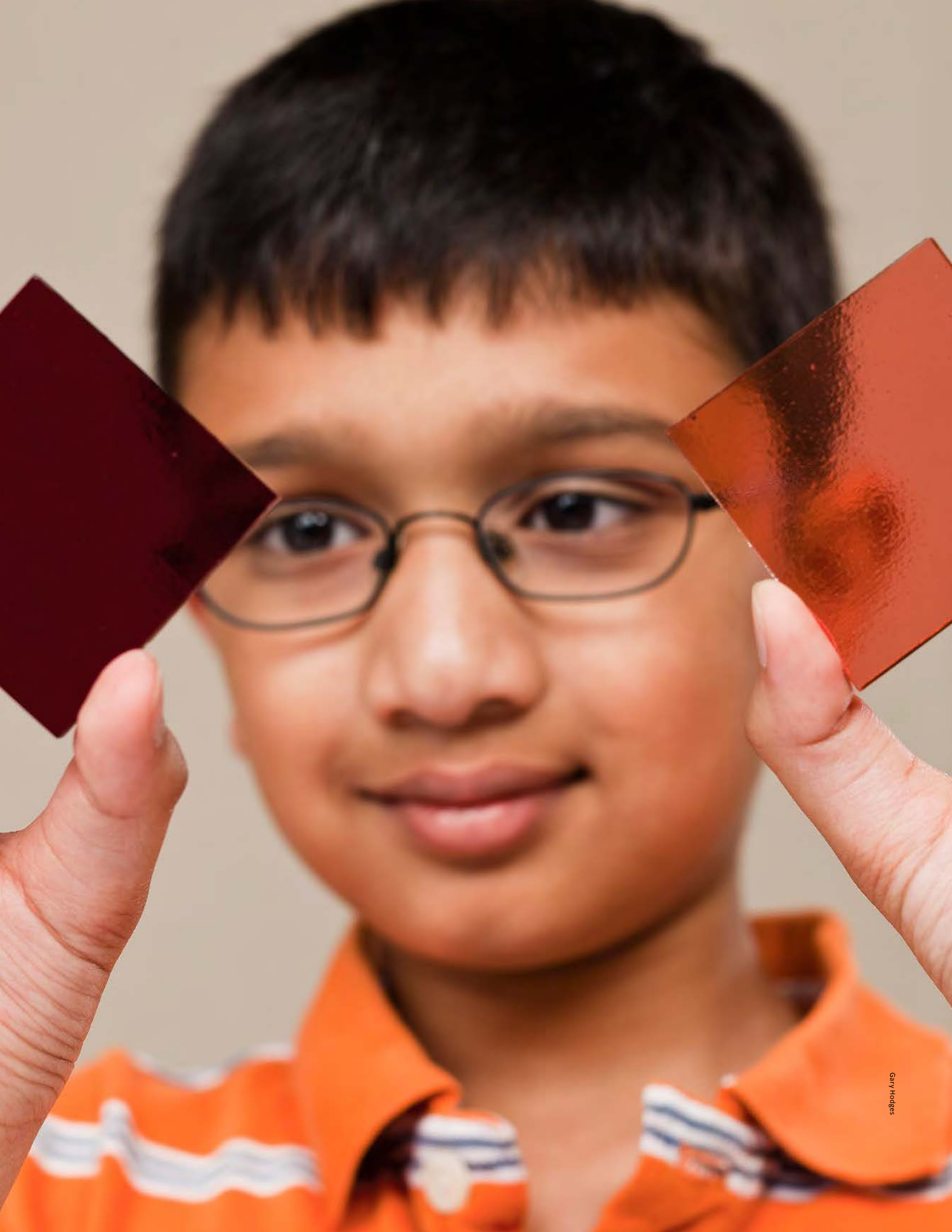
1. Nanoscale things are very small, and often behave differently than larger things do.
2. Scientists and engineers have formed the interdisciplinary field of nanotechnology by investigating properties and manipulating matter at the nanoscale.
3. Nanoscale science, engineering, and technology lead to new knowledge and innovations that weren't possible before.
4. Nanotechnologies have costs, risks, and benefits that affect our lives in ways we cannot always predict.

1

"Nanotechnology Spin-a-Prize!" lesson plan
18 pages



"Nanotechnology Spin-a-Prize!" presentation
37 slides



Gary Hodges

SECTION 2

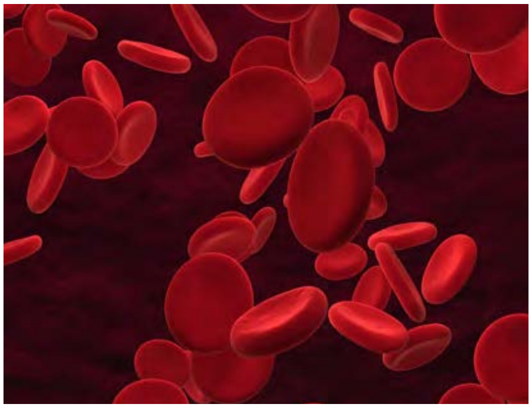
Nano is small and different

Nanoscale things are very small, and often behave differently than larger things do.

The nanoscale is very, very small.

The world is full of things of all different sizes. In everyday life, we come across things in at least three different size scales: the *macroscale*, the *microscale*, and the *nanoscale*. Macroscale objects are big, and we can see them with our eyes. Microscale objects are smaller, and we need tools like microscopes to see them clearly. Nanoscale objects are even smaller. We need special tools to study and work on the nanoscale.

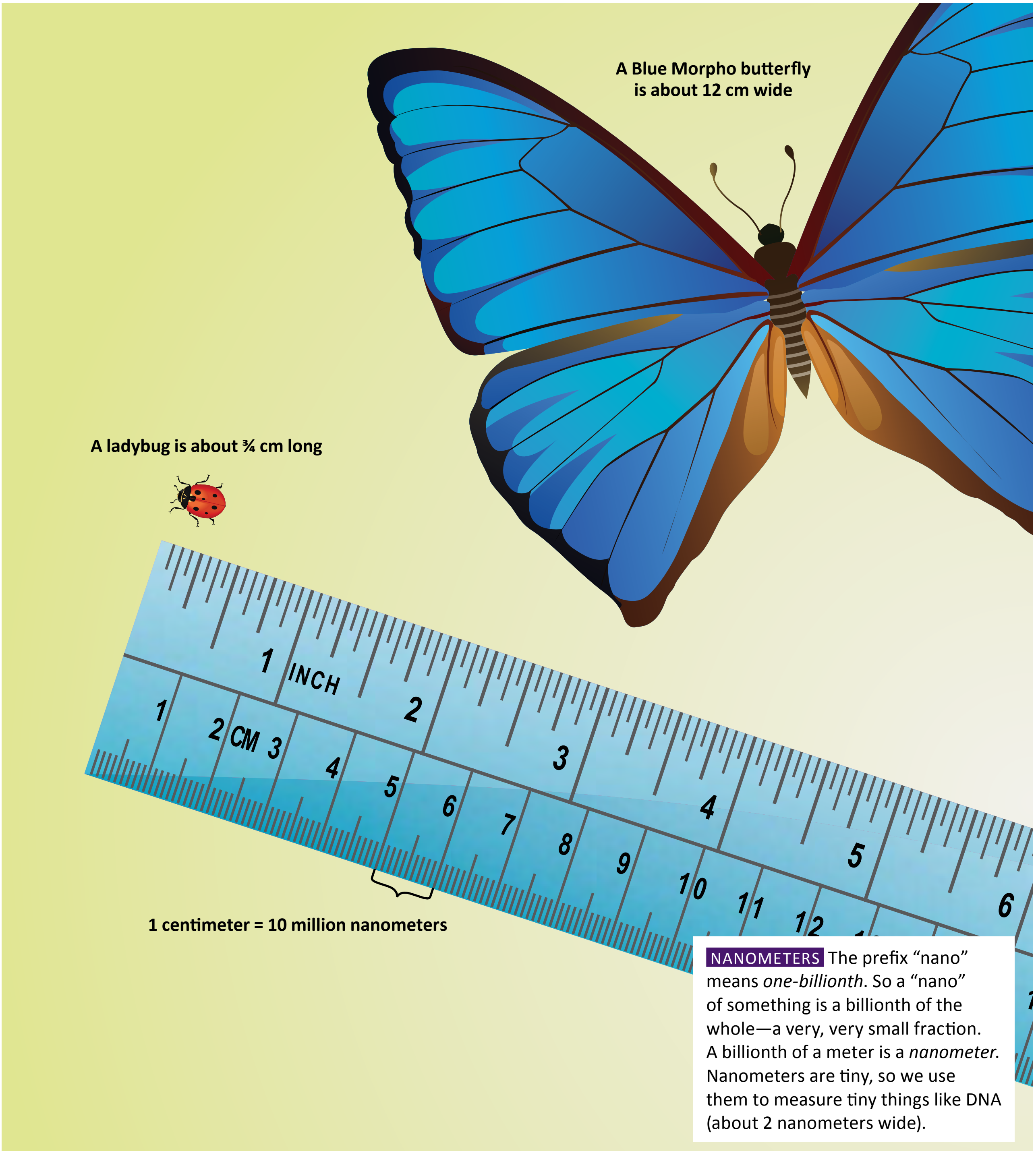
MACRO:
A child is about 1 meter tall
1 meter = 1,000,000,000 nm (1 billion nanometers)



MICRO:
A red blood cell is about 10 micrometers wide
10 micrometers = 10,000 nm (10 thousand nanometers)

NANO:
DNA is about 2 nanometers wide

Nanoscale science focuses on things that are measured in *nanometers*, including atoms and molecules, the basic building blocks of our world. A nanometer is a billionth of a meter.

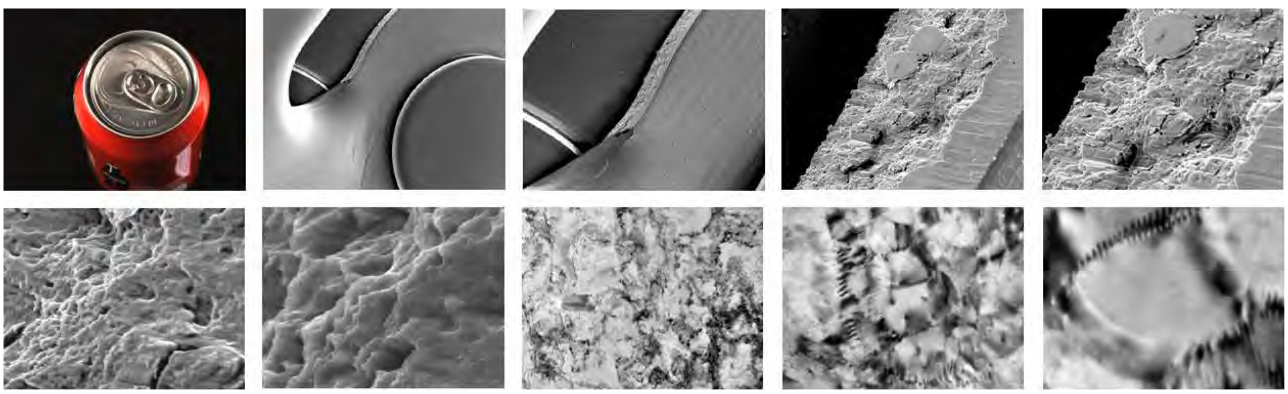


NANOMETERS The prefix “nano” means *one-billionth*. So a “nano” of something is a billionth of the whole—a very, very small fraction. A billionth of a meter is a *nanometer*. Nanometers are tiny, so we use them to measure tiny things like DNA (about 2 nanometers wide).

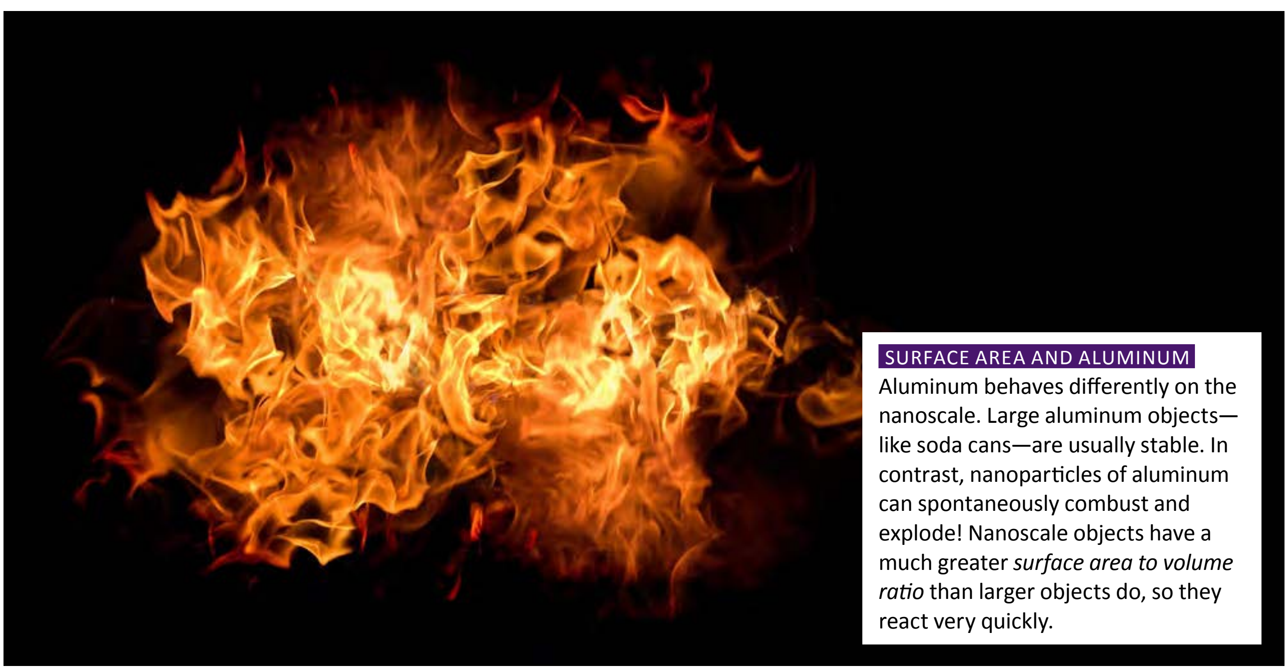
Some materials behave differently at a small scale than they do at a large scale.

Many materials have surprising properties at the nanoscale. For example, chemical reactions often take place much more quickly. That's because reactions occur on the surface of objects, and nanoscale objects have a lot of surface area per unit of volume.

Zooming in on an aluminum can



Courtesy MRS and Ontario Science Centre

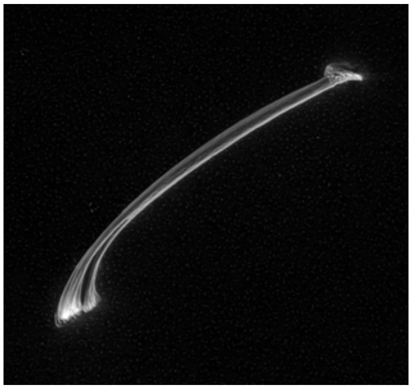


SURFACE AREA AND ALUMINUM

Aluminum behaves differently on the nanoscale. Large aluminum objects—like soda cans—are usually stable. In contrast, nanoparticles of aluminum can spontaneously combust and explode! Nanoscale objects have a much greater *surface area to volume ratio* than larger objects do, so they react very quickly.

Different physical forces dominate at the nanoscale, making things behave in unexpected ways. For example, at the nanoscale gravity is a relatively weak force, while intermolecular forces (attraction between molecules) are relatively strong.

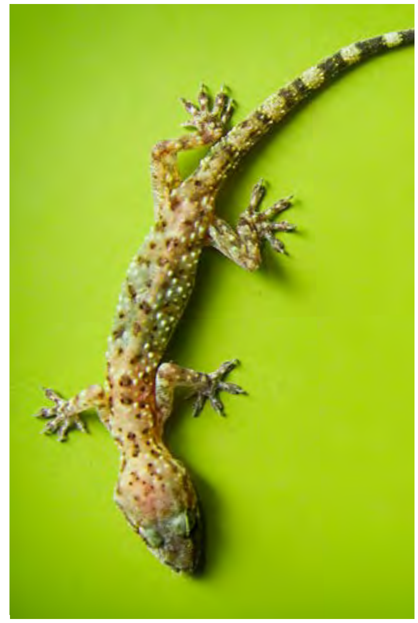
A single "hair" from a gecko toe



A.Kellar, Lewis & Clark College

Tiny "hairs" on a gecko toe

C. Mathisen, FEI Company



A.Dhinojwala, University of Akron

PHYSICAL FORCES AND GECKO FEET Geckos can climb up walls and across ceilings, but there's no glue on the bottom of their feet! Instead, millions of tiny nano-sized structures form bonds with the wall.

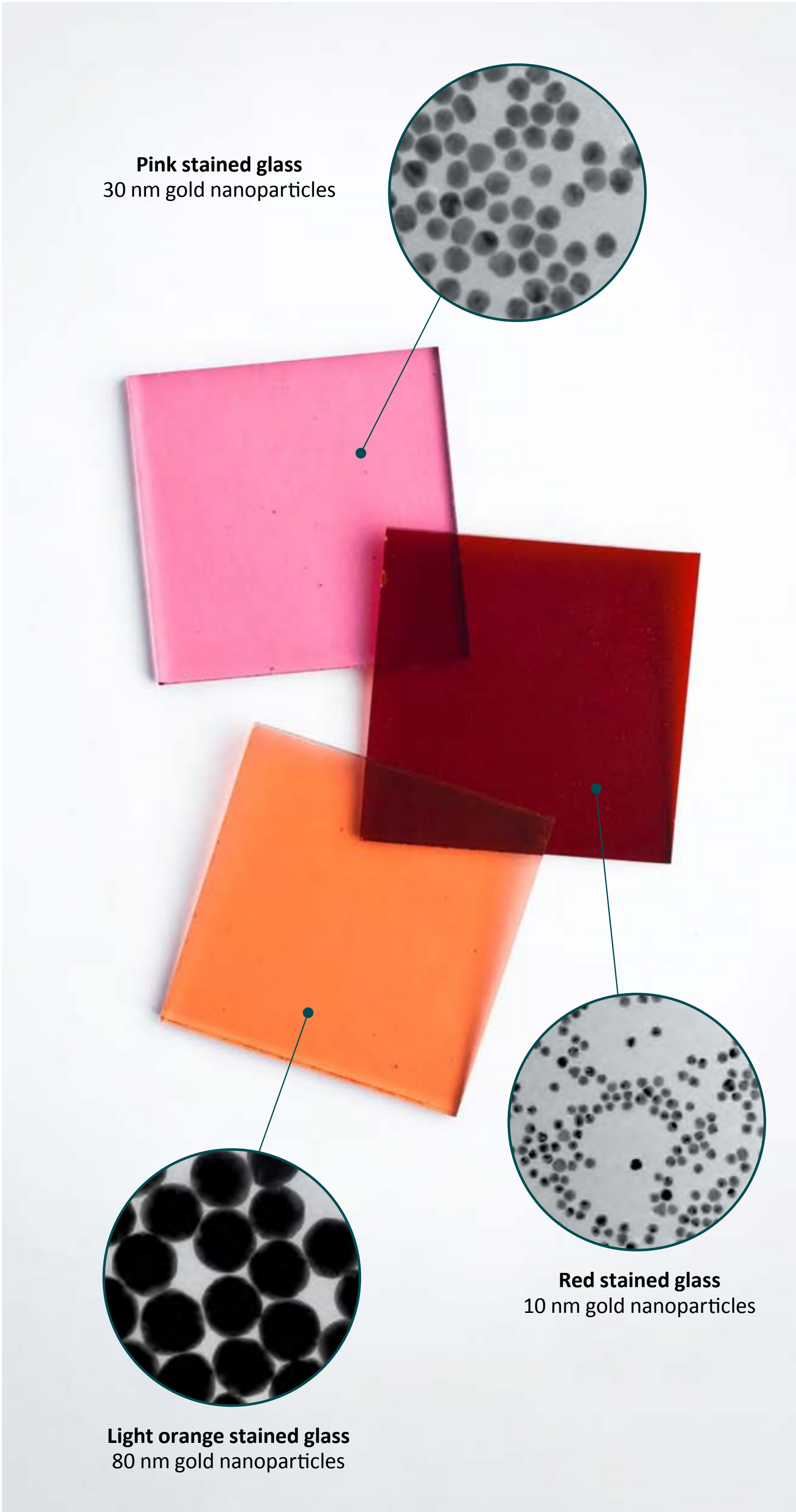
Gecko feet are covered with very small "hairs" called *setae*. Each one splits into thousands of even smaller ends, called *spatulae*, which are only about 200 nanometers wide. Molecules in these "split ends" are attracted to molecules in the wall, and they form a temporary bond. Although each bond is weak, there are enough of them to allow intermolecular forces to overcome the force of gravity. To move, the gecko tilts it foot, breaking the bonds.

Nanoscale properties can lead to new uses for common materials.

Nanomaterials and nanotechnologies take advantage of novel properties at the nanoscale. For example, some materials appear as a different color on the nanoscale, because light interacts differently with very small particles. Scientists are learning how to take advantage of special nanoscale properties to create new materials and technologies.

MINERAL SUNBLOCKS Lifeguards used to put white ointment on their noses made of microscale mineral particles that blocked UV rays (titanium dioxide or zinc oxide). Today, many sunblocks are transparent because they're made with nanoscale mineral particles.

Nanoscale particles offer the same UV protection, but they're so small that they don't reflect visible light. Sunblocks are one of the most common applications of nanotechnology.



NANOSCALE GOLD Gold is a familiar metal, but on the nanoscale, it has some unfamiliar properties. Large pieces of gold are shiny and golden, but nanoparticle gold can be red, purple, or blue. The color depends on the size of the particles and the distance between them.

Nanoscale gold has been the secret ingredient in red stained glass since the Middle Ages! Today, the color-changing properties of gold nanoparticles have many different medical and biological applications.

Exploring Forces—

Gravity

Try this!

1. Fill the full-size cup by dipping it in the water.

2. Try to pour the water back into the container. What happens?

3. Now fill the miniature cup with water. Can you pour the water back out?

What's going on?

It's easy to pour water out of a full-size cup, but not out of a miniature cup. That's because size can affect the way a material behaves. The size of the cup—and the amount of water it holds—determines which force is more important, gravity or surface tension.

Water droplet on a nasturtium leaf

When you tip a cup of water upside down, the two forces are at work against each other. Gravity works to pull the water down and out of the cup. Surface tension (the natural tendency of water molecules to stick together) works to hold the water together inside the cup.

With a regular-size cup, the force of gravity is much stronger than surface tension, so the water falls out of the cup. But in a miniature cup, there's a lot less water, and surface tension is strong enough to hold it together.

So when you tip the miniature cup, surface tension beats out gravity and the water stays in the cup. You also see surface tension at work when water beads up into droplets.

How is this nano?

A material can act differently when it's nanometer-sized. Different physical forces dominate when things get very, very small. For example, gravity is very apparent to us on the macroscale, but it's hardly noticeable at the nanoscale.

The miniature cup is tiny, but it's still much, much bigger than things measured in nanometers. A nanometer is a billionth of a meter.

Nanotechnology takes advantage of the different physical forces at the nanoscale to make new materials and tiny devices. Nanotechnology allows scientists and engineers to make things like smaller, faster computer chips and new medicines to treat diseases like cancer.

Learning objectives

A material can act differently when it's nanometer-sized.

Different physical forces dominate when things get very, very small.

Materials

- Regular teacup
- Miniature teacup
- Container for water

Miniature teacups are available at dollhouse suppliers. One source is www.dollhousesandmore.com (#CB2719).

Notes to the presenter

Before beginning this activity, fill the container with water.

Credits

This activity was adapted from "Shrinking Cups: Changes in the Behavior of Materials at the Nanoscale," in *Nanoscale Science: Activities for Grades 6-12* by M. Gail Jones, Michael R. Falvo, Amy R. Taylor, and Bethany P. Broadwell. pp. 89-94. Arlington, VA: NSTA Press.

Photo of water droplet courtesy A. Otten and S. Herminghaus, Göttingen, Germany.

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

Exploring Properties—

Surface Area

Try this!

1. Pour 20 ml of colored water from the pitcher into each measuring cup.

2. Remove two antacid tablets from their wrapper. Break one in half, and drop it into a cylinder. Break the other tablet into many small pieces, and put it in the other cylinder.

3. At the same time, pour the water from each cup into a cylinder.

4. Which fizzes up faster, the tablet you broke in half or the tablet you broke into lots of pieces?

What's going on?

The crushed tablet fizzes faster than the halved tablet. That's because it has a greater *surface area to volume ratio*. For the same amount of antacid, the crushed tablet has more surface—or exterior—to react with the water. Because the water can reach more of the antacid immediately, the chemical reaction (fizzing) happens faster.

Small things have more surface area for their volume than larger things do. Some things that aren't reactive at all in big pieces are very reactive when they're tiny. Steel wool catches fire, but you can't easily light a lump of metal on fire!

Nano adhesives stick graphics onto cardboard boxes

How is this nano?

A material can act differently when it's nanometer-sized. Things on the nanoscale have a lot of surface area, so they react much more easily and quickly than they would if they were larger.

Nanotechnology takes advantage of different material properties at the nanoscale—such as increased surface area—to make new materials and tiny devices. For example, an extra-sticky, eco-friendly glue can be made from starch molecules that are only 100 nanometers in size.

Nanotechnology allows scientists and engineers to make other things like smaller, faster computer chips and new medicines to treat diseases like cancer.

Learning objectives

A material can act differently when it's nanometer-sized.

Things on the nanoscale have a lot of surface area, so they react much more easily and quickly than they would if they were larger.

Materials

- 100 ml graduated cylinders (2)
- Small plastic measuring cups (2)
- Pitcher
- Effervescent antacid tablets
- Food coloring

Notes to the presenter

SAFETY: The antacid tablets contain medication. Visitors should be supervised when doing this activity, and should not be allowed to consume the tablets or the water they're dissolved in. You may choose to perform this as a demonstration, rather than allowing visitors to do it as a hands-on activity.

Before beginning this activity, fill the pitcher with water and add food coloring.

You'll need a place to dump wastewater. If there isn't a sink near your activity area, you can dump wastewater into a bucket and dispose of it periodically.

Between demonstrations, give the cylinders a good shake to remove excess water.

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

Exploring Size—

Measure Yourself

Try this!

1. Mark your height on the wall chart.

2. How tall are you in nanometers?

3. Are you super tall? Or is a nanometer super small?

Then try this!

1. Trace your hand on a worksheet.

2. How many nanometers long is it?

3. Is your hand really big? Or is a nanometer really tiny?

What's going on?

One meter is a billion nanometers. (A meter is a little longer than a yard.) So a kid who is a little over three feet tall measures one billion nanometers! Saying that you're a billion nanometers tall sounds pretty impressive, but it doesn't mean that you're super tall—it means that a nanometer is super small.

Image of a human blood vessel

Here are some other ways to think about how small a nanometer is:

- The ridges in your fingerprints are around 250,000 nanometers wide.
- A strand of your hair is around 75,000 nanometers wide.
- One red blood cell is around 7,000 nanometers wide.
- Your fingernails grow one nanometer every second.

How is this nano?

A nanometer is a billionth of a meter. That's really, really tiny! Nanometers are used to measure things that are too small to see. It takes a lot of nanometers to measure something relatively big, like your body.

Nanoscale science focuses on things that are measured in nanometers, anything between 1–100 nanometers in size. Scientists use special tools and equipment to work with nanometer-sized things. Regular tools like rulers are too big!


Computer chip

In the field of nanotechnology, scientists and engineers make tiny devices, new materials, faster computer chips, new medicines to treat diseases like cancer, and thin, flexible solar panels to capture energy from the sun.

Learning objective

A nanometer is a billionth of a meter.

Materials

- "How Tall Are You?" height chart
- "How Big is Your Hand?" worksheet
- Masking tape

The height chart can be downloaded from www.nisenet.org/catalog/. The height chart requires a large format printer.

Notes to the presenter

Before beginning this activity, adhere the height chart to a wall. Make sure you choose a location where visitors can easily stand in front of it to measure themselves. The bottom of the chart should touch the floor.

If you print the height chart or worksheet from the digital file, be sure you don't allow page scaling.

Credits

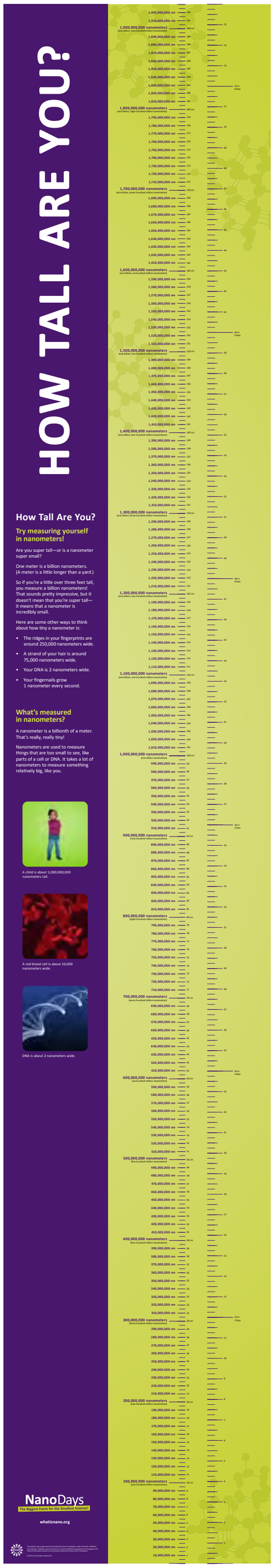
This activity is a revised version of the *Exploring Size—Measure Yourself* NanoDays activity developed by the Sciencenter for the NISE Net.

The original version was adapted from *"How Many Nanometers Tall Are You?"* from It's a Nano World, a traveling exhibition funded by the National Science Foundation and developed by the Sciencenter in Ithaca, NY, the Nanobiotechnology Center at Cornell University, and Painted Universe Inc.

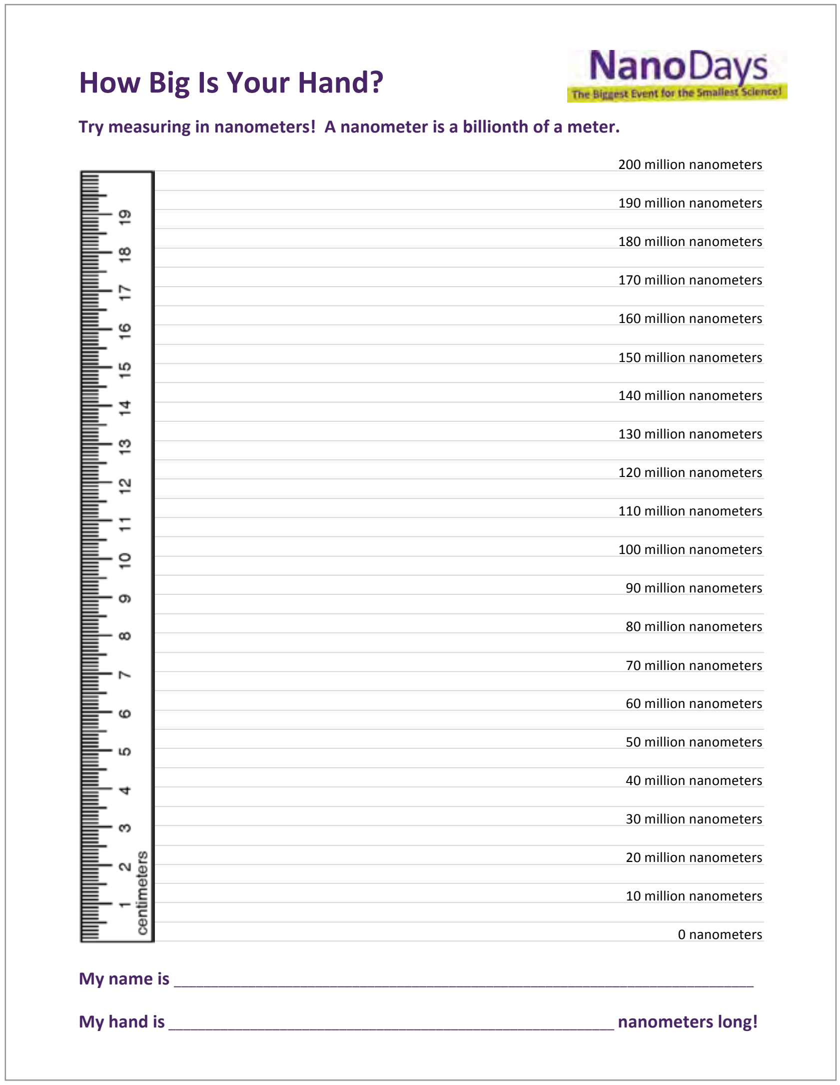
Photo of human blood vessel courtesy of Roger Wagner, University of Delaware.

This project was supported by the National Science Foundation under Award No. 0940143. 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.

Additional Graphic Resources



"How Tall Are You?" height chart
13 x 76 inches


How Big Is Your Hand?

NanoDays
The Biggest Event for the Smallest Science!

Try measuring in nanometers! A nanometer is a billionth of a meter.

200 million nanometers
190 million nanometers
180 million nanometers
170 million nanometers
160 million nanometers
150 million nanometers
140 million nanometers
130 million nanometers
120 million nanometers
110 million nanometers
100 million nanometers
90 million nanometers
80 million nanometers
70 million nanometers
60 million nanometers
50 million nanometers
40 million nanometers
30 million nanometers
20 million nanometers
10 million nanometers
0 nanometers

centimeters

My name is ______________________________

My hand is ______________________________ nanometers long!

"How Big is Your Hand?" worksheet
8.5 x 11 inches

Exploring Size—

Scented Solutions

Try this!

1. Can you sort the bottles of grape drink, from the most concentrated to the most dilute? Use your eyes to look at the color, and your nose to sniff the scent.

2. How many containers could you get in order? When could you no longer tell the difference among the bottles?

What's going on?

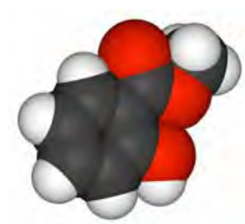
Using your eyes, it's pretty hard to sort the bottles past the third bottle, which is one part grape drink per 100 parts water. But using your nose, you might even be able to detect a whiff of scent in the fifth bottle, which is one part grape drink per 10,000 parts water.

Many people find that they can detect differences in concentration better with their nose (smelling) than with their eyes (seeing). Our sense of smell allows us to experience nanometer-sized things—scent molecules—that are too small to see with our eyes.

How is this nano?

A nanometer is a billionth of a meter. That's very, very small—too small to see with just your eyes. We can use our sense of smell to explore the world on the nanoscale, because we can smell some things that are too small to see.

Nanoscale science focuses on the building blocks of our world, atoms and molecules. Scientists use special tools and equipment to detect and manipulate tiny, nanometer-sized particles.



Molecular model of wintergreen oil

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.

Learning objective

A nanometer is a billionth of a meter.

Materials

• Squeeze bottles filled with grape drink (see below for preparation instructions)

Preparing the bottles

A set of five bottles is needed for this activity. If you'd like the final bottle to be one part per billion, however, you should make a set of ten. The first bottle in your set should be filled with full strength grape drink (prepared from a powdered mix). Each subsequent bottle should be diluted with water by a power of ten:

Bottle 1: Full strength grape drink

Bottle 2: 10% solution

Bottle 3: 1% solution

Bottle 4: 0.1% solution

Bottle 5: 0.01% solution (one part per ten thousand)

Bottle 6: 0.001% solution

Bottle 7: 0.0001% solution

Bottle 8: 0.00001% solution

Bottle 9: 0.000001% solution

Bottle 10: 0.0000001% solution (one part per billion)

Notes to the presenter

SAFETY: Flush eyes with water immediately if solution gets in them. The diluted grape drink is nontoxic, but visitors should not taste the contents of the bottles.

Visitors should squeeze the bottles gently as they sniff them.

It will be easier for visitors to sort the bottles by color if they rest on a white surface. You can use a laminated sheet of white paper if your tabletop is a dark color.

Credits

This activity was adapted from "Nanotechnology Activity Guides: NanoSolutions," developed by the National Science Foundation-supported Internships in Public Science Education (IPSE) Educator Resources, Materials Research Science and Engineering Center on Nanostructured Materials and Interfaces at the University of Wisconsin-Madison. The original activity is available at: mrsec.wisc.edu/Edetc/IPSE/educators/activities/nanoSolutions.html

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

Exploring Size—
Tiny Ruler

Try this!

1. Take a paper ruler. It's 20 centimeters long—a fifth of a meter. Do you think you can cut it down to a nanometer in size?

2. Cut the ruler in half so you have a piece that's 10 centimeters long.

3. Take the 10 centimeter piece and cut it in half.

4. Keep cutting the halves in half. How small a piece can you get before you can't cut it any more?

What's going on?

You probably didn't manage to cut the paper ruler down to a nanometer. A nanometer is a billionth of a meter. That's really small!

Most people can't cut the paper smaller than about a millimeter. (The lines on the ruler mark millimeters.)

A nanometer is a million times smaller than that!

How is this nano?

A nanometer is a billionth of a meter. That's way too small to see, and definitely smaller than you can cut a piece of paper!

Nanoscale science focuses on things that are measured in nanometers, including atoms and molecules, the basic building blocks of our world. Scientists need special tools and equipment to work on the nanoscale. Regular tools like scissors are too big!

Silicon wafer patterned with computer chips

In the field of nanotechnology, scientists and engineers study the world of the nanometer and 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.

Learning objective

A nanometer is a billionth of a meter.

Materials

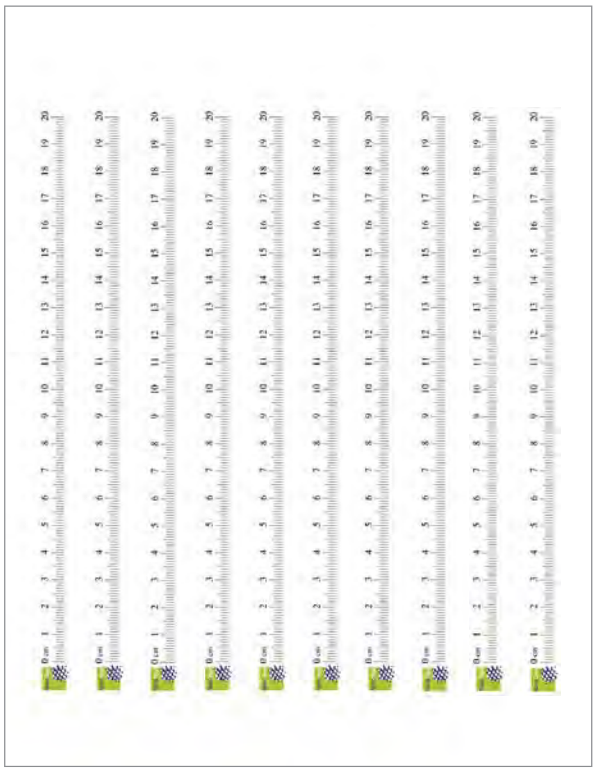
- Paper rulers
- Safety scissors

A photocopy master for the paper rulers can be downloaded from www.nisenet.org/catalog/

Notes to the presenter

To make the paper rulers, photocopy the master and use a paper cutter to make individual paper rulers.

Additional Graphic Resources



"Paper Rulers"
8.5 x 11 inches

Credits

This activity was adapted from "Cutting It Down to Nano Outreach Activity," developed by the National Science Foundation-supported Internships in Public Science Education (IPSE) Program at the Materials Research Science and Engineering Center (MRSEC) on Nanostructured Materials and Interfaces at the University of Wisconsin-Madison. The original activity is available at: mrsec.wisc.edu/Edetc/EExpo/cutting/index.html

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Exploring Size—

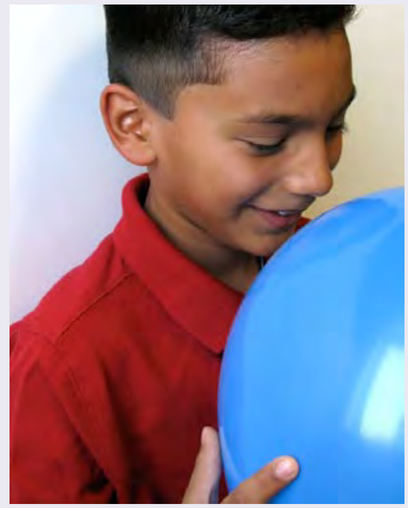
Scented Balloons

Try this!

1. Smell the balloons. Each one has a flavored extract inside it.

2. Can you identify all the different scents? Match the balloon colors with the scents listed on the poster.

3. Why do you think you can smell the extracts through the balloon?

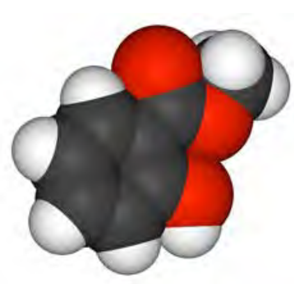


What's going on?

Tiny scent molecules are leaking out of the balloons. They're too small to see, but you can smell them!

Your sense of smell works by identifying the shape of scent molecules. Molecules are made of particles called atoms that bond together. Everything in the world is made of atoms, including the balloon you're holding and the scented air inside it.

Scent molecules are so small that they can travel through the balloon membrane. In fact, they're so tiny that they're measured in nanometers! A nanometer is a billionth of a meter.



Molecular model of wintergreen oil

Air gradually leaks out of a tied balloon because the molecules inside the balloon move through the pores of the balloon's skin, in a process known as *diffusion*. Air always diffuses from areas of higher pressure to areas of lower pressure. An inflated balloon has greater air pressure than the air around it, so the air inside the balloon gradually escapes.

How is this nano?

A nanometer is a billionth of a meter. That's very, very small—too small to see with just your eyes. We can use our sense of smell to explore the world on the nanoscale, because we can smell some things that are too small to see.

Nanoscale science focuses on the building blocks of our world, atoms and molecules. Scientists use special tools and equipment to detect and manipulate tiny, nanometer-sized particles.

In the field of nanotechnology, scientists and engineers make new materials and tiny devices. Researchers are creating tiny, nanometer-sized sensors that can detect very small concentrations of chemicals. Some of them work the way your nose does: by detecting the different shapes of molecules in the air.

Biosensor with silicon nanowires

Learning objective

A nanometer is a billionth of a meter.

Materials

- Round balloons in different colors
- Variety of flavored extracts
- Balloon pump
- “Match the Scent” poster
- “Key” sheet
- Wet- or dry-erase marker
- Latex warning sign

Preparing the balloons

Add the extracts and inflate the balloons just before you do the activity:

1. Put about half a teaspoon of extract into a balloon.
2. Use the pump to blow up the balloon. Tie the balloon.
3. Shake the balloon a few times to encourage the extract to vaporize.
4. Repeat steps 1–3 for every extract. Choose a different color balloon for each extract.

Prepare the key and poster:

1. Fill in the key, indicating the scent you put in each color balloon.
2. Fill in the poster, jumbling the order of the scents so you can play a matching game with visitors.

Notes to the presenter

SAFETY: The balloons are latex. In addition to posting the included sign, you may wish to verbally warn visitors of possible sensitivities or allergies to latex.

Just before doing this activity, prepare the balloons (see instructions above). The scents will last a few hours.

If you prefer not to use balloons, you can put the extracts into flexible squeeze bottles and label the bottles with colored stickers. Visitors should squeeze the bottles gently as they sniff.

Credits

This activity was adapted from “Odors Aloft,” in *No Hassle Messy Science with a Wow: Chemistry in the K-8 Classroom,* published by the Oregon Museum of Science and Industry, 1998 and 2007. The original activity is available at: http://www.omsi.edu/sites/all/FTP/files/chemistry/NH-PDF/NH-E19-OdorsAloft.pdf

Photo of biosensor courtesy Raj Mohanty, Boston University.

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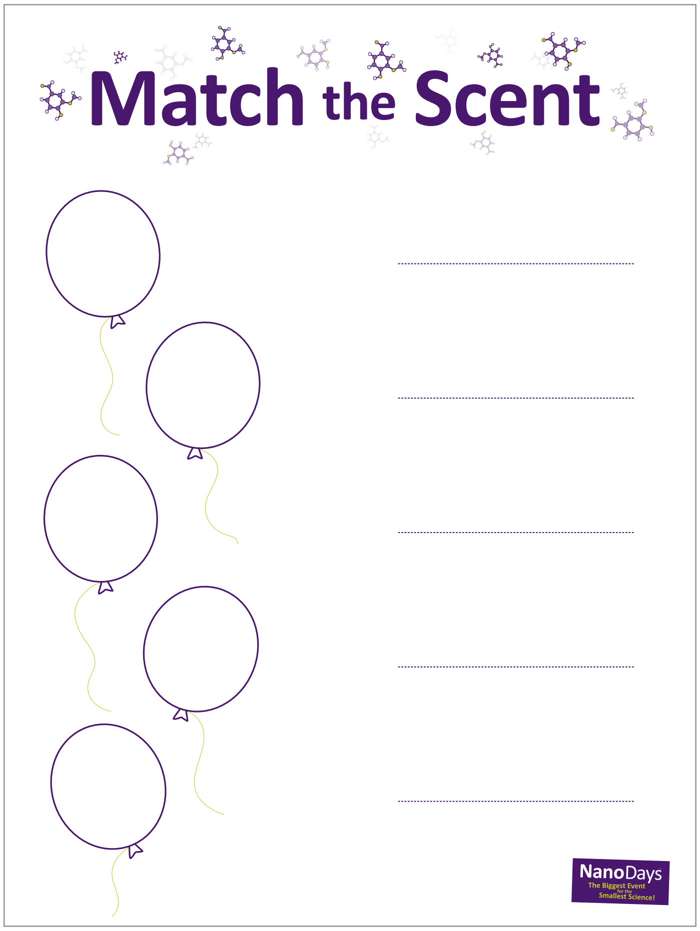
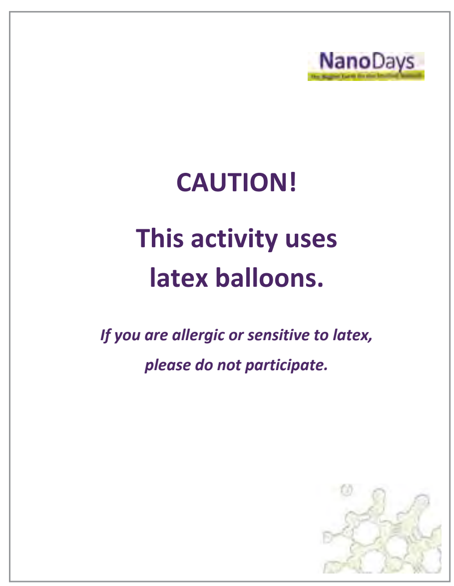
Additional Graphic Resources



"Match the Scent" poster
18 x 24 inches

Balloon Color	Scent

"Key" sheet
8.5 x 11 inches



Latex warning sign
8.5 x 11 inches

Exploring Size—

StretchAbility Game

Try this!

Left foot nano!

1. Players take off their shoes.

2. The referee spins the spinner and calls out the first move.

3. All players place a hand or foot on a circle of the right scale—macro, micro, or nano.

4. The referee spins again, and players try the next move.

5. Players who fall over (or support themselves on any body part other than hands and feet) are out of the game.

6. Keep spinning! The last player to stay up wins.

What's going on?

Things come in different sizes—and size is important! We use different scales to measure things that are different sizes. In this game, we explore three different scales: the macroscale, the microscale, and the nanoscale.

Macroscale objects are in purple circles

The macroscale includes objects we can see with our eyes. There are lots of ways to measure objects on the macroscale, including meters. (A meter is a little over three feet.) Kids around six or seven years old are about a meter tall.

Microscale objects are in green circles

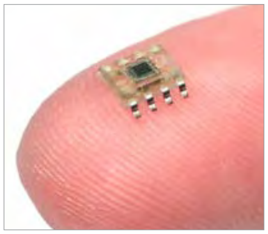
The next scale down is the microscale. To see microscale things clearly, we need tools like microscopes. Objects on the microscale are measured in micrometers. A micrometer is a millionth of a meter. Red blood cells are measured in micrometers.

Nanoscale objects are in orange circles

There's an even smaller scale: the nanoscale! Nanoscale things are so tiny that we can't see them with just our eyes—we need special tools to make images of them. Nanoscale objects are measured in nanometers. A nanometer is super small—a billionth of a meter! DNA is measured in nanometers.

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.


Microchip on finger

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.

Learning objectives

Things come in different sizes—and size is important!

A nanometer is a billionth of a meter.

Materials

- Playing mat
- Spinner
- "Macroscale Objects," "Microscale Objects," and "Nanoscale Objects" sheets

Graphics for the playing mat, spinner, and chart can be downloaded from www.nisenet.org/catalog

The playing mat is available as one file (to print on a large format printer) or as individual circles (to print separately and attach to a shower curtain).

The spinner graphic can be attached to blank 4-inch spinner board, available from www.rolcogames.com (#GSPI007L).

Notes to the presenter

This game was developed by the NISE Network, and cannot be referred to as "Twister."

Credits

This activity was adapted from *Macro, Micro and Nano Stretch-Ability,* developed by the Children's Museum of Houston for the NISE Network.
The original program is available at: www.nisenet.org/catalog

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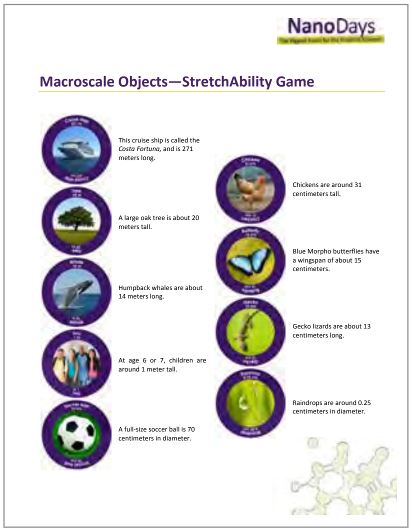
Additional Graphic Resources



"Macroscale Objects," "Microscale Objects," and "Nanoscale Objects" sheets
8.5 x 11 inches

Playing mat
52 x 74 inches

Spinner
8 x 8 inches

Exploring Forces—
Static Electricity

Try this!

1. Hold the tube of small balls by the cap.

2. Use the piece of fleece to rub the sides of the tube.

3. Stop rubbing, and hold the tube right side up.
What happens? Look closely at the balls.

4. Now hold the tube of large balls by the cap, and rub it with the fleece. Does the same thing happen?

What's going on?

Many of the small balls are suspended inside the tube, but most of the larger ones fall to the bottom. That's because size can affect the way a material behaves. The size of the balls determines which force is more important, gravity or static electricity.

When you rub the tubes with fleece, the two forces work against each other. Gravity pulls the balls down to the bottom of the tube. Static electricity pushes the balls apart, and makes them cling to the sides of the tube.

Static electricity builds up on slides

The force of the static electricity has a big effect on the small balls, but it barely affects the larger balls. That's because static electricity builds up on the surface—or outside—of the balls.

Each of the tubes contains the same volume of balls, but the smaller balls have a lot more surface area. This means that more static electricity can build up on the small balls. The larger balls have a lot less surface area for the same volume—so the force of gravity pulls them down.

You also see static electricity at work when your hair stands on end after you pull off a fleece, or when you get a shock after walking across a carpet.

How is this nano?

A material can act differently when it's nanometer-sized. Different physical forces dominate when things get very, very small. For example, gravity is very apparent to us on the macroscale, but it's hardly noticeable at the nanoscale. In the nano world, static electricity is much more important!

The small balls are pretty little, but they're still much, much bigger than things measured in nanometers.

One small ball is about two millimeters across, which is two million nanometers! (A nanometer is a billionth of a meter.)

Nanotechnology takes advantage of the different physical forces at the nanoscale to make new materials and tiny devices. Nanotechnology allows scientists and engineers to make things like smaller, faster computer chips and new medicines to treat diseases like cancer.

Learning objectives

A material can act differently when it's nanometer-sized.

Different physical forces dominate when things get very, very small.

Materials

- Tube of large balls
- Tube of small balls
- Polar fleece

Tubes with caps (baby soda bottles) are available from www.SteveSpanglerScience.com (#WBSB-150).

Delrin balls are available from www.mcmaster.com (3/32" diameter #9614K51 and 3/16" diameter #9614K54). You'll need 300 small balls and 40 large balls. They come in packs of 100.

Silica gel dessicant (optional) is available from silicagelpackets.com (2-4 mm beads). If you use dessicant, you'll need just a couple of beads per tube.

Notes to the presenter

Holding the tube by the cap helps the static electricity build up in the tubes. Hold the tubes by the cap while you're trying to charge them with the fleece.

Touching the tubes near the bottom helps discharge the static electricity. Hold the tubes by the bottom and swirl the balls to help discharge them.

You don't need to completely discharge the tubes between visitors. It's more important for visitors to see the difference between the large and small balls when they're both charged than it is for them to compare charged and uncharged balls.

Static electricity builds up better when the air is dry, so there are a couple of clear beads of silica gel dessicant in each tube.

Credits

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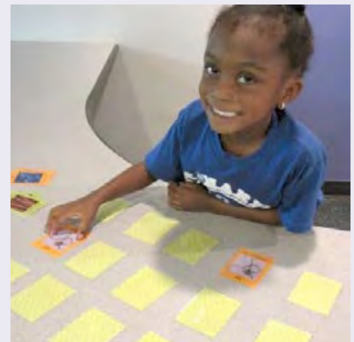
Exploring Size—

Memory Game

Try this!



1. Shuffle the cards and arrange them face down on the table. (You can line them up in rows or set them out randomly.)

2. Pick two cards and flip them right side up.

3. If the cards match, put them to the side and take another turn. If they don't match, flip them back over and try again.

4. Look for matches until you find all the pairs.

What's going on?

Things come in different sizes—and size is important! We use different scales to measure things that are different sizes. In this game, we explore three different scales: the macroscale, the microscale, and the nanoscale.

Macroscale objects are on purple cards

The macroscale includes objects we can see with our eyes. There are lots of ways to measure objects on the macroscale, including meters. (A meter is a little over three feet.) Kids around six or seven years old are about a meter tall.

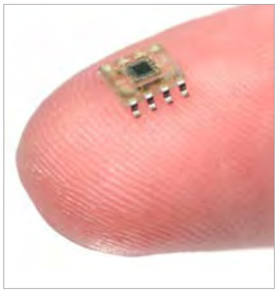
Microscale objects are on green cards

The next scale down is the microscale. To see microscale things clearly, we need tools like microscopes. Objects on the microscale are measured in micrometers. A micrometer is a millionth of a meter. Red blood cells are measured in micrometers.

Nanoscale objects are on orange cards

There's an even smaller scale: the nanoscale! Nanoscale things are so tiny, we can't see them with just our eyes. We need special tools to make images of them. Nanoscale objects are measured in nanometers. A nanometer is super small—a billionth of a meter! DNA is measured in nanometers.

How is this nano?



Microchip on finger

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.

Learning objectives

Things come in different sizes—and size is important!

A nanometer is a billionth of a meter.

Materials

• "Macro, Micro, Nano" playing cards
• "Making a Match" sheet
• "Macroscale Objects," "Microscale Objects," and "Nanoscale Objects" sheets

Notes to the presenter

You can use the "Making a Match" sheet to show visitors how to match pairs, and to explain that the objects on the card are three different size scales: macroscale, microscale, and nanoscale.

Visitors can play this game alone or in groups. Single visitors can see how quickly they can find all the pairs. Groups can take turns looking for matches, competing to get the most pairs.

To reinforce the learning objectives, provide narration as the game progresses. Once a match is made, you can identify the scale and object. ("Great job! You found the buckyball pair. Buckyballs are tiny molecules made of carbon atoms.")

The game should be played with at least 12 pairs of cards (four pairs from each scale).

To make the game more interesting for older visitors, try letting visitors justify matches other than identical cards. For example, two orange cards could be a match because they are both nanoscale. Or, the macroscale gecko could be matched to the nanoscale structures of the gecko foot, because they're images of the same object at different scales. (There may be leftover cards with this version of the game.)

Credits

This activity was adapted from *Macro, Micro and Nano Stretch-Ability,* developed by the Children's Museum of Houston for the NISE Network.
The original program is available at: www.nisenet.org/catalog

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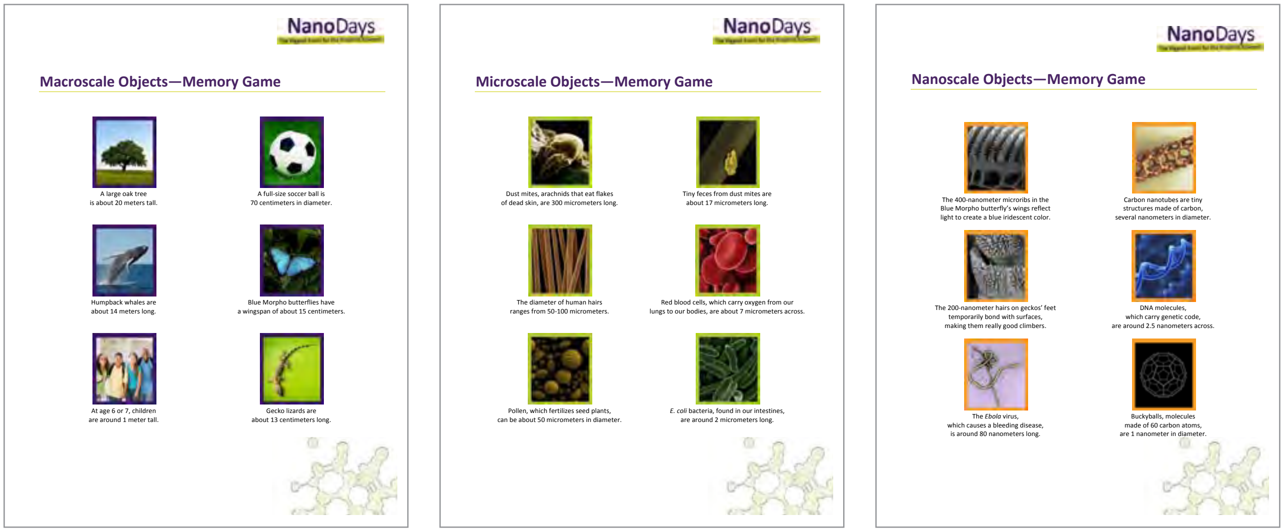
Additional Graphic Resources



"Macroscale Objects," "Microscale Objects," and "Nanoscale Objects" sheets
8.5 x 11 inches

"Making a Match" sheet
8.5 x 11 inches

"Macro, Micro, Nano" playing cards
Set of 38 cards, 2.5 x 3.5 inches

Exploring Size—

Powers of Ten Game

Try this!

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.

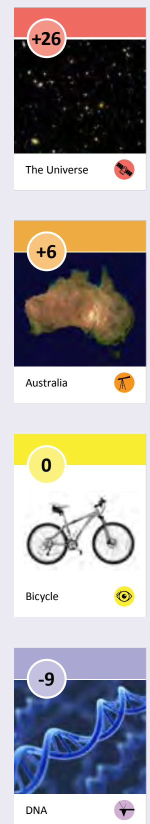
   • Each card has a number on it that tells you how big or small the object is. Bigger objects have positive numbers. Smaller objects have negative numbers.

   • 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.)



Sample row

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 (-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.

Computer chip

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.

Learning objectives

Things come in different sizes—and size is important!

A nanometer is a billionth of a meter.

Materials

- "Sizing Things Down" playing cards
- "Sizing Things Down" orders of magnitude sheet

Notes to the presenter

Here are some hints for learning and playing the game with visitors:

• After each group of visitors, leave the last hand played out on the table. The cards and pictures will attract the attention of another group. Use the last hand's cards to explain the game, and then deal a new hand.

• Add more rows if you have many players. With fewer than four players, three rows are enough. With more players, additional rows give everyone more chances to play. One row per player is a good guideline.

• After each play, say the size comparison aloud: "A cruise ship is bigger than a breadbox," or "DNA is smaller than Jupiter." (Ask visitors to reconsider if they make an invalid move.)

• There's a useful training video showing how the game is played: vimeo.com/channels/nisenet#11049272

For older audiences, you can introduce additional vocabulary, explain the scientific notation system, or provide additional information:

• The metric system is a logarithmic scale. Each ten-fold increase in size is called an order of magnitude. The "Sizing Things Down" sheet provides more information.

• The numbers on the top left corner of the cards indicate the approximate length of the different objects in meters. For example, objects with a -9 are measured in nanometers. They're about 10^{-9} meters across.

• The colored circles on the bottom right corner of the cards indicate some of the tools used to see objects of different sizes.

Credits

This activity was adapted from *Sizing Things Down,* developed by the Oregon Museum of Science and Industry for the NISE Network.
The original program is available at: www.nisenet.org/catalog

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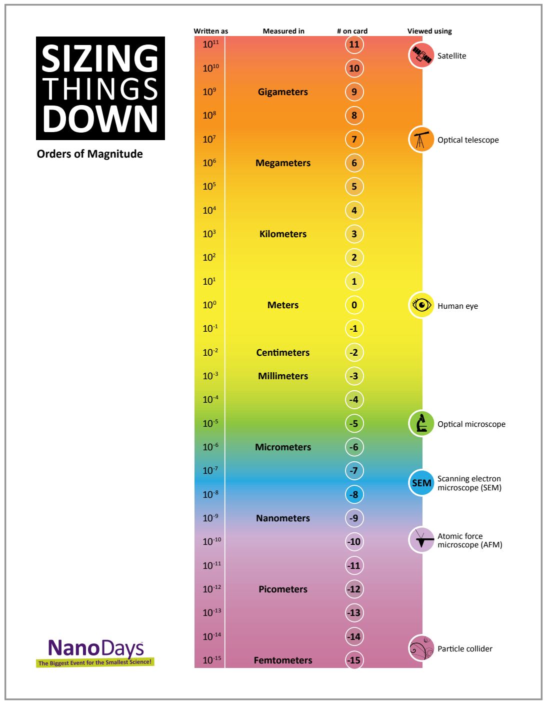
Additional Graphic Resources



“Sizing Things Down” orders of magnitude sheet
8.5 x 11 inches

“Sizing Things Down” playing cards
Set of 83 cards, 2.5 x 3.5 inches

Exploring Properties—

UV Bracelets

Try this!

1. Thread three UV beads onto a pipe cleaner.

2. Thread additional ordinary beads onto the pipe cleaner.

3. Wrap the pipe cleaner around your wrist and twist the ends to tie it.

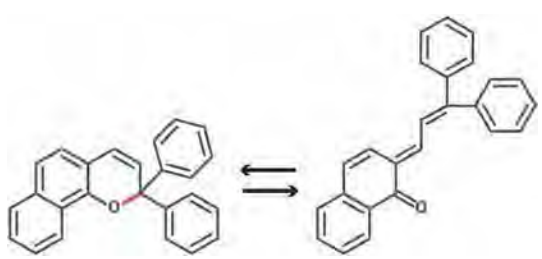
4. Shine the UV flashlight on the beads. What happens?

What's going on?

The ultraviolet (UV) beads change color, but the regular beads stay the same. The UV beads contain a special material called a photochromic dye. ("Photo" means "light" and "chromic" means "color.") The molecules of this special dye change color when exposed to ultraviolet light. The beads will change color when exposed to any UV light source, such as the sun or a special UV flashlight.

The UV light causes a bond in the molecule of the dye to break, allowing the molecule to twist into a new shape. The newly shaped molecule absorbs light differently, giving it a different color.

This process is reversible. Once the source of UV light is removed, the broken bond will reform and the bead will return to its original color. So when you turn off the flashlight (or come out of the sun), the UV beads turn white again. You can test this by turning off the flashlight (or coming out of the sun).



Ultraviolet light causes a molecule to change shape

How is this nano?

The way a material behaves on the macroscale is affected by its structure on the nanoscale. Changes to a material's molecular structure are too small to see directly, but we can sometimes observe corresponding changes in a material's properties. The UV beads in this activity change color as a result of nanoscale shifts in the shape of the dye molecules.

Nanotechnology takes advantage of special properties at the nanoscale to create new materials and devices. The most common uses of photochromic dyes are in eyeglass lenses. Some people have glasses that are clear indoors but darken into sunglasses when exposed to UV light outdoors. There are also new windows that use a similar technology to keep buildings cool and save energy.


Some eyeglass lenses darken in sunlight

Learning objectives

The way a material behaves on the macroscale is affected by its structure on the nanoscale.

The UV beads in this activity change color as a result of nanoscale shifts in the shape of their molecules.

Materials

- Pipe cleaners
- UV beads
- Ordinary pony beads
- UV flashlight

UV beads are available from www.teachersource.com (#UV-AST).

UV flashlights are available from www.homedepot.com (#809-2717-D).

Notes to the presenter

SAFETY: The ends of the pipe cleaners can be sharp. Use caution while handling them.

SAFETY: The UV flashlight emits very low levels of UV radiation. It is safe to use, but you should discourage visitors from looking directly at the UV bulbs when the light is on. Supervise visitors at all times during this activity.

This activity should be done in a location out of direct sunlight so the UV beads will be white or very pale when visitors start the activity (not brightly colored). If you prefer not to use the UV flashlight, you may be able to do the activity near a window, using sunlight to expose the beads to UV light. After the UV beads change color, they will slowly return to white once the ultraviolet light source is removed.

Children, individuals with limited dexterity, and low-vision visitors may need assistance threading the beads onto the pipe cleaners.

Additional information on the photochromic dye: The UV beads contain naphthopyran dye molecules. The energy from the UV flashlight breaks a bond in these molecules, changing their shape. The bond that breaks is indicated in orange in the illustration on the front side of the guide. This same process occurs for all colors of beads (though the exact composition of the dye molecule is different for each color).

Credits

This activity was adapted from “Reversible Sunglasses” developed by The Franklin Institute, in partnership with Penn State MRSEC and the Cornell Center for Materials Research, through funding by the National Science Foundation and Penn State University.

The original activity is available at: www.mrsec.psu.edu/education/museum_shows/small_wonders/

This project was supported by the National Science Foundation under Award No. 0940143. 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.

Exploring Size—

Moving Molecules

Try this!

1. Look inside the toy. Is it filled with anything?

2. Try to get the pinwheels to spin! Stand a few feet away.

3. Aim the toy, pull back the handle, and release it. (Try again if you miss the first time.)

4. What made the pinwheels move?

What's going on?

Molecules moved the pinwheels! The toy isn't empty—it's filled with air. When you pull and release the plastic sheet on the back of the toy, you push air toward the pinwheels. When the air hits the pinwheels' blades, they spin.

Wind farm

Like everything on Earth, air is made of tiny "building blocks" called molecules. Examples of molecules in air are oxygen (O_2), nitrogen (N_2), carbon dioxide (CO_2), and water (H_2O).

These molecules are made of atoms, which are tiny particles smaller than a nanometer. (A nanometer is a billionth of a meter.) Examples of atoms include carbon, oxygen, and hydrogen. Around 90 different kinds of atoms occur naturally on Earth.

Individual molecules are too small to see with our eyes. The molecules that make up gases are relatively far apart, so we can't see air. The molecules that make up solid things are relatively close together, so we can see a pinwheel (but not its individual molecules).

Although we can't see air, we can feel it and observe how it interacts with other things, like pinwheels or giant wind turbines. Wind turbines gather energy from moving air, which can be turned into electricity.

How is this nano?

A nanometer is a billionth of a meter. That's very, very small—too small to see with just your eyes. Atoms and molecules, the building blocks of our world, are examples of things measured in nanometers.

Researchers use special tools and equipment to detect and manipulate nanometer-sized things. In the field of nanotechnology, scientists and engineers make new materials and tiny devices smaller than 100 nanometers in size. Sometimes, they build things out of individual atoms!

Nanotechnology allows scientists and engineers to make things like smaller, faster computer chips and new medicines to treat diseases like cancer.


Computer chip

Learning objectives

A nanometer is a billionth of a meter.

Air is made of molecules, which are tiny nanometer-sized particles.

Materials

- Air cannon toy
- Pinwheels (4)
- Pinwheel stand

Airzooka air cannon toys are readily available from toy stores, including www.walmart.com and www.toysrus.com.

Notes to the presenter

Before doing this activity, insert the pinwheels into the stand. Test to see that they spin freely. If they don't, loosen them up by spinning them by hand.

Visitors should stand a small distance away from the pinwheels. In order to be able to talk to visitors and assist them, you should stand near them (rather than next to the pinwheels).

You may need to help young children and individuals with limited strength to hold the toy and pull the handle. To make the toy easier to use for some visitors, you can remove the elastic cord that attaches the plastic sheet to the barrel. Visitors can then push in the plastic sheet to make a puff of air, without having to pull against the elastic band. With this accommodation, visitors will need to stand very close to the pinwheels. Alternatively, they can direct the air onto the hand of another person to feel, rather than using the pinwheels. (Note that it will take some time to reattach the elastic if you make this modification.)

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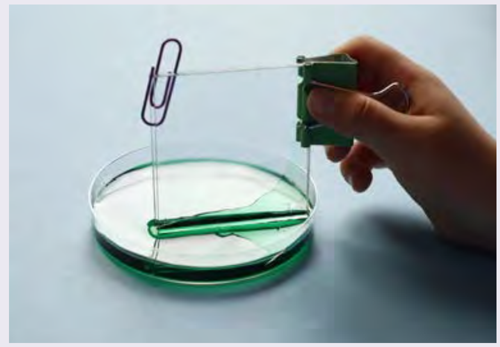
Exploring Properties—

Capillary Action

Try this!



1. Hold an acrylic setup in a small amount of colored water.

2. Observe the water level between the two pieces of acrylic. What happens? Is the water level the same across the setup?

What's going on?

The water level between the two acrylic pieces rose as a result of *capillary action.* Capillary action is the ability of a liquid to flow in narrow spaces—even against gravity. The water level was higher where the pieces were closer together and the space was narrower. As capillary spaces get smaller and smaller, liquids can move farther and faster.

Now try this!

1. Use water-based markers to draw on a coffee filter.

2. Add several drops of water to the coffee filter.

3. Now hold the paper up vertically and watch the water move. What do you notice?

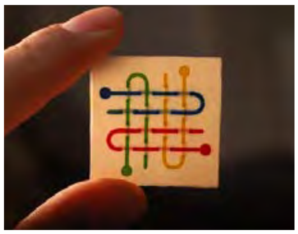
What's going on?

The ink pigment dissolves in the water because it is water-soluble. As the water travels up the paper by capillary action, it carries the pigment along with it. How fast each pigment travels depends on the size of the pigment molecule and on how strongly the pigment is attracted to the paper. The spaces between the fibers in the paper act as capillary tubes.


Color moving on paper

This technique is called chromatography and was originally used for separating pigments that made up plant dyes. There are many different types of chromatography. In all of them, a liquid (like the water) or a gas flows through a stationary substance (like the paper). Chromatography can determine the chemical makeup of a flavor or scent, the components of pollutants, and can separate blood proteins.

How is this nano?


Paper diagnostics

When things get small they can behave in surprising ways. Different physical forces dominate when things get very, very small. For example, gravity is very important to us on the macroscale, but it's hardly noticeable at the nanoscale.

Researchers at Harvard University are making special patterned paper that wicks small volumes of fluid by capillary action. The fluid is tested and analyzed through different sensors printed right onto the paper. The result is a flexible, disposable test that can check a tiny amount of urine or blood for evidence of infectious diseases or chronic conditions. Currently, paper diagnostics use microtechnologies, but nanoscale features may make them even more useful and accurate.

Learning objectives

At the nanoscale things behave in surprising ways.

Technologies and society influence each other.

Materials

• Coffee filters
• Water-soluble markers
• Squeeze bottle of water
• "Lab-on-a-Chip & Paper Diagnostics" sheet
• Acrylic capillary action setup (two acrylic squares, binder clip, paper clip, petri dish, food coloring)
• Paper towels (optional for cleanup)

Notes to the presenter

SAFETY: Although nontoxic, visitors should be careful handling these materials. Visitors should not drink the dyed water.

Before doing this activity, prepare the capillary action setup: You may need to peel the brown paper backing off the acrylic. Hold the two acrylic squares together with the binder clip along one edge. Insert the paper clip on the opposite edge to make a small wedge. Fill the petri dish halfway with colored water.

Tips: You'll want to use a high concentration of food coloring (3 or more drops) in order to see the water wick up between the plastic squares. The kit includes two sets of the capillary action setup. Alternate between the two sets to allow for drying and resetting.

Timing: It may take a few moments for the liquid to rise up between the acrylic squares. Do the coffee filter activity first and come back to the demo afterwards to see how much the water moved.

Knowing your visitors: The filter paper activity is an opportunity for visitors to explore and experiment with capillary action. Young visitors can draw freely and choose how much water to add. Make it a more controlled experiment for older children or adults by drawing a line on one edge of the filter and holding the paper vertically to watch the water rise up against gravity.

Conversations: This activity is based on a demonstration of capillary action, but it provides an opportunity to engage visitors in conversation about potential new nanotechnologies, like a lab-on-a-chip and paper diagnostics, and ways that these technologies can both influence and be influenced by society.

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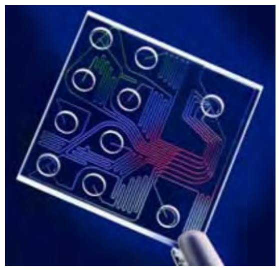
Additional Graphic Resources

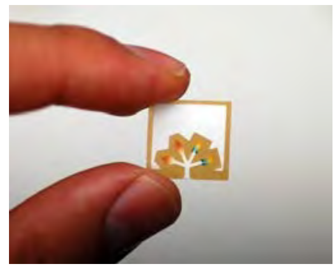
NanoDays
The Biggest Event for the Smallest Science!

Lab-on-a-Chip & Paper Diagnostics

Nanotechnology is making it cheaper and faster to detect diseases. Small chips the size of a postage stamp could run a variety of medical tests, using only a drop of blood and producing results in just a few minutes. These "labs-on-a-chip" owe their efficiency to tiny channels that take advantage of capillary action and nano-sized sensors. These devices are currently available, but scientists are working to make even smaller channels with faster response time. Researchers are also working on special patterned paper that wicks tiny amounts of fluid—like blood—to test for illness. The paper diagnostics that have been made so far use microtechnologies, but nanoscale features may make them even more useful and accurate. Patients could quickly learn if they have an infectious disease or have been exposed to toxic chemicals.



Small devices the size of a postage stamp move fluid through tiny channels by capillary action



Paper wicks fluid for different diagnostic tests

"Lab-on-a-Chip & Paper Diagnostics" sheet
8.5 x 11 inches

Exploring Properties—
Heat Transfer

Try this!

1. Feel both blocks. Which one feels warmer to your touch?

2. Make a prediction: Which block will cause an ice cube to melt faster?

3. Place a cube of ice on each block. Do they melt at the same rate? Which one melted faster?

What's going on?

One of the blocks is made of aluminum and the other is made of high-density foam. They are both at room temperature, but even though the aluminum block feels colder, it actually makes the ice melt faster!

When you touch the aluminum block, the heat of your hand quickly transfers away into the block. This leaves your hand feeling cold. But when you touch the foam block, only a little heat slowly flows into the block. So your hand still feels warm. Remember both blocks are at room temperature, much warmer than an ice cube! Heat transfers quickly from the aluminum block to an ice cube, melting it very quickly. But heat only slowly transfers to the ice cube on the foam block, making it melt more slowly.

The difference happens because of *thermal conductivity.* Thermal conductivity measures how quickly heat flows through a material. The aluminum has a higher thermal conductivity and the foam has a lower thermal conductivity.

Now, try this!

1. Press the edge of the graphite piece into an ice cube.

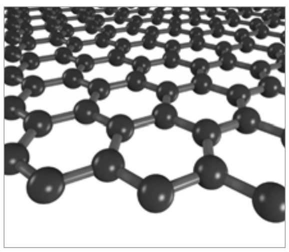
2. What happens to the ice? Do you feel anything surprising in the fingers holding the graphite?

What's going on?

You are slicing the ice with the heat from your hand! The little piece of graphite is a very good conductor of thermal energy. The heat flows from your hand quickly and easily through the graphite and to the ice. The graphite piece in the demo is a very pure and highly ordered form of graphite—unlike the graphite in a regular pencil, which has various clays in it.

How is this nano?

The way a material behaves on the macroscale is affected by its structure on the nanoscale. Graphene is a single layer of carbon atoms arranged in a honeycomb pattern. It is the thinnest material that exists.



Graphene

While most nanoscale films have poor thermal conductivity, graphene has excellent thermal conductivity. In 2008, researchers at the University of California, Riverside showed that graphene's thermal conductivity is about 20 times greater than aluminum, 10 times greater than copper, and 3 to 5 times greater than diamond (the previous record holder). Graphene has the potential to play a major role in keeping future electronic devices from overheating!

Learning objectives

The way a material behaves on the macroscale is affected by its structure on the nanoscale.

Heat flows through different materials at different rates.

Materials

- Black aluminum block
- Black high-density foam block
- O-rings (2)
- Pyrolytic graphite piece
- Sponge
- Insulated bag
- Ice cube tray and ice
- "Thermal Conductivity of Graphene" sheet

Ice-melting block sets are available from scientific suppliers, such as www.arborsci.com (#P6-7060).

Pyrolytic graphite pieces are available from magnet suppliers, such as www.kjmagnetics.com (#PG1).

Notes to the presenter

Important note: Take care when using the pyrolytic graphite piece. It is fragile and can break easily. For younger visitors, offer to help them slice the ice and then allow them to touch the graphite piece to feel the cold.

Advanced preparation:

Be sure to have enough ice on hand for the number of visitors you are expecting. The ice should be stored in the freezer until it is needed for the activity. If you make the ice in advance and mix it all together in the freezer bag, be sure it doesn't stick together as this can make it harder to do the activity.

During the activity:

• The provided insulated bag will help to keep the ice cool during the activity for at least a few hours, but may need to be emptied and refilled if the ice begins to melt.

• The O-rings are meant to contain the water on the block after the ice is melted. They may be omitted from the activity if you wish.

• After performing the demo, be sure to dry off the blocks with the sponge provided in preparation for the next visitor.

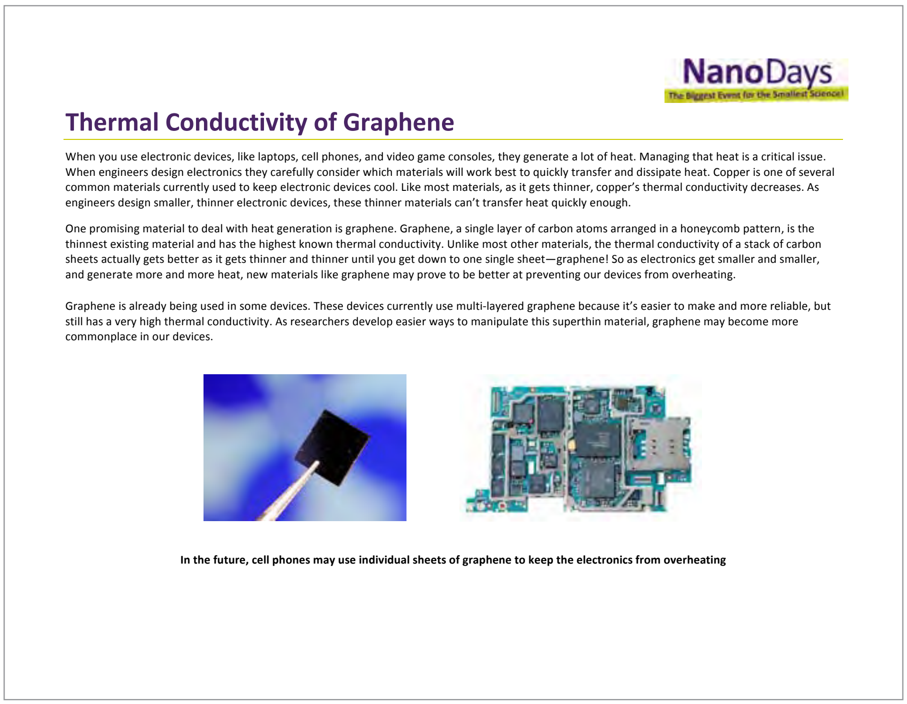
Discussion ideas:

In your discussion of thermal conductivity, use familiar examples to illustrate how thermal energy flows between materials. Some visitors may have noticed that in the morning, bathroom tiles feel cold and uncomfortable, while a bathroom rug feels warmer. The rug and the tiles in the room are the same temperature, but the tiles have a higher thermal conductivity and the heat from your feet flows more quickly into them—making them feel cold to the touch.

You may also want to discuss how the materials we use for certain products are influenced by their thermal conductivity. In cooking, we use copper, aluminum, and stainless steel pots because those materials quickly transfer heat from the burner to the food. (They have a high thermal conductivity.) On the other hand, materials like Styrofoam and feathers transfer heat slowly—they have a low thermal conductivity. These materials make good insulators, so we use them in products like coolers or jackets to prevent heat from being transferred.

You can connect these examples to graphene by saying that engineers are still trying to find or create materials that have even better heat transfer properties, and one of the promising materials is graphene.

Additional Graphic Resources



NanoDays
The Biggest Event for the Smallest Science!

Thermal Conductivity of Graphene

When you use electronic devices, like laptops, cell phones, and video game consoles, they generate a lot of heat. Managing that heat is a critical issue. When engineers design electronics they carefully consider which materials will work best to quickly transfer and dissipate heat. Copper is one of several common materials currently used to keep electronic devices cool. Like most materials, as it gets thinner, copper's thermal conductivity decreases. As engineers design smaller, thinner electronic devices, these thinner materials can't transfer heat quickly enough.

One promising material to deal with heat generation is graphene. Graphene, a single layer of carbon atoms arranged in a honeycomb pattern, is the thinnest existing material and has the highest known thermal conductivity. Unlike most other materials, the thermal conductivity of a stack of carbon sheets actually gets better as it gets thinner and thinner until you get down to one single sheet—graphene! So as electronics get smaller and smaller, and generate more and more heat, new materials like graphene may prove to be better at preventing our devices from overheating.

Graphene is already being used in some devices. These devices currently use multi-layered graphene because it's easier to make and more reliable, but still has a very high thermal conductivity. As researchers develop easier ways to manipulate this superthin material, graphene may become more commonplace in our devices.

In the future, cell phones may use individual sheets of graphene to keep the electronics from overheating

"Thermal Conductivity of Graphene" sheet
8.5 x 11 inches

This project was supported by the National Science Foundation under Award No. 0940143 and 0937591. 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.

Storytime

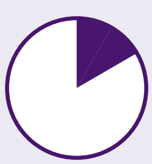
Horton Hears a Who!

Facilitated Activity

In this storytime program, visitors actively listen to *Horton Hears a Who!* by Dr. Seuss. Before the story is read, visitors make paper "elephant ears" to wear. After the story, they use their sense of smell to explore scent molecules that are too small to see.

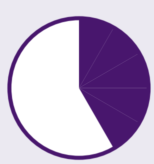
Time Required

Setup



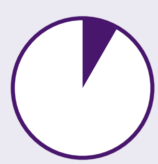
10 min

Program



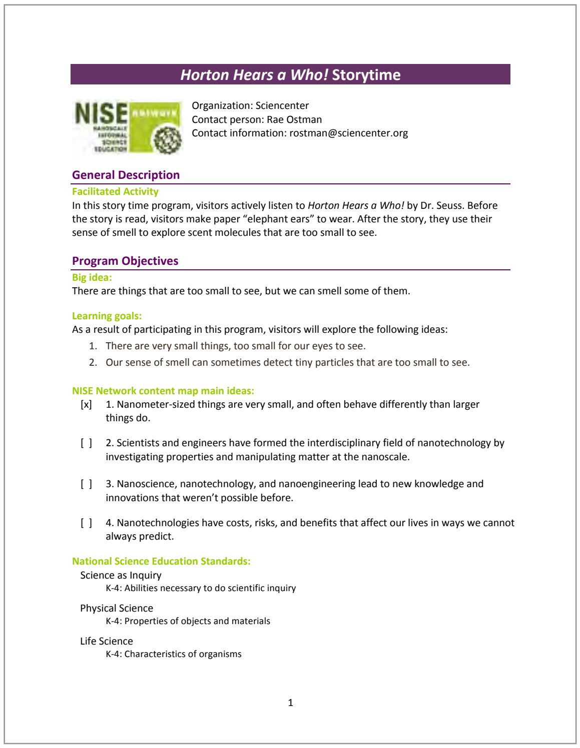
25 min

Cleanup



5 min

Program Resources



Horton Hears a Who! Storytime

Organization: Sciencenter
Contact person: Rae Ostman
Contact information: rostman@sciencenter.org

General Description

Facilitated Activity

In this story time program, visitors actively listen to *Horton Hears a Who!* by Dr. Seuss. Before the story is read, visitors make paper "elephant ears" to wear. After the story, they use their sense of smell to explore scent molecules that are too small to see.

Program Objectives

Big idea:

There are things that are too small to see, but we can smell some of them.

Learning goals:

As a result of participating in this program, visitors will explore the following ideas:

1. There are very small things, too small for our eyes to see.
2. Our sense of smell can sometimes detect tiny particles that are too small to see.

NISE Network content map main ideas:

[x] 1. Nanometer-sized things are very small, and often behave differently than larger things do.

[ ] 2. Scientists and engineers have formed the interdisciplinary field of nanotechnology by investigating properties and manipulating matter at the nanoscale.

[ ] 3. Nanoscience, nanotechnology, and nanoengineering lead to new knowledge and innovations that weren't possible before.

[ ] 4. Nanotechnologies have costs, risks, and benefits that affect our lives in ways we cannot always predict.

National Science Education Standards:

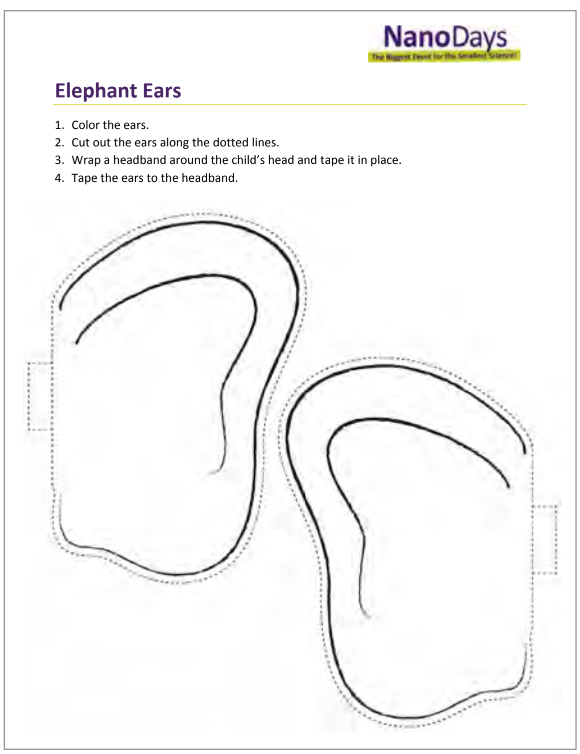
Science as Inquiry
K-4: Abilities necessary to do scientific inquiry

Physical Science
K-4: Properties of objects and materials

Life Science
K-4: Characteristics of organisms

1

"*Horton Hears a Who!* Storytime" lesson plan
10 pages



Elephant Ears

1. Color the ears.
2. Cut out the ears along the dotted lines.
3. Wrap a headband around the child's head and tape it in place.
4. Tape the ears to the headband.

"Elephant Ears" sheet
8.5 x 11 inches

Gary Hodges

SECTION 3

Nano is studying and making tiny things

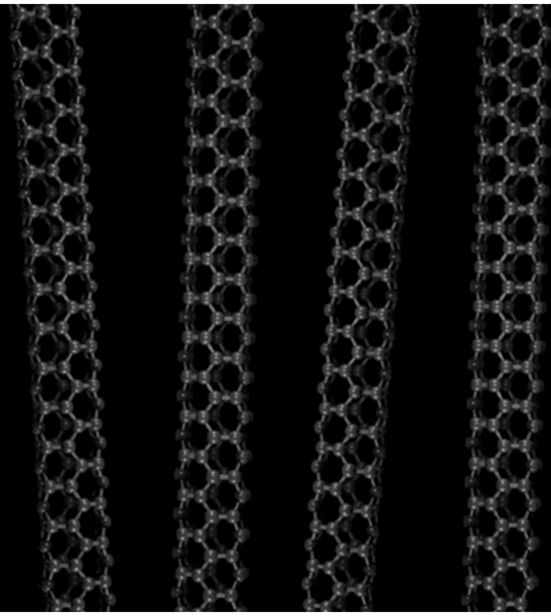
Scientists and engineers have formed the interdisciplinary field of nanotechnology by investigating properties and manipulating matter at the nanoscale.

Everything is made of atoms.

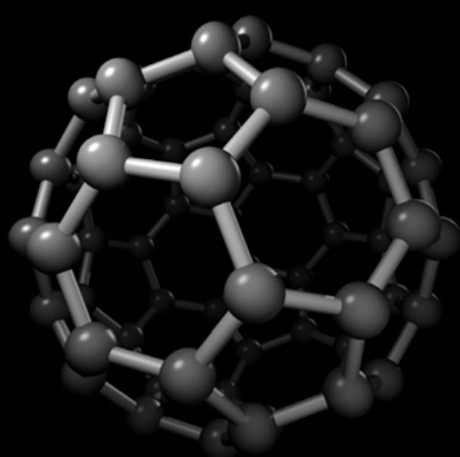
Everything on Earth is made of *atoms*, which are tiny particles smaller than a nanometer. Carbon, oxygen, and hydrogen are examples of atoms. Atoms join together in different ways to form *molecules*. The way these tiny building blocks are arranged helps determine the properties, or behavior, of a material.

DIAMOND AND GRAPHITE Carbon atoms can form diamonds, the hardest natural material known on Earth. But they can also form one of the softest materials, graphite (pencil lead). Both diamonds and graphite are made entirely from carbon. They have different properties because the carbon atoms are arranged differently. Diamonds are hard and shiny because they have a sturdy molecular structure. Graphite is soft and slippery because its carbon atoms are stacked in sheets.

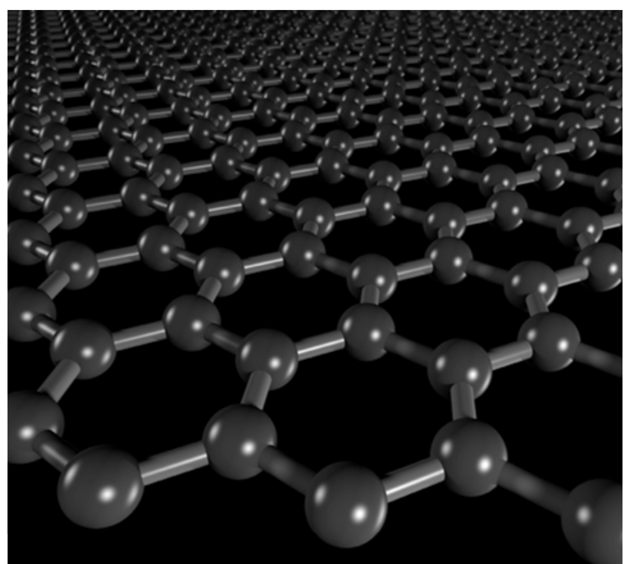
CARBON NANOTUBES AND BUCKYBALLS Carbon can form nanoscale structures, including carbon nanotubes, buckyballs, and graphene. Like larger forms of carbon, these tiny objects have special properties due to the way their carbon atoms are arranged. Researchers are now able to study these nanoscale forms of carbon and use them to build nanotechnologies.



CARBON NANOTUBES are very strong and light, and can act as semiconductors or conductors. Researchers are studying ways to use carbon nanotubes in electronics, fuel cells, and other technologies.



BUCKYBALLS are good lubricants because of their spherical shape. Their hollow structure could make them useful for delivering medicine in the future.

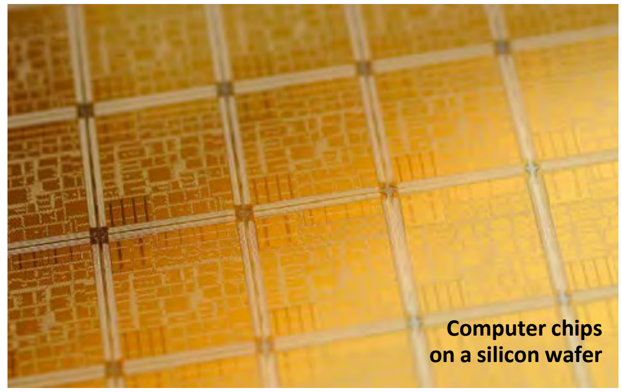


GRAPHENE is strong and flexible, and it conducts electricity and heat. Potential uses for graphene include integrated circuits in computers and sensors to detect gases.

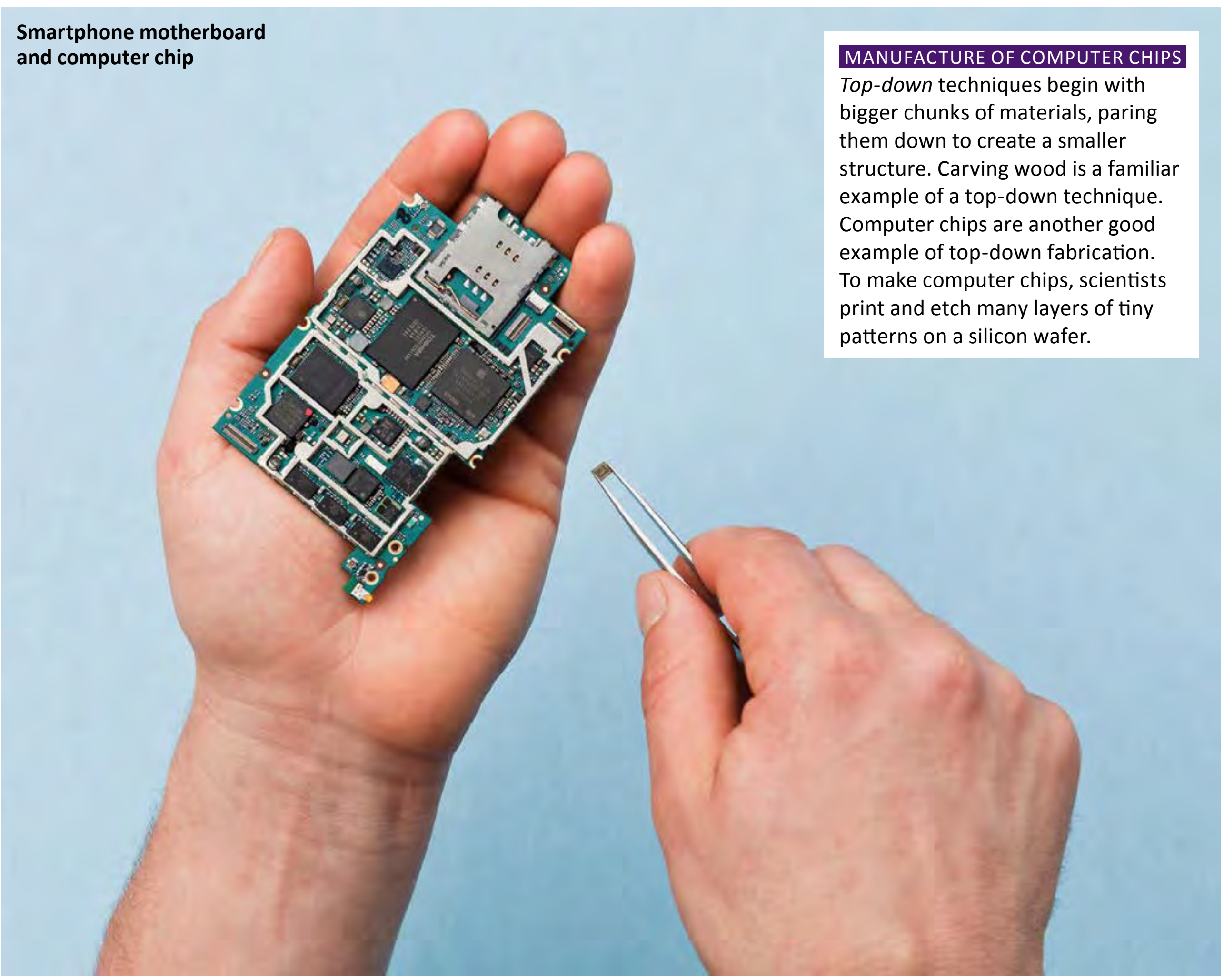
Scientists have developed new ways to study and build tiny nanoscale things.

Nanoscientists and engineers study and make things that are less than 100 nanometers in size. Sometimes nanotechnologies and materials can be built from individual atoms!

To work at such a small scale, nano researchers have developed new ways to investigate and build tiny things. The two main ways to make nanoscale objects and devices are known as *top-down* and *bottom-up* techniques.



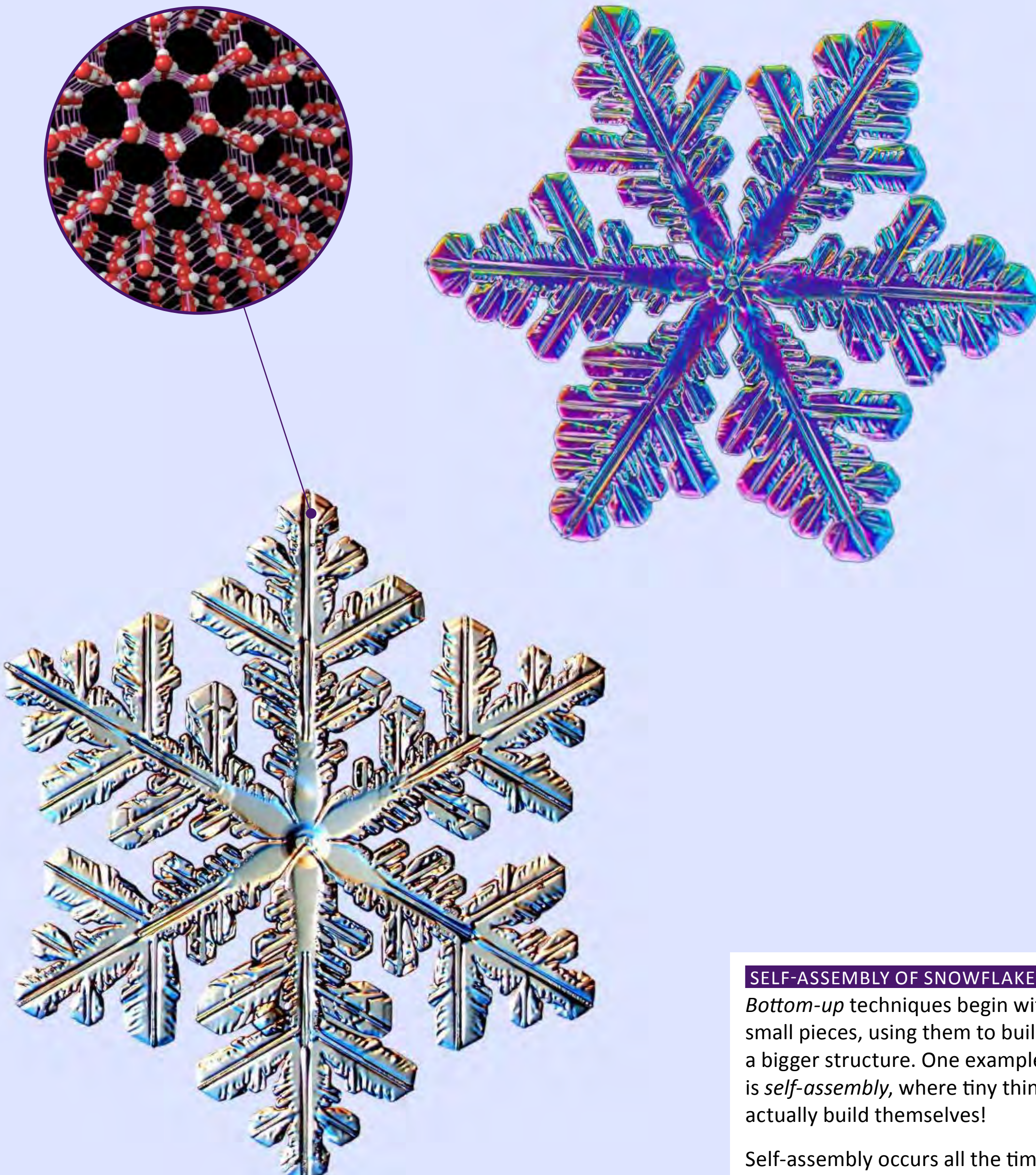
Computer chips on a silicon wafer



Smartphone motherboard and computer chip

MANUFACTURE OF COMPUTER CHIPS

Top-down techniques begin with bigger chunks of materials, paring them down to create a smaller structure. Carving wood is a familiar example of a top-down technique. Computer chips are another good example of top-down fabrication. To make computer chips, scientists print and etch many layers of tiny patterns on a silicon wafer.



Snowflakes: Kenneth Libbrecht, Caltech, www.snowcrystals.com, Crystal structure: Martin McCarthy

SELF-ASSEMBLY OF SNOWFLAKES

Bottom-up techniques begin with small pieces, using them to build a bigger structure. One example is *self-assembly*, where tiny things actually build themselves!

Self-assembly occurs all the time in nature. For example, water molecules self-assemble into ice crystals and fall to the ground as snowflakes. Researchers are learning how to make different objects self-assemble in the lab.

Nano is all around us—in nature and in technology.

Some of the beautiful and surprising things we observe in nature are due to special nanoscale properties. The iridescent color of insect wings, the self-cleaning property of lotus leaves, and the "sticky" feet of geckos are examples of natural phenomena caused by tiny nanostructures. Researchers can be inspired by nature to create new materials and technologies.

Qualcomm Technologies, Inc.

Low-energy display

Tiny nanostructures: S.Yoshioka, Osaka University

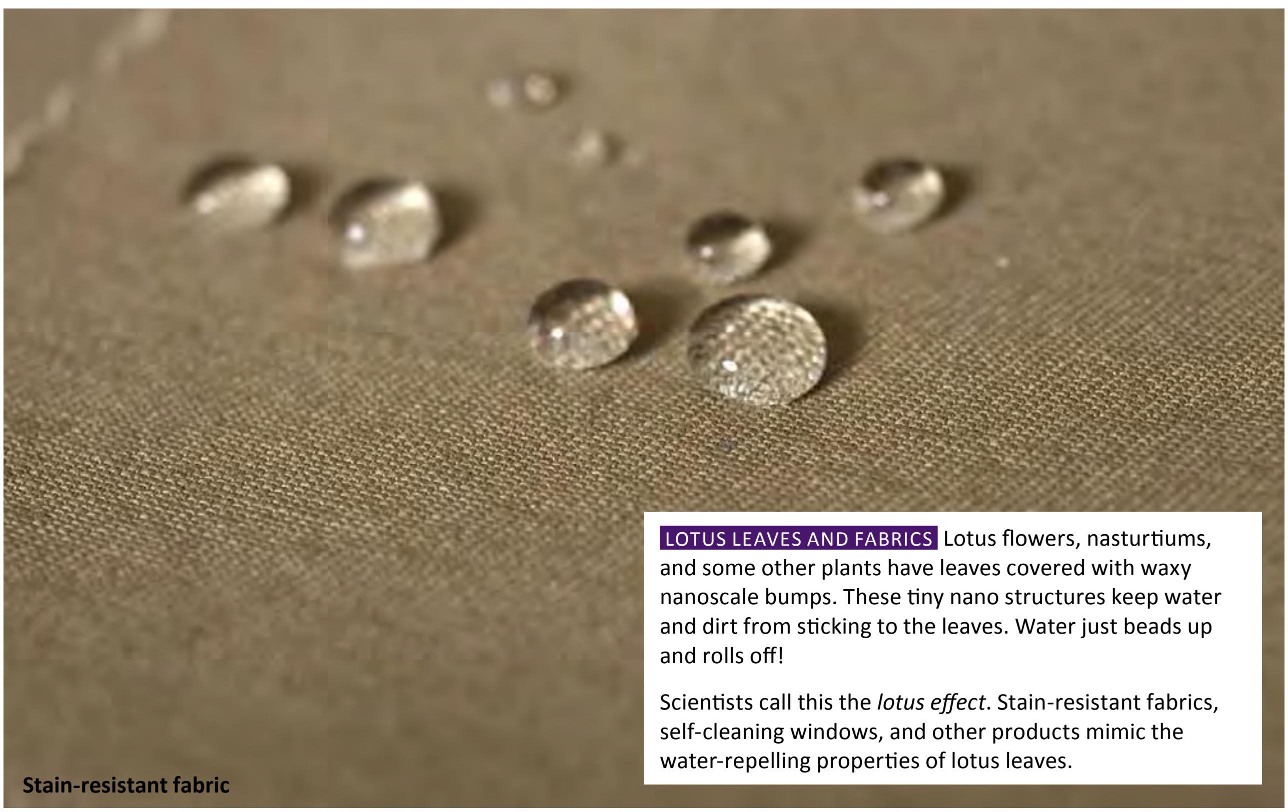
Tiny nanostructures on the scales of a Blue Morpho butterfly

BUTTERFLY WINGS AND DISPLAYS

Blue Morpho butterfly wings are a bright, shimmering blue. Surprisingly, their iridescent color is actually created by tiny, colorless scales with nano-sized ridges! Light waves bounce off the scales and interfere with each other, reflecting blue light to your eyes.

Researchers are working on new nanotechnologies that mimic the Blue Morpho's wings. They've already invented low-energy displays that adjust the spacing between materials to create colors.

Water drops on a lotus leaf



Stain-resistant fabric

LOTUS LEAVES AND FABRICS Lotus flowers, nasturtiums, and some other plants have leaves covered with waxy nanoscale bumps. These tiny nano structures keep water and dirt from sticking to the leaves. Water just beads up and rolls off!

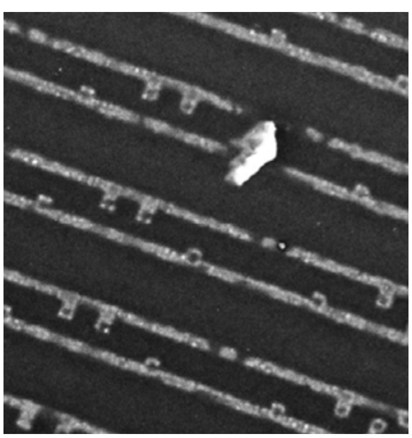
Scientists call this the *lotus effect*. Stain-resistant fabrics, self-cleaning windows, and other products mimic the water-repelling properties of lotus leaves.

Nanoscale science, engineering, and technology are possible because of new tools and techniques.

Nanoscale science and engineering is a large, interdisciplinary field. Nanoscientists and engineers work in many areas of science, including physics, chemistry, materials science, and biology.

Nano research often combines two or more fields, allowing new ideas, knowledge, and innovations to emerge. By working together, researchers with different expertise can tackle problems in new ways.

Cornell NanoScale Science & Technology Facility / Charles Harrington Photography

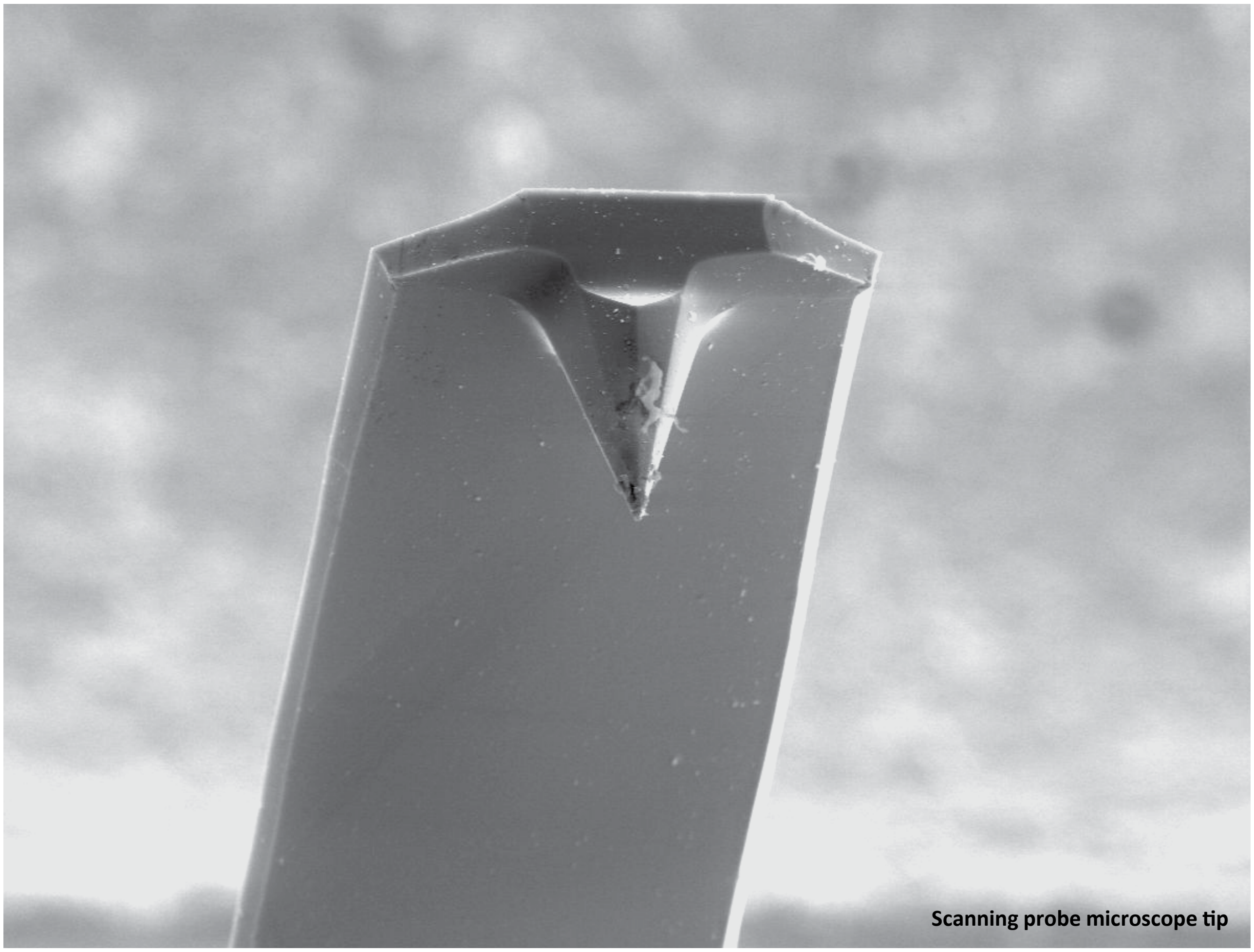


Dust on a computer chip

NANO LABS Computer chips and some other nanotechnologies are made in labs known as *cleanrooms*. Dust and other tiny particles in the environment are huge in size compared to nanoscale objects. Just one speck of dust can destroy an entire device!

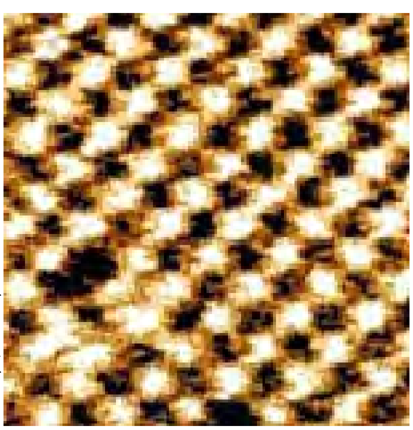
Cleanrooms let researchers study and build nanoscale things. Researchers who work in cleanrooms use special clothes, tools, and equipment.

Researchers have developed new tools and techniques to work on the nanoscale. Nanoscale objects are too small to see with regular microscopes, because they're smaller than the wavelength of visible light. Tools such as scanning probe microscopes (SPMs) allow researchers to image and move nanoscale objects, making the field of nanotechnology possible.



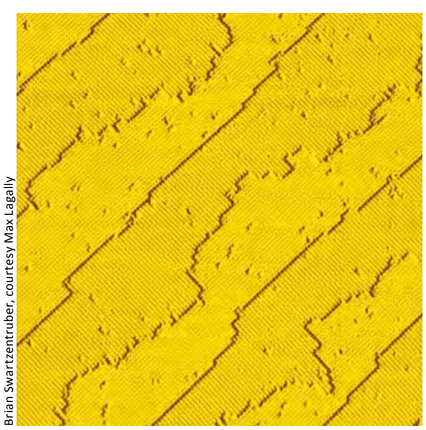
SecretDisc

Scanning probe microscope tip



Ernst Meyer, University of Basel

SPM image of salt



Brian Swartzentruber, courtesy Max Lagally

SPM image of silicon

SCANNING PROBE MICROSCOPE Scanning probe microscopes can detect and make images of things as small as a single atom!

SPMs have a sharp tip that moves back and forth across a sample. As it moves, the tip "feels" and measures changes in the surface. A computer combines the information gathered by the tip and makes an image.

Some kinds of SPMs can also be used to move atoms around. This allows researchers to build tiny things one atom at a time!

Exploring Structures—
Buckyballs

Try this!

1. Take a precut paper shape.

2. Fold it along the scored lines to make a model of a nanoscale structure.

3. Put the tabs in the slots to hold it together. What does your model look like?

What’s going on?

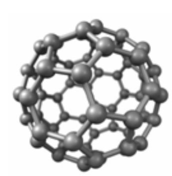
You’ve made a model of a buckyball, a tiny molecule made of 60 carbon atoms.

Buckyballs look like soccer balls or geodesic domes. They're named after the architect Buckminster Fuller, who made dome structures popular.

Buckyballs are just one form of carbon. Carbon can also form diamond, the hardest natural material known on Earth, and graphite, one of the softest materials.

Diamond ring

Pencil lead (graphite)



Model of a buckyball

Diamond, graphite, and buckyballs are all made entirely from carbon! They have different properties because the carbon atoms are arranged differently at the nanoscale.

How is this nano?

Buckyballs are tiny, soccer ball-shaped molecules made of carbon. Buckyballs are only one nanometer across! (A nanometer is a billionth of a meter.)

In the field of nanotechnology, scientists and engineers study the world of the nanometer and make new materials and tiny devices. They use special tools and equipment to detect and manipulate nanometer-sized particles like buckyballs.

Buckyballs are good lubricants because of their spherical shape. Their hollow structure could make them useful for delivering medicine in the future.

Learning objective

Buckyballs are tiny, soccer ball-shaped molecules made of carbon.

Materials

- Die-cut paper buckyballs
- “Carbon Structures” poster

Custom buckyball die (#180967) can be ordered from Custom Shape Pros, customshapepros.com.

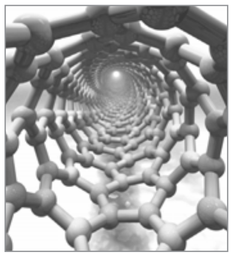
Buckyball Background Information

What are buckyballs?

Buckyballs are tiny molecules made of 60 carbon atoms. They're named after Buckminster Fuller, an architect who designed geodesic dome structures similar to the one at Epcot Center.

Buckyball molecules are just one form of carbon. Carbon atoms can bond together into many different structures, and different forms of carbon have very different properties.

What other forms can carbon take?



Model of the inside of a carbon nanotube

Carbon can form diamond, the hardest natural material known on Earth. But it can also form one of the softest materials, graphite (pencil lead). Both diamonds and graphite are made entirely from carbon. They have different properties because the carbon atoms are arranged differently at the nanoscale.

Carbon can also form two tiny, nanometer-sized structures that are too small to see: buckyballs and carbon nanotubes. Buckyballs have a soccer ball shape. Carbon nanotubes are long, hollow tubes. Buckyballs and carbon nanotubes have special properties due to the way their carbon atoms are arranged.

How are buckyballs and carbon nanotubes used?

Buckyballs are good lubricants because of their spherical shape. Their hollow structure could make them useful for delivering medicine in the future.

Carbon nanotubes are very strong and light, and can act as semiconductors or conductors. They're used to strengthen composite materials. Researchers are studying ways to use carbon nanotubes in electronics, fuel cells, and other applications.

Buckyballs and carbon nanotubes occur naturally. They're found in soot and in outer space, and are produced when lightning strikes. Scientists who work on the nanoscale are studying how to make these tiny particles and how to use them to build other things.

Credits

The information presented in this guide was adapted from:

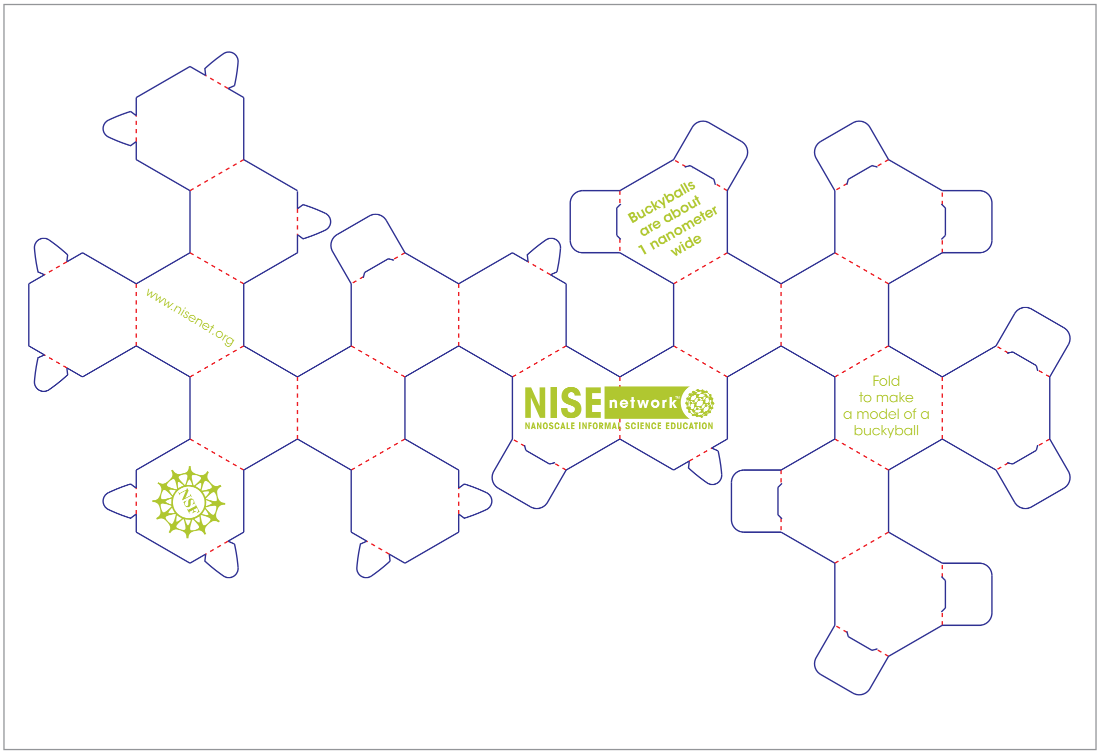
"Applications Activity: Nanoarchitecture," developed by the National Science Foundation-supported Internships in Public Science Education (IPSE) Program at the Materials Research Science and Engineering Center (MRSEC) on Nanostructured Materials and Interfaces at the University of Wisconsin-Madison. The original activity is available at: mrsec.wisc.edu/Edetc/IPSE/educators/carbon.html

"Carbon Nanotubes & Buckyballs," developed by the National Science Foundation-supported Materials Research Science and Engineering Center (MRSEC) on Nanostructured Interfaces at the University of Wisconsin-Madison. The original activity is available at: mrsec.wisc.edu/Edetc/nanoquest/carbon/

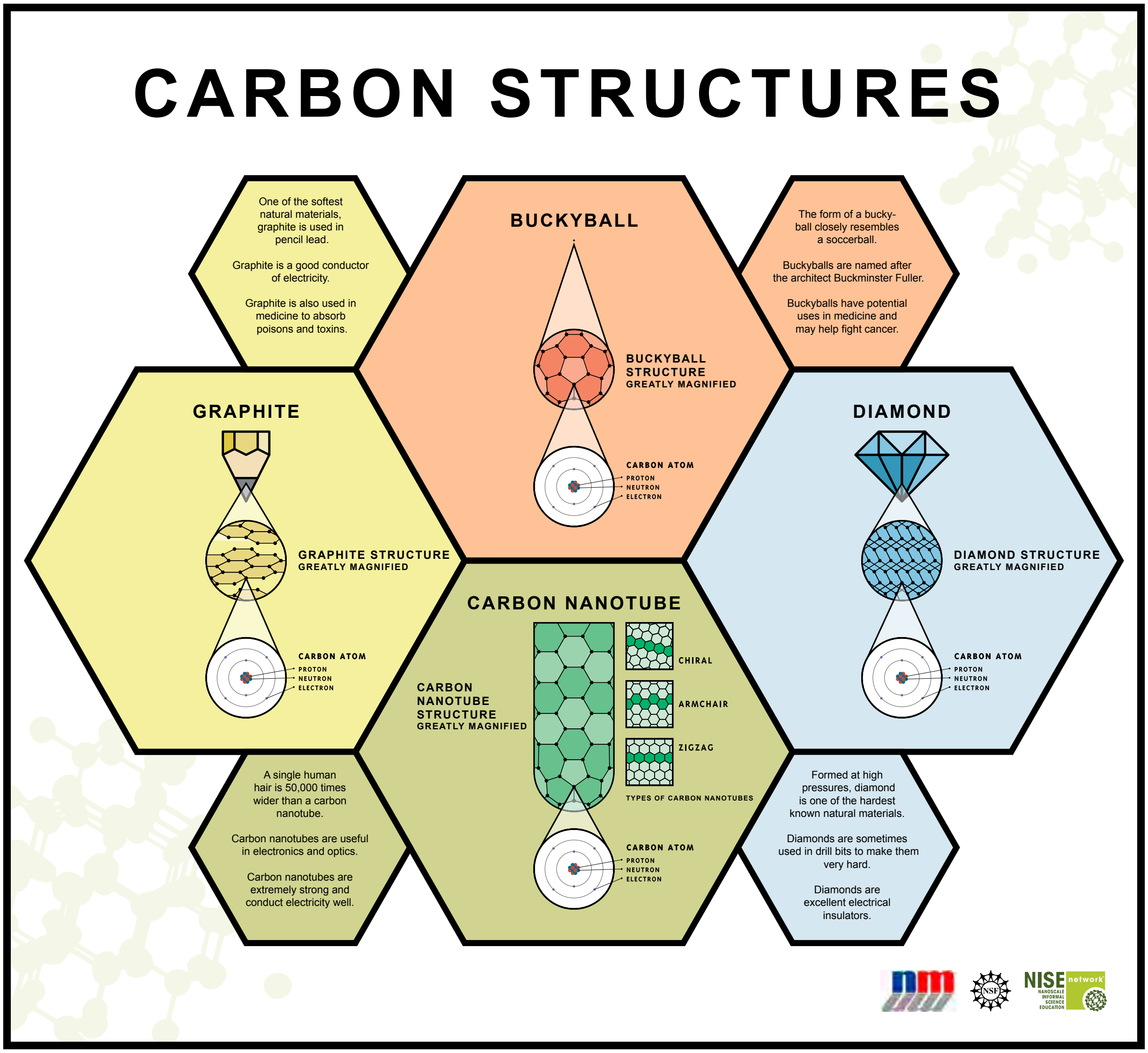
"Nanoarchitecture: Forms of Carbon," developed by the National Science Foundation-supported Internships in Public Science Education (IPSE) Program at the Materials Research Science and Engineering Center (MRSEC) on Nanostructured Materials and Interfaces at the University of Wisconsin-Madison. The original activity is available at: mrsec.wisc.edu/Edetc/IPSE/educators/activities/carbon.html

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

Additional Graphic Resources



Die-cut paper buckyballs
Set of eight graphics, 8.5 x 11 inches



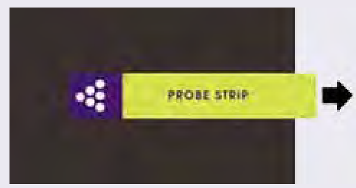
"Carbon Strutures" poster
8.5 x 11 inches

Exploring Tools—
Special Microscopes

Try this!

1. Take a magnet. You're going to pretend it's a scanning probe microscope, a tool that "feels" a surface to find out what it's like.

2. Remove the "probe strip" from the side of the magnet.



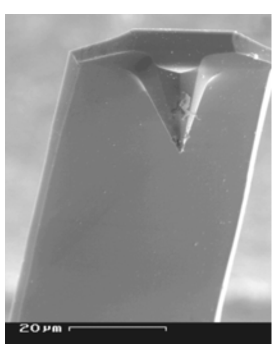
3. Turn the magnet over so it's black side up. This is the surface you're going to feel.

4. Hold the probe strip the way it's shown in the picture, and pull it slowly across the magnet from left to right. What do you feel?

5. Now pull the strip across the magnet from top to bottom, again holding it the way it's shown in the picture. Does it feel different?

What's going on?

The magnet is a model for how a special tool, called a scanning probe microscope (SPM), works. It lets you "feel" something that you can't see: in this case, a magnetic field. The north and south poles run in alternating bands across the magnet.



Tip of an SPM, magnified 1000x

You feel the strip bump across the surface when it's pulled across the bands, because it's alternately attracted to and repelled by the poles it encounters. When the strip is pulled parallel to the bands, you don't feel the bumps because it's always attracted to the surface.

A scanning probe microscope similarly works by "feeling" something you can't see with your eyes. But in addition to detecting magnetic fields, an SPM can also detect lots of other kinds of things about a surface: nanometer-sized hills and valleys, atoms, conductivity, friction, stiffness, and more.

SPMs use a super-sharp tip to move across a nanoscale surface. By dragging this tip around on different surfaces and recording the bumps and grooves, scientists are able to piece together what a surface looks like at the atomic level.

These tools can even detect and make images of individual atoms, which are much too small to be seen with a regular microscope.

How is this nano?

Scientists use special tools and equipment to work on the nanoscale. Scanning probe microscopes allow researchers to detect and make images of individual atoms and other things that are too small to see.

The invention of scanning probe microscopy was a great breakthrough in the field of nanotechnology. Once scientists could make pictures of individual atoms and the world of the nanometer, they could begin to manipulate and study things at this super-tiny scale. (A nanometer is a billionth of a meter.) Without the SPM, nanotechnology wouldn't be where it is today!

Learning objective

Scientists use special tools and equipment to work on the nanoscale.

Materials

• Small magnets
• Large demonstration magnet (optional)
• "Magnetic Field" sheets

The NanoDays "Feel Nano" magnets are available from Off the Wall Magnetics (www.4thefridge.com). The artwork is on file—just ask for the nano magnets. NISE Network partners may use the artwork free of charge as long as the magnets are used for educational, non-commercial purposes.

You can do this activity with almost any flexible magnet, but the magnetic field may be oriented differently than the ones created for this activity. If you try different magnets, experiment with them ahead of time—you may need to cut the "probe strip" from the long end of the magnet rather than the short end.

Notes to the presenter

In order to feel the "bumps" using the NanoDays magnets, visitors need to hold the probe strip and magnet as shown in the instructions and move the strip slowly across the surface. The large magnet can be used to demonstrate how to move the probe strip over the magnet.

There are two versions of the magnetic field illustration. You can show visitors the single illustration of how the magnetic field is arranged in this magnet, or you can show them the illustration with two different possibilities and ask them to figure out which one best represents the magnetic field.

You can engage visitors in other models of how SPMs work:

• Ask visitors to close their eyes, make a fist, and run a fingertip over their knuckles. Their finger is a model for how an SPM tip moves over a surface, going up and down as it encounters nanometer-sized hills and valleys.

• Ask several visitors to line up shoulder to shoulder. Close your eyes, and run your hand along the tops of their heads. Your hand is a model for an SPM tip.

Credits

This activity was adapted from "Quick Reference Activity Guide: Refrigerator Magnet," developed by the National Science Foundation-supported Materials Research Science and Engineering Center (MRSEC) on Nanostructured Materials and Interfaces at the University of Wisconsin-Madison. The original activity is available at: mrsec.wisc.edu/Edetc/supplies/ActivityGuides/Refrig_Magnet_Guide_2005.pdf

Image of SPM tip by SecretDisc. Illustration of AFM by Askewmind. Image of sodium chloride courtesy of Ernst Meyer, University of Basel. All from Wikimedia Commons.

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

SPM Background Information

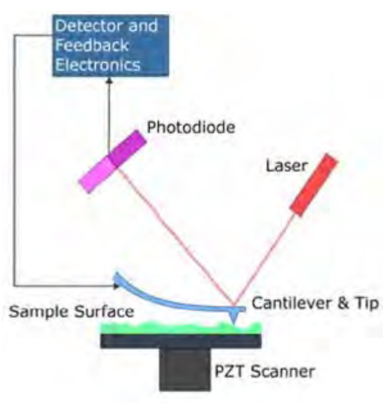
What are scanning probe microscopes?

Scanning probe microscopes (SPMs) are a family of tools used to make images of nanoscale surfaces and structures, including atoms. They use a physical probe to scan back and forth over the surface of a sample. During this scanning process, data are gathered that are used to generate a three-dimensional image of the surface. In addition to visualizing nanoscale structures, some kinds of SPMs can be used to manipulate individual atoms and move them around.

SPMs are different from other kinds of microscopes because the user doesn't "see" the surface directly. Instead, the tool "feels" the surface and creates an image to represent it.

How do they work?

SPMs are very powerful microscopes, sometimes with a resolution of less than a nanometer. (A nanometer is a billionth of a meter.)



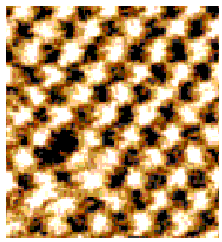
Atomic force microscope

An atomic force microscope, or AFM, is a specific kind of SPM. An AFM has a probe tip mounted on the end of a cantilever. The tip can be as sharp as a single atom. It can be moved precisely and accurately back and forth across the surface, even atom by atom.

When the tip is near the sample surface, the cantilever is deflected by a force. AFMs can measure deflections caused by many kinds of forces, including mechanical contact, electrostatic forces, magnetic forces, chemical bonding, van der Waals forces, and capillary forces.

The distance of the deflection is measured by a laser that is reflected off the top of the cantilever and into an array of photodiodes. AFMs can detect differences in height that are a fraction of a nanometer!

Scientists use AFMs in a number of different ways, depending on the information they're trying to gather from a surface. An AFM can operate in many modes. The two primary modes are contact mode and tapping mode. In contact mode, the force between the tip and the surface is kept constant. This allows a scientist to quickly image a surface. In tapping mode, the cantilever oscillates, intermittently touching the surface. Tapping mode is especially useful when a scientist is imaging a soft surface.

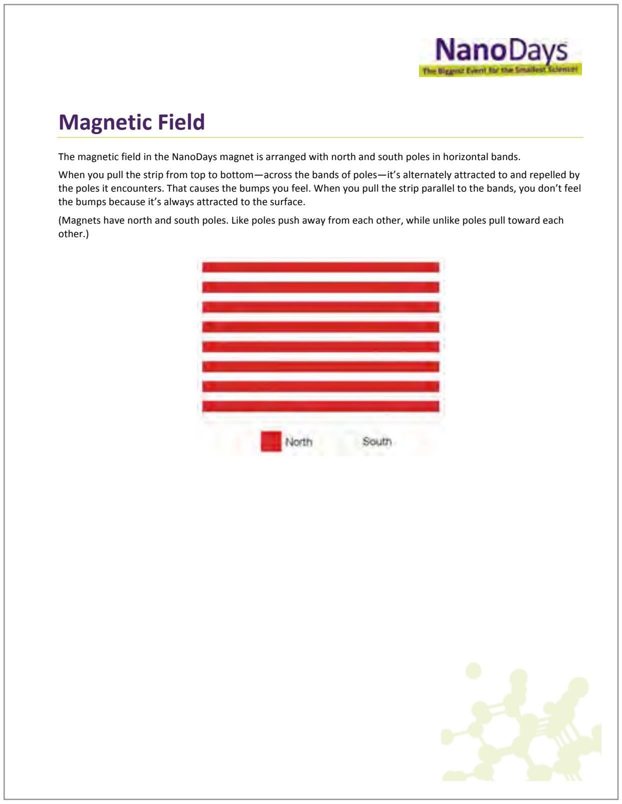


AFM image of salt (NaCl)

The tip of an AFM is moved across the sample many times. A computer combines the data to create an image.

AFM images are inherently black and white. They are often colorized, with different colors representing differences in height along the surface

Additional Graphic Resources

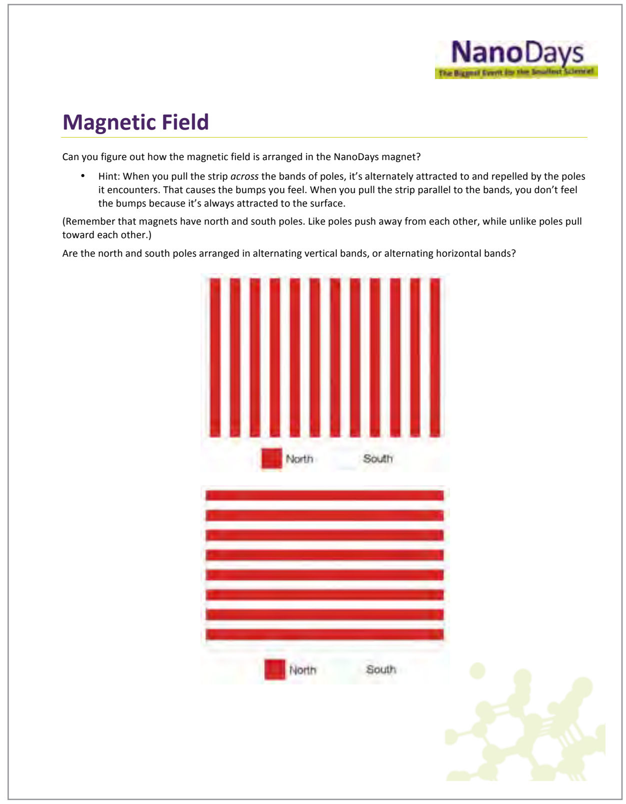

NanoDays

Magnetic Field

The magnetic field in the NanoDays magnet is arranged with north and south poles in horizontal bands.

When you pull the strip from top to bottom—across the bands of poles—it's alternately attracted to and repelled by the poles it encounters. That causes the bumps you feel. When you pull the strip parallel to the bands, you don't feel the bumps because it's always attracted to the surface.

(Magnets have north and south poles. Like poles push away from each other, while unlike poles pull toward each other.)


NanoDays

Magnetic Field

Can you figure out how the magnetic field is arranged in the NanoDays magnet?

- Hint: When you pull the strip *across* the bands of poles, it's alternately attracted to and repelled by the poles it encounters. That causes the bumps you feel. When you pull the strip parallel to the bands, you don't feel the bumps because it's always attracted to the surface.

(Remember that magnets have north and south poles. Like poles push away from each other, while unlike poles pull toward each other.)

Are the north and south poles arranged in alternating vertical bands, or alternating horizontal bands?

"Magnetic Field" sheets
Set of two, 8.5 x 11 inches

Exploring Fabrication—

Self-Assembly

GAME 1: RING

Ready, set…

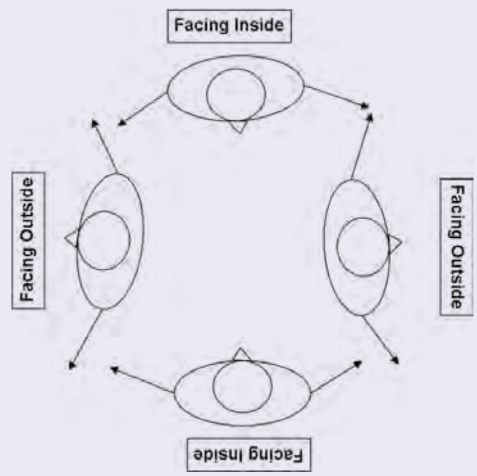
This game requires an even number of participants.

Self-assemble!

1. Everyone hold hands! No hand can be left untouched. You must find a different partner to hold each of your hands.

2. Your right hand must hold someone else's right hand, and your left hand must hold someone else's left hand.

3. You cannot cross your arms.



What's going on?

You made a circle, with every other person facing in, by following rules that created a specific pattern. As long as you follow these same rules, you'll always "self-assemble" into this same pattern!

How is this nano?

Self-assembly is a process by which molecules and cells form themselves into functional structures. Self-assembly occurs in nature—snowflakes, soap bubbles, and DNA are just three examples of things that build themselves.

Soap bubbles

Illustration of DNA

Researchers in the field of nanotechnology are studying self-assembly in order to create new materials and technologies smaller than 100 nanometers in size. (A nanometer is a billionth of a meter.) Nanotechnology allows scientists and engineers to make things like smaller, faster computer chips and new medicines to treat diseases like cancer.

What's going on?

You made a capsule! You're a model for nanocapsules, tiny particles with an outside shell and hollow interior.

Nanocapsules can be filled and designed to deliver medicine to diseased parts of the

GAME 2: CAPSULE

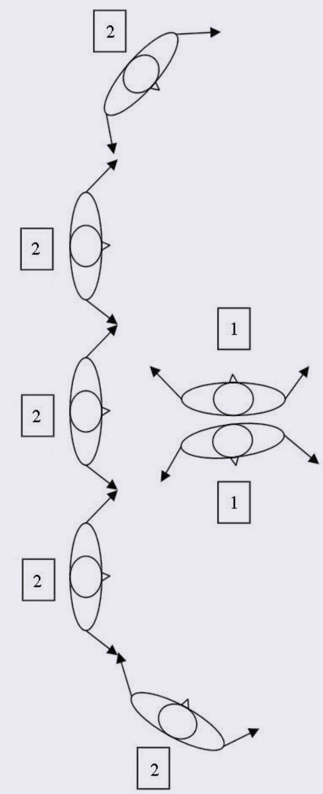
Ready, set…

1. Define a space for the activity to take place.

2. Divide into two groups:

Group 1: about a third of your participants

Group 2: about two-thirds of your participants



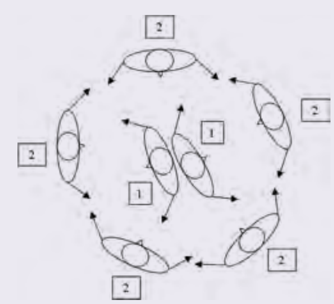
Self-assemble!

Group 1:

1. You must stand within the defined area.
2. You can walk—not run—within this space.
3. You cannot touch anyone from Group 2.

Group 2:

1. Line up at the edge of Group 1's space. Join hands to form a chain.
2. Walk—don't run—toward Group 1 and try to engulf them.
3. Don't break your chain, and don't touch anyone from Group 1.
4. When you have everyone from Group 1 inside your chain, the two ends of the chain hold hands to form a circle.



body, bypassing healthy parts. These "smart drugs" require much less medicine, so they have less harmful side effects. Self-assembly is an important process for creating nanocapsules.

How is this nano?

Self-assembly is a process by which molecules and cells form themselves into functional structures. Self-assembly occurs in nature—snowflakes, soap bubbles, and DNA are just three examples of things that build themselves.

Researchers in the field of nanotechnology are studying self-assembly in order to create new materials and technologies smaller than 100 nanometers in size. (A nanometer is a billionth of a meter.) Nanotechnology allows scientists and engineers to make things like smaller, faster computer chips and new medicines to treat diseases like cancer.

GAME 3—SNOWFLAKE

Ready, set...

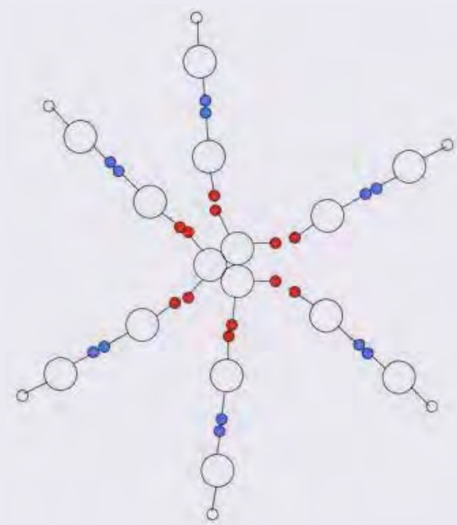
1. This game requires 9 or 15 participants.
With 9 participants, divide into two groups.
With 15 participants, divide into three groups.

2. Divide into groups:

Group 1: 3 people, wearing **RED** gloves on BOTH hands

Group 2: 6 people, each wearing ONE **RED** glove and ONE **BLUE** glove

Group 3: 6 people, wearing ONE **BLUE** glove on one hand



Self-assemble!

Group 1:

1. Stand so that each of your shoulders touches the shoulder of someone else in Group 1.

2. You cannot face anyone else in Group 1.

Group 2:

1. Extend your arms out from your sides.

2. Find a hand to hold.

3. You cannot hold hands with anyone else in Group 2.

4. You must hold hands with someone wearing the same color glove.

Group 3:

1. Extend your arms out from your sides.

2. You must hold hands with someone who has the same color glove.

3. You cannot hold hands with anyone else in Group 3.

What's going on?

You made a giant model of a snowflake! Snowflakes are one of nature's best examples of self-assembly.

Snowflake

How is this nano?

Self-assembly is a process by which molecules and cells form themselves into functional structures. Self-assembly occurs in nature—snowflakes, soap bubbles, and DNA are just three examples of things that build themselves.

Researchers in the field of nanotechnology are studying self-assembly in order to create new materials and technologies smaller than 100 nanometers in size. (A nanometer is a billionth of a meter.) Nanotechnology allows scientists and engineers to make things like smaller, faster computer chips and new medicines to treat diseases like cancer.

Learning objectives

Self-assembly is a process by which molecules and cells form themselves into functional structures.

Researchers in the field of nanotechnology are studying self-assembly in order to create new materials and technologies.

Materials

- 12 blue gloves
- 12 red gloves

The gloves can be any two colors. For one-time use, non-powdered vinyl or nitrile gloves (not latex) work well. For reuse, knit "magic" stretch gloves work well.

Notes to the presenter

Explain how the game will work before you begin. You can say something like:

Today we're going to learn about a process called self-assembly. Self-assembly happens millions of times every day, all around us. Self-assembly is a process by which molecules and cells form themselves into functional structures. We're going to be molecules and experiment with the process. Let's start with our first game!

Before each game, read the all the rules out loud to visitors.

Credits

This activity was adapted from Ready, Set, Self-Assemble, developed by the Children's Museum of Houston for the NISE Network.
The original program is available at: www.nisenet.org/catalog

Illustration of DNA by James J. Caras, courtesy of National Science Foundation. Photo of snowflake courtesy Kenneth Libbrecht, www.snowcrystals.com

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

Exploring Tools—

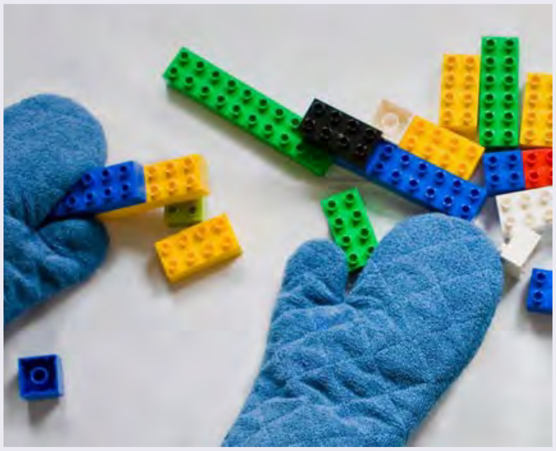
Mitten Challenge

Try this!

1. Put on a pair of oven mitts.

2. Try to build a house out of the bricks, like the one shown in the picture. (Or build an idea of your own using the bricks.)

3. Now try building without the mitts. Is it easier or harder?



What's going on?

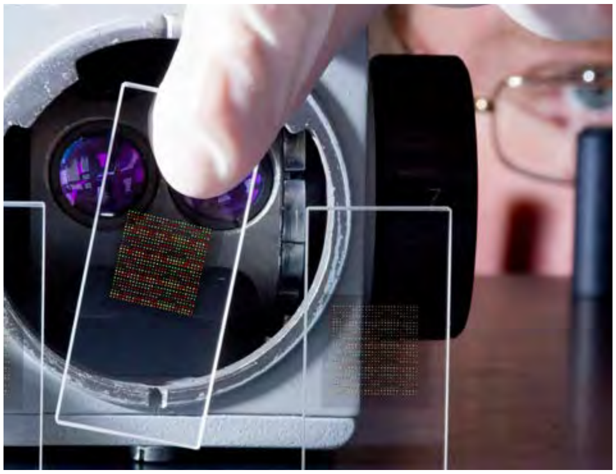
It's difficult to build small things if your tools are too big! Your fingers are just the right size for building with toy bricks. Oven mitts cover your fingers and make your hands bigger, so you can't work as easily or precisely wearing them. Like everyone else, scientists and engineers need the right size tools for the job.

In the field of nanotechnology, researchers study and make tiny things that are measured in nanometers. A nanometer is a billionth of a meter. That's very, very small—the size of atoms and molecules, the building blocks that make up everything in our world.

Moving atoms around with regular tools is kind of like trying to build something out of toy bricks with oven mitts on your hands! As the new field of nanotechnology develops, we may be able to use atoms and molecules just like building blocks, putting them together easily to create tiny structures and machines.

How is this nano?

Scientists use special tools and equipment to work on the nanoscale. Nanoscale science focuses on things that are measured in nanometers, including atoms and molecules, the basic building blocks of our world. Nanotechnology allows them to make things like smaller, faster computer chips and new medicines to treat diseases like cancer.



DNA chip used to analyze human genes

Learning objectives

Scientists and engineers need special tools and equipment to work on the nanoscale.

In the field of nanotechnology, researchers study and make tiny things that are measured in nanometers.

Materials

- Oven mitts (2)
- Brick building set (Lego®, Duplo® or similar)
- “Build a House” sheet

Notes to the presenter

When presenting to younger audiences, larger building bricks work well. If you like, you can introduce smaller bricks to make this activity more challenging for older audiences.

Credits

This activity was adapted from “Nanoscale Activity: Nanotechnology Mitten Challenge” developed by the National Science Foundation-supported Internships in Public Science Education (IPSE) Program at the Materials Research Science and Engineering Center (MRSEC) on Nanostructured Materials and Interfaces at the University of Wisconsin-Madison. The original activity is available at: mrsec.wisc.edu/Edetc/IPSE/educators/mittenChall.html

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

"Build a House" sheet
8.5 x 11 inches

Exploring Fabrication—

Gummy Capsules

Try this!

1. Place the sieve into the bowl of salt water (calcium chloride solution).

2. Gently squeeze the bottle of sodium alginate "worm goo," so that individual droplets of liquid fall into the sieve.

3. Lift the sieve out of the bowl.

4. Feel the droplets. Are they still liquid?

5. Try squeezing a droplet. What happens?

What's going on?

When the liquid droplets come into contact with the salt water, a chemical reaction takes place and creates a *polymer*. A polymer is a long chain-like molecule made up of many repeating units linked together.

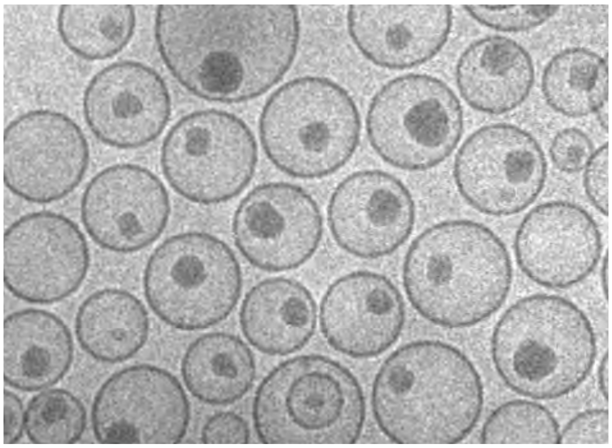
The polymer forms on the outside surface of the droplets, where they touch the salt water, creating a shell around the liquid interior. The salt water is a solution of calcium chloride. The liquid in the squirt bottle is *sodium alginate*, a polysaccharide with many short polymer molecules. The calcium ions in the salt water cross-link (bond) these short polymer molecules into longer strands, turning the sodium alginate liquid into a thick gel.

The polymer droplets you made are similar to *nanocapsules*, tiny particles with an outside shell and hollow interior that can be filled. To create functional structures that are 100 nanometers or smaller in size, scientists use a process called *self-assembly,* in which nanostructures actually assemble themselves! (A nanometer is a billionth of a meter.)

Nanocapsules can be designed to deliver medicine to diseased parts of the body, bypassing healthy parts. For example, research at Duke University led to the development of liposome nanocapsules that bring cancer medication to tumors. These targeted delivery systems use much less medicine, so they can have fewer and less harmful side effects.

How is this nano?

Self-assembly is a process by which molecules and cells form themselves into functional structures. Self-assembly occurs in nature—snowflakes, soap bubbles, and DNA are just three examples of things that build themselves.



Nanocapsules carrying cancer medication

Researchers in the field of nanotechnology are studying self-assembly in order to create new materials and technologies smaller than 100 nanometers in size. (A nanometer is a billionth of a meter.)

Nanotechnology allows scientists and engineers to make things like smaller, faster computer chips and new medicines to treat diseases like cancer.

Learning objectives

Self-assembly is a process by which molecules and cells form themselves into functional structures.

Self-assembly is used to make nanocapsules, which can deliver medication.

Materials

- "Worm goo" sodium alginate liquid in squirt bottle
- "Worm goo activator" calcium chloride crystals
- Small bowl
- Small sieve (mesh strainer) that nests inside the bowl
- Plastic spoon

The chemicals for this activity are available at www.stevespangler.com (#WORM-700).

Notes to the presenter

SAFETY: Visitors should not ingest the chemicals. Visitors should be supervised when doing this activity. You may choose to perform this as a demonstration, rather than allowing visitors to do it as a hands-on activity.

Before beginning this activity, fill the bowl with warm water. Add half a spoon of calcium chloride and stir.

During the activity, you'll need a trash can nearby to dispose of the polymer.

Credits

This activity was adapted from Sweet Self-Assembly, developed by the Children's Museum of Houston for the NISE Network. The original program is available at: www.nisenet.org/catalog.

Image of nanocapsules courtesy Katarina Edwards, Uppsala University.

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

Exploring Size—

Ball Sorter

Try this!

1. Look at the white balls in the container. How many sizes do you see? How could you sort the balls by size?

2. Stack the sieves in size order. Put the sieve with the largest screen holes on the top and the one with the smallest holes on the bottom.

Tip: To stack and lock two sieves, fit the bump from the top sieve into the notch of the bottom sieve, and turn.

3. Slowly pour the balls into the stacked sieve set.

4. Keeping the sieve set on the table, gently shake it back and forth.

5. Carefully separate the sieves. What happened to the balls?

What's going on?

Using sieves with different-sized holes, you sorted the balls by size! There are lots of tools to sort and separate materials by size. In everyday life, we use strainers, screens, and filters. The right sorting tool depends on the kind of materials you're sorting and how big they are.

In the field of nanotechnology, researchers study and make tiny things that are measured in nanometers. A nanometer is a billionth of a meter. That's very, very small—the size of atoms and molecules! Researchers are developing new technologies that can sort nano-sized things, including filters with nano-sized holes.

Many water filters can get out relatively big things like dirt and bacteria, but only filters with very small pores can remove tiny things like viruses and salt ions. These special filters can be used to purify water all over the world.

Researchers are also investigating the natural, nano-sized pores in the human body to better understand how our bodies filter materials. This is allowing them to develop new medical treatments that use the body's built-in filtration system to get medication to the right places.

How is this nano?

A nanometer is a billionth of a meter. Nanoscale science focuses on things that are measured in nanometers, including atoms and molecules, the basic building blocks of our world.

In the field of nanotechnology, researchers study and make tiny things that are measured in nanometers. (A nanometer is a billionth of a meter.)

New nanotechnologies include water filters with nano-sized pores and medications that use the human body's natural filtration system.

Nano water filter

Learning objectives

A nanometer is a billionth of a meter.

New nanotechnologies include water filters with nano-sized pores and medications that use the human body's natural filtration system.

Materials

- Nesting sieves with three screen sizes
- Small balls in three sizes
- Container for balls

Nesting sieves are available from www.pioneermining.com (sizes 4, 6, and 30 work with the balls included in the NanoDays kit).

Delrin balls are available from www.mcmaster.com (1/8" balls #9614K58, 3/16" balls #9614K54, and 3/8" balls #9614K52).

Notes to the presenter

Have visitors pour the balls into the sieve slowly—they can bounce out if they're poured too quickly.

Children and persons with limited dexterity may need assistance with this activity.

This activity can also be used to introduce potential societal and ethical issues related to nanotechnology:

Some people are concerned that the size of nanoparticles may make a difference in how safe they are. Our bodies have natural filters and barriers to keep out things that could harm us, including our skin, nose hairs, cilia, and cell walls. Nano-sized particles are so small that they can get through our natural defenses. We can use this to our advantage, by developing new medications that go directly to the part of the body where they're needed. But we also need to think about whether nanoparticles in other kinds of nanotechnologies might get through our bodies' natural defenses by mistake, and whether that might be harmful.

Credits

Image of water filter courtesy Lifesaver Systems, Ltd.

This project was supported by the National Science Foundation under Award No. 0940143. 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.

Additional Graphic Resources

NanoDays
The Biggest Event for the Smallest Science!

Nano Filter for Purifying Water

“Nano Water Filter” sheet
11X 8.5 inches

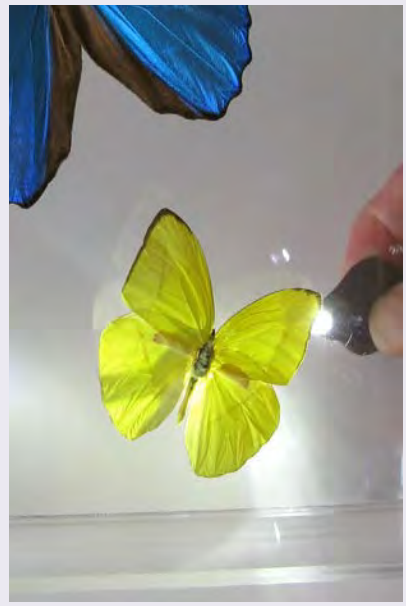
Exploring Structures—Butterfly

Try this!

1. Examine the blue and yellow butterflies. Try tilting the case to see the butterflies from different angles. And be sure to look at both the front and back!

2. Shine the light through the butterflies, holding the light underneath the case. Do the butterflies look the same with the light passing through them?

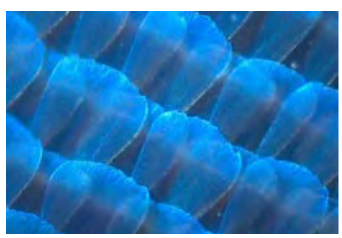
Tip: Squeeze the mini-light to turn it on.



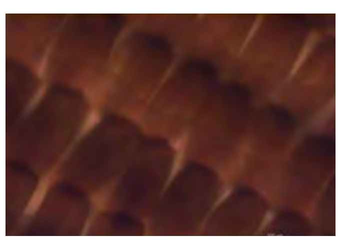
What's going on?

When you turn on the light, the yellow butterfly stays yellow, but the blue butterfly turns brown! That's because the yellow color comes from pigment, but the blue is created by the interference of light bouncing off tiny nanostructures.

The Blue Morpho's wings have very small overlapping scales covered with tiny "ribs." The size and arrangement of these nanostructures makes the wings look blue—but they're actually transparent! There's an air space of a few nanometers between the ribs. Light waves bouncing off the top and bottom surfaces of neighboring ribs interfere with each other. Most light waves are cancelled by the interference and only certain wavelengths—seen as colors—bounce back to your eyes. So when you look at the front of the butterfly, it's a beautiful, iridescent blue.



Light passing through the wings



Light reflecting off the wings

When the bright light passes through the Blue Morpho's wings, the effect is lost and you see the wings' brown undersides. The back side of the wings is colored by pigment—so the brown side always looks brown.

How is this nano?

The way a material behaves on the macroscale is affected by its structure on the nanoscale. Nanotechnology takes advantage of different material properties at the nanoscale to make new materials and tiny devices smaller than 100 nanometers in size. (A nanometer is a billionth of a meter.)

Nanotechnology allows scientists and engineers to make things like smaller, faster computer chips and new medicines to treat diseases like cancer.

Low-energy display

Some nanotechnology and nanomaterials are inspired by nature. Scientists are working on new nanotechnologies that mimic the Blue Morpho's wings. They've already invented low-energy smartphone displays, paints, and fabrics that change color by changing the spacing between materials.

Learning objectives

The way a material behaves on the macroscale is affected by its properties on the nanoscale.

Some nanotechnologies are inspired by nature.

Materials

- Butterflies in protective case
- Mini-light
- "Blue Morpho Butterfly" image sheet

Blue Morpho and Buttercup butterflies mounted in an acrylic case are available at www.butterflyutopia.com.

Mini-lights (extra-bright LEDs) are available from www.teachersource.com.

Notes to the presenter

If you're doing this activity near a bright window or other light source, the mini-light may not be effective. You might be able to hold the butterfly up to the window or light source to get the same effect (and not use the mini-light at all), or you might need to relocate the activity to a less brightly lit area.

Extension

Visitors can experiment further by dropping alcohol onto a Blue Morpho butterfly wing. The alcohol fills up the spaces between the nanoscale structures of the wings, so they reflect green light waves rather than blue light waves. When the alcohol evaporates, the wings look blue again.

Credits

Image of structures in Blue Morpho wing courtesy S. Yoshioka, Osaka University.
Images of Blue Morpho wing with reflected and nonreflected light courtesy F. Nijhout, Duke University.
Low-energy display photo courtesy Qualcomm Technologies, Inc.

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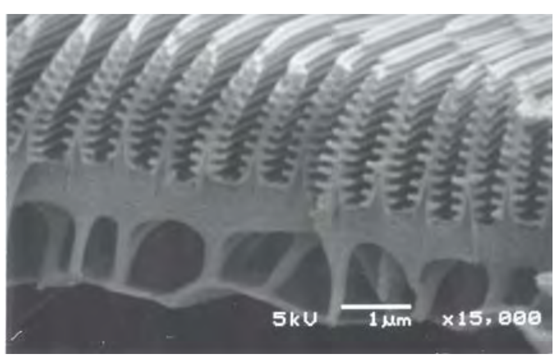
Blue Morpho Butterfly

Blue Morpho butterfly



Magnified view of nanostructures in Blue Morpho butterfly wing

"Blue Morpho Butterfly" image sheet
8.5 x 11 inches

Exploring Structures—

DNA

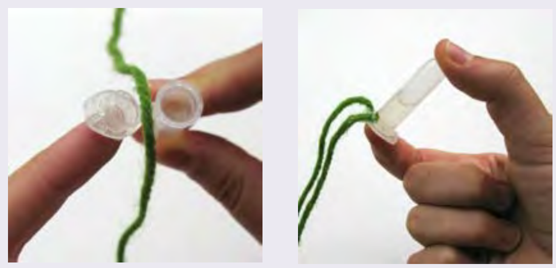
Try this!

1. Use a pipette to add a squirt of wheat germ liquid into a plastic tube. Fill it halfway.

Tip: Be sure not to get wheat germ solids in the pipette!

2. Use the dropper bottle to add alcohol to the tube. Fill it almost all the way to the top.

3. Put a piece of yarn over the edge of the cap, and snap it shut.



4. Gently rock the tube a few times, and look inside. Can you see anything forming in the tube?

5. Tie the yarn—you have a DNA necklace.

What's going on?

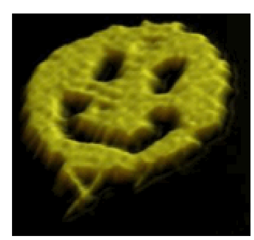
That white, slimy stuff you see is DNA! When you added the alcohol to the wheat germ, you made the DNA clump together.

DNA is in every plant and animal cell. It helps cells to grow and do their jobs. DNA is an example of the way things in nature build themselves, or self-assemble.

DNA
2 nm wide

How is this nano?

Self-assembly is a process by which molecules and cells form themselves into functional structures. Self-assembly occurs in nature—snowflakes, soap bubbles, and DNA are just three examples of things that build themselves.



Smiley face made of DNA
100 nm wide

Researchers in the field of nanotechnology are using materials that self-assemble—like DNA—to create new materials and technologies smaller than 100 nanometers in size. (A nanometer is a billionth of a meter.)

For example, at Cal Tech a researcher got DNA to fold itself up into a nano-sized smiley face! And at Arizona State University, scientists built a nano-sized spider robot that can walk along a sheet of folded-up DNA.

Learning objectives

Self-assembly is a process by which molecules and cells form themselves into functional structures.

Researchers in the field of nanotechnology are using materials that self-assemble—like DNA—to create new materials and technologies smaller than 100 nanometers in size.

Materials

For the activity:

- Cup of wheat germ liquid
- Dropper bottle of alcohol
- 1.5 ml microcentrifuge tubes (Eppendorf tubes)
- Pipettes (1 ml)
- Yarn
- Scissors
- Ice pack
- Small plastic bin

For the advance preparation:

- Raw wheat germ (not processed)
- Hot water
- Meat tenderizer
- Shampoo (or dishwashing detergent)
- Plastic spoon
- Isopropyl alcohol or ethyl alcohol (91%)
- Cup
- Dropper bottle

Microcentrifuge tubes are available from www.amazon.com (look for 1.5 ml tubes with snap caps).

Raw wheat germ is available from grocery stores.

Notes to the presenter

SAFETY: Do not allow visitors to ingest any of the materials!

You must prepare some of the materials ahead of time—see advance preparation instructions below.

Children and individuals with limited dexterity might need help manipulating the materials in this activity.

Advance preparation

Several hours before the activity:

- Put the ice pack in the freezer.
- Put the alcohol in the refrigerator.

30 minutes before the activity:

- Prepare the cup of wheat germ liquid (this makes enough for 20 visitors)
  1. Add ½ cup hot water to the cup.
  2. Add 1 spoon of wheat germ to the cup of hot water.
  3. Add ½ spoon of meat tenderizer to the cup.
  4. Add a squirt of shampoo (about a teaspoon).
  5. Stir well.
  6. Let mixture settle for 15 minutes.

- Prepare the dropper bottle of alcohol:
  1. Fill the dropper bottle with chilled alcohol.
  2. Place the ice pack in the small plastic bin.
  3. While you do the activity, set the dropper bottle of alcohol on the ice pack to keep it cold.

Credits

This activity was adapted from DNA Nanotechnology, developed by the Sciencenter for the NISE Network. The original program is available at: www.nisenet.org/catalog.

Colorized image of DNA by James J. Caras, National Science Foundation. Image of DNA smiley face courtesy Paul Rothemund, California Institute of Technology. Image of DNA spider robot courtesy of Paul Michelotti, showing research by Kyle Lund at Arizona State University.

This project was supported by the National Science Foundation under Award No. 0940143. 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.

DNA Background Information

What is DNA?

DNA stands for deoxyribonucleic acid. DNA is present inside the cells of every living thing. It contains the chemical instructions and genetic information to help organisms develop and function.

DNA is made of two long strands twisted together in a structure called a double helix. It looks like a long spiral ladder. DNA is only two nanometers across, but if you could unravel all the strands of DNA from just one human cell and line them up end to end, you'd have a thread two meters long!

The rungs of a DNA ladder are made of four different types of molecules, called base pairs. Adenine (A) and Thymine (T) are one pair, and Guanine (G) and Cytosine (C) are the other. The base pairs always join in the same way. A and T always join together, and G and C always join together. The instructions that help our bodies grow and live are carried in the sequence of the base pairs, and are called genes.

The human genome (all of our genetic material) is contained in 46 long, thin "threads" of DNA called chromosomes. We inherit 23 chromosomes from each of our parents, for a total of 46 chromosomes. Most of our DNA (99.5%) is the same as everyone else's, but a small amount is unique. Only identical twins have exactly the same DNA as another person.

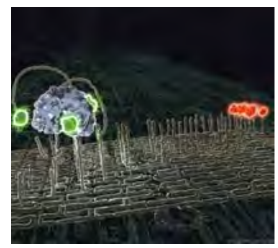
How does DNA extraction work?

You can extract DNA from many different things, including wheat germ, which is a plant seed. In this activity, shampoo and meat tenderizer break down the cell membrane so the contents of the cell come out, including the DNA. The alcohol makes the tiny pieces of DNA precipitate, or clump together.

When enough DNA has precipitated, you can see it. But each individual strand of DNA is still too small to see—there are millions of strands of DNA in a visible clump!

How is DNA used in nanotechnology?

Self-assembly is a process by which molecules and cells form themselves into functional structures. Self-assembly occurs in nature—snowflakes, soap bubbles, and DNA are just three examples of things that build themselves.



Tiny robot made of DNA
DNA is 2 nm wide

Researchers in the field of nanotechnology are using materials that self-assemble—like DNA—to create new technologies smaller than 100 nanometers in size. (A nanometer is a billionth of a meter.)

For example, at Cal Tech a researcher got DNA to fold itself up into a nano-sized smiley face! And at Arizona State University scientists built a nanoscale spider robot that can walk along a sheet of folded-up DNA.

Exploring Tools—
3D Imaging

Try this!

1. Look at the “micro view” images. What do you notice about them?

2. Put on the 3D glasses and look at the images again. Do they look different?

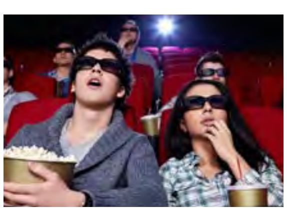
3. Can you guess what you’re looking at? (Flip it over to find out.)

What’s going on?

With the glasses, the images appear to be in three dimensions—the objects seem to pop out of the page. Without the glasses, the images appear blurry.

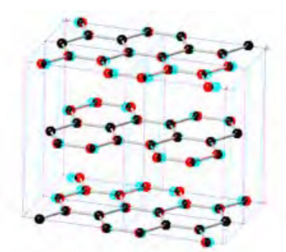
Each of these “3D” images is actually made of two photos of the same scene taken from slightly different angles. The two photos are printed on top of each other, one red and the other blue.

When you wear glasses with one red and one blue lens, the colored filters restrict your vision. One eye sees only the red photo and the other eye sees only the blue photo. Your mind merges these two separate images together into a single 3D image with depth.



When we look at a regular (non-3D) photo printed on paper, we use other clues to figure out how things are positioned relative to each other. For example, in the picture above, we can tell that the people who look larger are in front of the people who look smaller and are partially blocked from view.

How is this nano?



3D computer model of graphite sheets

Scientists use special tools and equipment to work on the nanoscale. Things that are measured in nanometers are very, very small. (A nanometer is a billionth of a meter.)

Nanometer-sized things are too small to be seen even with a powerful light microscope, so scientists use other tools to study them. Examples of these tools include scanning electron microscopes (SEMs) and atomic force microscopes (AFMs).

With special tools like these, scientists can’t directly see nano-sized objects. Instead, they see representations of them on a flat computer screen. Techniques like 3D imaging let scientists see the images with depth, making it easier to understand the relative position of things. This is especially important when scientists are studying complicated structures. Try looking at the image of graphite (above) with and without the 3D glasses!

Learning objective

Scientists use special tools and equipment to work on the nanoscale.

Materials

- Red/blue 3D glasses
- Set of 3D images
- “Seeing in 3D” sheet

Red/blue glasses are available from www.rainbowsymphonystore.com (#03101).

Notes to the presenter

It will be easier for small children and individuals in wheelchairs to see the images if you hold them up at their eye level (rather than placing them on the table).

In this activity, red/blue glasses are used to filter the red/blue images. The glasses force each eye to see only one of the images. There are other techniques to see 3D images, but they all rely on making each eye see a different image.

Extension

Try this activity to explore how our eyes see two different images of the same scene:

1. Choose a stationary object in the distance. Close one eye, then hold up a thumb at arm’s length so that it blocks your view of the object.

2. Without moving your thumb, close your other eye and open the first. What happens?

3. Try the same experiment again, this time holding your thumb closer to your face. Does your thumb appear to move the same amount?

Your thumb doesn’t really move—it only seems that way. When you switch eyes, objects that are closer to your face appear to move more than objects that are farther away.

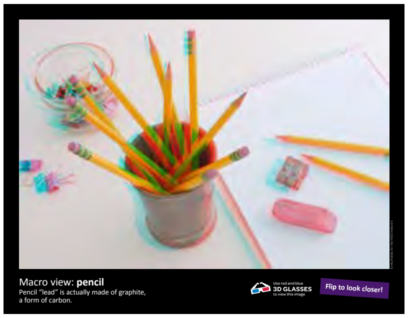
People have stereoscopic vision. Our eyes are a small distance apart, so each one sees the world from a slightly different angle. When we look at something with both eyes, we see two slightly offset images of the same scene. Our brain combines these two images into a single view of the world that has depth.

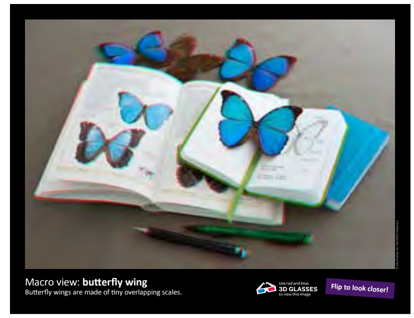
Credits

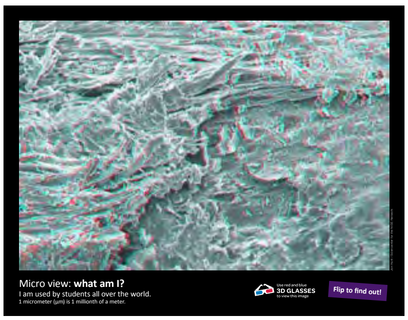
Three-dimensional SEM images by John Hunt, Cornell Center for Materials Research, with support from NSF Award No. DMR-1120296.
Three-dimensional photographs of macro-sized objects by Emily Maletz for the NISE Network. Graphite image courtesy Yingchao Yu, Cornell University.

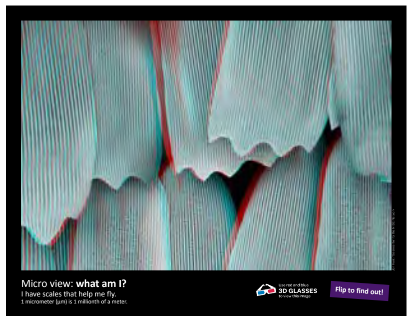
This project was supported by the National Science Foundation under Award No. 0940143. Any opinions, findings, and conclusions or recommendations expressed in this program are those of the author and do not necessarily reflect the views of the Foundation.

Additional Graphic Resources









Set of 3D images
6 double-sided cards, 8.5 x 11 inches

"Seeing in 3D" sheet
11 x 8.5 inches

Exploring Tools—

Mystery Shapes

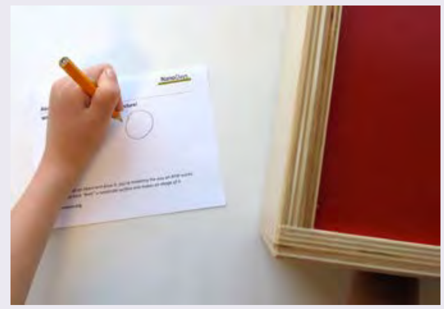
Try this!

1. Put your hand inside the box. What do you feel?

2. Draw a picture of one of the objects you feel inside the box.

3. Now take the object out of the box and compare it to your picture. What information does your picture include? What's missing?

4. Try another object and compare it to the first.



What's going on?

When you feel a mystery shape in the box and draw an image of what it looks like, you're modeling the way that a special tool called a scanning probe microscope (SPM) works. Your hand is acting like the sensing part of the SPM, while your brain acts like the computer program that creates a picture of what the tool "feels."

Researcher using an SPM

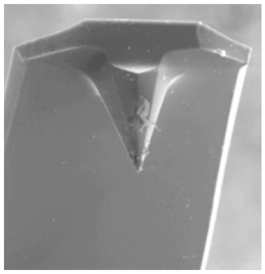
SPMs let us make images of tiny, nano-sized things like atoms that are much too small to see, even with powerful light microscopes. Things this small are measured in nanometers. A nanometer is a billionth of a meter.

SPMs use a super-sharp tip to move across a nanoscale surface. To make an image, researchers move the tip back and forth across the sample many times. A computer program combines the data to create an image.

SPMs are very powerful. Some of them can even detect and make images of individual atoms! However, they still can't capture every detail about nano-sized objects. Researchers use other tools to learn things that SPMs can't detect.

Similarly, your fingers can't detect all the information about the mystery shapes in the box. When you pulled out the objects and looked at them, you probably were able to gather even more information about them (such as what color they were). The pictures you drew captured some of the information you could gather by touching the objects, but some other things you could feel (such as the material) might be missing from your picture.

How is this nano?



Tip of an SPM

Scientists use special tools and equipment to work on the nanoscale. Scanning probe microscopes (SPMs) allow researchers to detect and make images of objects measured in nanometers—or even smaller. (A nanometer is a billionth of a meter.)

The invention of SPMs was a great breakthrough in the field of nanotechnology. Once scientists could make pictures of things as small as individual atoms, they could begin to manipulate and study things at this super-tiny scale. Without SPMs, nanotechnology wouldn't be where it is today!

Learning objective

Scientists use special tools and equipment to work on the nanoscale.

Materials

- Tactile box
- Assorted small objects to hide in the box
- "Scanning Probe Microscope" cards
- Pencils

The tactile box included in the NanoDays kit is available from www.lakeshorelearning.com (#RJ27). You can substitute a cloth bag or a cardboard box with holes cut in the sides.

Notes to the presenter

SAFETY: Some of the objects used in this activity could present a choke hazard to young children. Supervise visitors at all times while doing this activity. You may choose to remove or replace the smaller objects.

There are two holes in the tactile box, one on each end. One is for visitors to feel the objects and one is for you to use to hide new objects.

It works well to have visitors start with a selection of balls that are different colors and materials, then try other objects such as small toy animals. You can find other mystery shapes for visitors to feel, in addition to those included in the activity.

Young children, individuals with limited dexterity, and low-vision visitors may prefer to describe what they feel rather than draw it.

While most visitors are enthusiastic about discovering the "mystery shapes" in the box, some may hesitate to put their hands inside. You can reassure them that there's nothing scary or icky in the box!

Credits

Photograph of researcher using AFM by Charles Harrington Photography, courtesy of Cornell Nanoscale Facility. Image of AFM tip by SecretDisc, from Wikimedia Commons. Illustration of AFM by Emily Maletz for the NISE Network. Image of sodium chloride courtesy of Ernst Meyer, University of Basel, from Wikimedia Commons.

This project was supported by the National Science Foundation under Award No. 0940143. 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.

SPM Background Information

What are SPMs?

Scanning probe microscopes (SPMs) are a family of tools used to make images of nanoscale surfaces and structures. They use a physical probe to scan the surface of a sample, gathering data to create a three-dimensional image of it. In addition to visualizing nanoscale structures, some kinds of SPMs can be used to move individual atoms.

SPMs are different from other kinds of microscopes because the user doesn't see the surface directly. Instead, the tool "feels" the surface and creates an image to represent it.

How do they work?

SPMs are very powerful microscopes. An atomic force microscope, or AFM, is a specific kind of SPM.

An AFM has a probe tip mounted on the end of a cantilever. The tip can be as sharp as a single atom. It can be moved precisely and accurately back and forth across the surface of the sample.

When the tip is near the sample surface, the cantilever is deflected by a force. AFMs can measure deflections caused by many kinds of forces, including mechanical contact, electrostatic forces, and magnetic forces. The distance of the deflection is measured by a laser that is reflected off the top of the cantilever and into an array of photodiodes.

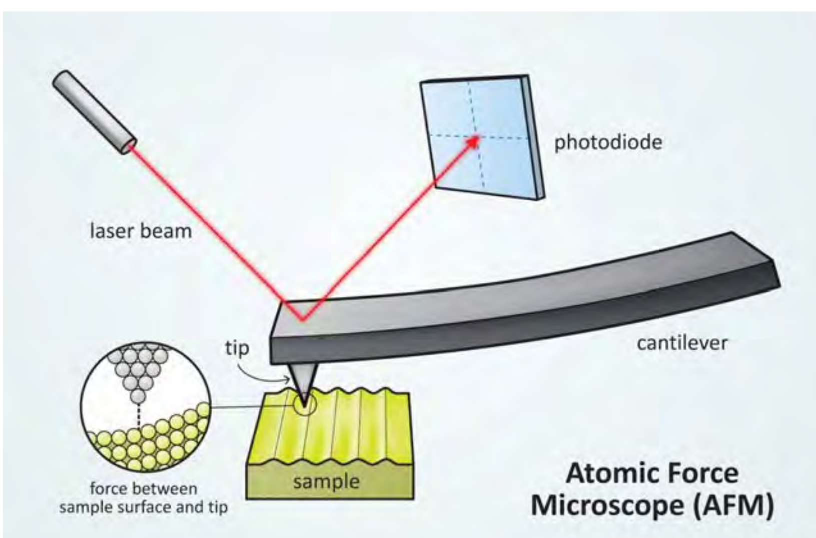
Some AFMs can detect differences in height that are a fraction of a nanometer! (A nanometer is a billionth of a meter.)

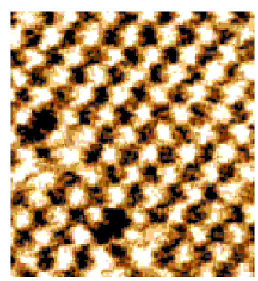
Researchers use AFMs in a number of different ways, depending on the information they're trying to gather. The tip of the tool can be in constant contact with the sample, it can be slightly above the sample, or it can tap gently on the sample as it moves.

The AFM tip is moved back and forth across the sample many times. A computer program combines the data to create an image.

AFM images are inherently black and white. To make them easier to interpret, they are often colorized. Different colors are used to indicate differences in height along the surface.

AFMs can be used with almost any type of material, including biological samples. They have been used to image DNA, individual proteins, and even living cells.




AFM image of salt (NaCl)

Additional Graphic Resources

Scanning Probe Microscopes

What do you feel in the box? Draw a picture!

When you feel an object and draw it, you're modeling the way an SPM works. This special tool "feels" a nanoscale surface and makes an image of it.

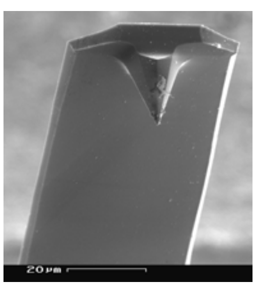
whatisnano.org

"Scanning Probe Microscope" card
4.25 x 5.6 inches

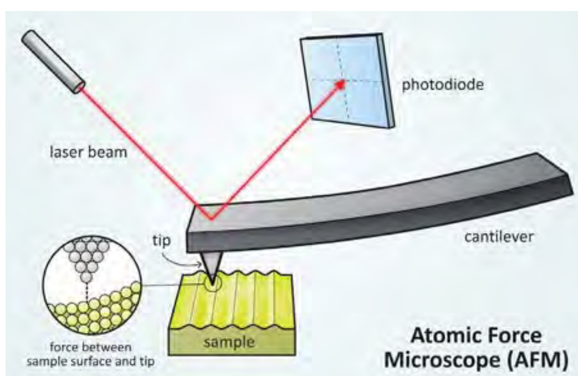
Atomic Force Microscopes

Atomic force microscopes, or AFMs, are a kind of scanning probe microscope. AFMs have a probe tip mounted on the end of a cantilever. When the tip is near the sample surface, the cantilever is deflected, or moved, by a force. AFMs can detect many kinds of forces, including physical contact, electrostatic forces, and magnetic forces. The deflection is measured by a laser that is reflected off the top of the cantilever and into an array of photodiodes. AFMs can detect tiny deflections—as small as a fraction of a nanometer!

To analyze a sample, the AFM tip is moved back and forth across the surface many times. A computer program combines the data and creates an image.



Magnified image of an AFM tip



"Atomic Force Microscope" sheet
11 x 8.5 inches

Exploring Fabrication—

Electroplating

Try this!

1. Wearing safety goggles, connect the nickel coin to the negative side of the battery (using one alligator clip) and the copper bar to the positive side (using the second alligator clip).

2. Dip both the nickel and the copper bar into the salt solution. (Make sure they do not touch each other!) What do you notice?

3. Now take the coin and the copper out of the salt solution. What changed?

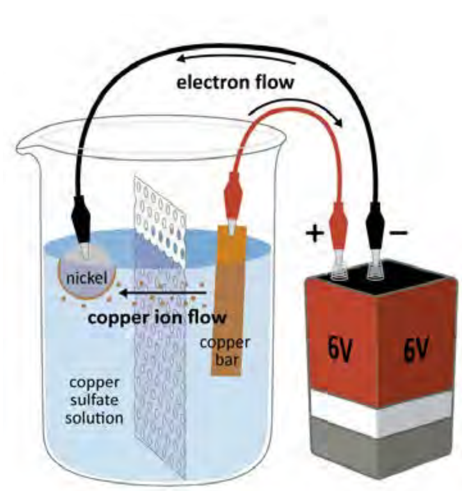
What's going on?

The nickel coin changed color because it now has a thin layer of copper on it. When the copper bar and nickel coin are connected to the battery and placed in the salt solution, you complete an electrical circuit. The electricity from the battery removes copper from the surface of the copper bar and deposits it onto the surface of the nickel. This process is called electroplating. The longer you keep the circuit connected, the thicker the layer will be.

The blue solution is copper sulfate (CuSO4) in water. When solid copper sulfate is dissolved in water it breaks up into two ions, Cu2+ and SO42-. These ions allow electric current to flow through the liquid.

When the current is flowing from the battery, the reaction at the copper bar converts copper metal (Cu), which has no electric charge, to copper ions (Cu2+), which have a positive charge.

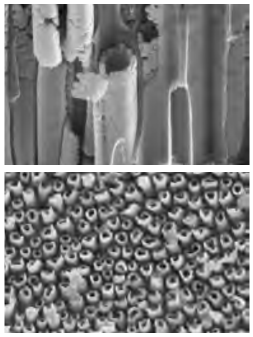
These copper ions travel through the solution to the coin connected to the negative side of the battery. The copper ions turn back to metallic copper and bond onto the coin. The copper ions present in the copper sulfate solution plate onto the coin, and the reaction at the copper bar continually replaces the copper ions in the solution allowing the plating to continue as long as the circuit is connected and there is still copper available.



Copper electroplating

Copper is just one of many metals used for electroplating. Other examples include zinc, gold, silver, and platinum. Electroplating is used for a variety of reasons such as making thin protective layers on cars or planes or coating jewelry with precious metals like gold.

How is this nano?



Electroplated nanotubes

Scientists use special tools and equipment to work on the nanoscale. The electroplating process can deposit nanometer-thin layers of material. (A nanometer is a billionth of a meter.) Researchers can reliably control how thick the electroplated layer is by carefully controlling the current flowing through the circuit.

Electroplating is a simple, low-cost process scientists can use to create thin films, coating, nanowires, and other nanoscale structures.

Learning objective

Scientists use special tools and equipment to work on the nanoscale.

Materials

- Safety goggles
- Glass beaker
- Plastic divider
- Battery
- Alligator clips
- Copper bar
- Nickel coins
- Sponge (with scouring pad)
- Copper sulfate solution (see below for preparation instructions)

Notes to the presenter

Before doing this activity, prepare the copper sulfate solution:

- Fill the bottle containing 125g copper sulfate pentahydrate ($CuSO_4 \bullet 5H_2O$) with **distilled** water (approx. 1 liter). Mix well.

SAFETY: At this concentration, the copper sulfate solution is safe to use with visitors. Refer to Materials Safety Data Sheet for specific safety info on the copper sulfate solution. Supervise visitors at all times while doing this activity. Safety goggles should be worn. Do not allow visitors to drink the solution. Some of the objects in this activity could present a choking hazard to young children.

Tips: *To demonstrate that electroplating requires electricity, you can dip the coin and copper bar in the salt solution without first connecting them to the battery.*

Be sure that you connect the coin and copper to the correct terminals of the battery. The copper should always be connected to the positive side of the battery and the coin to the negative side.

The plastic divider is meant to separate the coin and copper bar. Be sure that the coin and copper bar do not touch while they're connected to the battery. This will short-circuit the battery and drain it quickly.

For a good coating, the coin and copper bar should have a clean surface. The copper bar sometimes develops a brownish-greenish oxidation layer, which can usually be wiped off with the sponge. To clean the coins you can use a non-scratching scouring pad. For dirtier coins you may want to soak them in vinegar.

If the copper coating is not very noticeable, wait a little longer before removing the coin and copper bar.

Cleanup: The copper sulfate solution can be reused indefinitely. After use, return the solution to a sealed bottle and store in a cool, dry place. Do **not** pour down the sink unless allowed by federal, state and local regulations. For more detailed disposal information contact your local waste disposal facility.

Credits

Illustration of copper electroplating cell by Emily Maletz for the NISE Network.

This project was supported by the National Science Foundation under Award No. 0940143. 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.

Exploring Tools—

Transmission Electron Microscopes

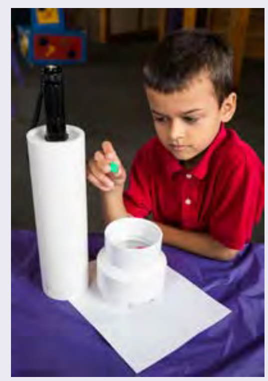
Try this!

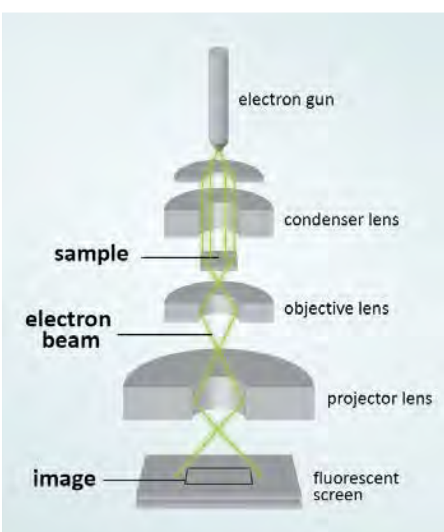
1. Shine the flashlight down the plastic imaging tube. With the flashlight on, look in the viewing window under the tube. What shadow shapes do you see?

2. Based on the shadow shapes, can you guess what the objects look like?

3. Take the large tube off so you can see the objects. Did you guess right?

4. Now try to build a sample from play dough to create the same shadow. When you shine the flashlight on it, do you get the same shadow? Try making some other shapes!





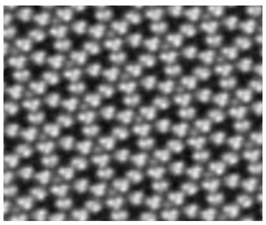
Transmission Electron Microscope (TEM)

What's going on?

The imaging tube is a model for a transmission electron microscope (TEM). TEMs allow scientists to image nanometer-sized features (a nanometer is a billionth of a meter). TEMs can even produce images that show the locations of individual atoms!

In a TEM, a high-energy electron beam is focused at a sample. Researchers observe how the electron beam changes after it goes through the sample. The electron beam needs to penetrate the sample, so TEM samples have to be very thin. If a sample has a regular, crystalline pattern, scientists can use the TEM to produce images that provide information about the structure. Scientists can also use special detectors to determine what elements, like carbon or iron, are in the sample. The model uses a flashlight, but TEMs use an electron beam. Electron beams, unlike visible light, can be focused into much smaller spots, allowing scientists to look at smaller features.

When we shine the flashlight on objects in the plastic tube model, we can see their shadow in the viewing window. While we can see the shadow, we lose some information about exactly how the sample looks. Is it tall or short? Is it solid? Or does it have a hole in the middle? Some objects may have the same shadow but look quite different in 3D. With the TEM, scientists have developed ways to overcome this challenge, such as imaging their samples from different angles, or thinly slicing a sample and imaging each slice.



TEM image of Silicon Nitride

How is this nano?

Scientists use special tools and equipment to work on the nanoscale. Transmission Electron Microscopes (TEMs) allow researchers to detect and make images of individual atoms and other features that are too small to see with other tools.

The invention of transmission electron microscopy was a breakthrough in the field of nanotechnology. Once scientists could create pictures of nanoscale objects and features, they could begin to study and understand this tiny scale.

Learning objective

Scientists use special tools and equipment to work on the nanoscale.

Materials

- Imaging tube
- Small foam pieces
- Play dough
- Flashlight
- Piece of plain white paper
- "Comparing Microscopes" image sheet
- "Comparing Microscopes Background" sheet

The imaging tube consists of a 3" dia. x 11" PVC pipe, a 4" dia. x 3" PVC pipe (with a 2" wide notch cut out), a 3" x 4" PVC coupling, a 3" dia. PVC end cap (with a 1 ¼" hole drilled in the center) and a 3 ¼" dia. clear acrylic disk.

Imaging tube parts are available through home improvement stores, such as Lowe's, www.lowes.com.

Notes to the presenter

Since this demo relies on creating shadows, it is very sensitive to ambient light. For best results, do not have this station near a window or other sources of bright light. You can also place a piece of white paper under the imaging tube so the shadows show up better.

Brighter flashlights produce shadows with more detail.

Credits

TEM image of Silicon Nitride courtesy James LeBeau, NC State University. TEM image of Silica and Silicon courtesy Pinshane Huang, Cornell University. Illustrations by Emily Maletz.

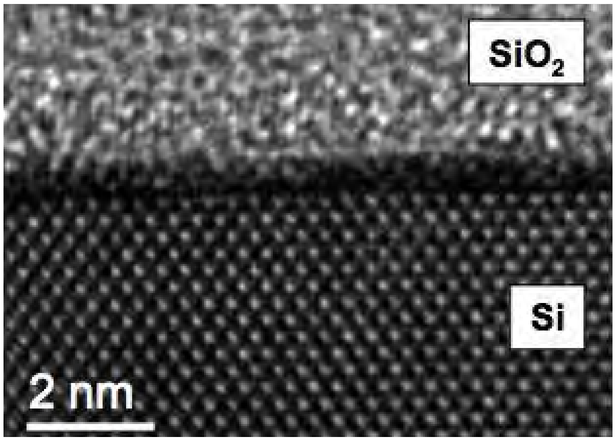
This project was supported by the National Science Foundation under Award No. ESI-0532536. Any opinions, findings, and conclusions or recommendations expressed in this program are those of the author and do not necessarily reflect the views of the Foundation.

TEM Background Information

What are transmission electron microscopes?

Transmission electron microscopes (TEMs) are a type of electron microscope. TEMs are similar to light microscopes, but they are able to image very small structures because they use electrons instead of light. While light microscopes can only image features that are larger than 200 nanometers, the best TEMs can show features that are smaller than 1 nanometer! (A nanometer is a billionth of a meter.)

Scientists use TEMs because they can provide very detailed images. TEMs can also identify the structure of ordered, crystalline materials. TEMs, as well as other electron microscopes, may also employ detectors that can identify the atomic composition of a sample.

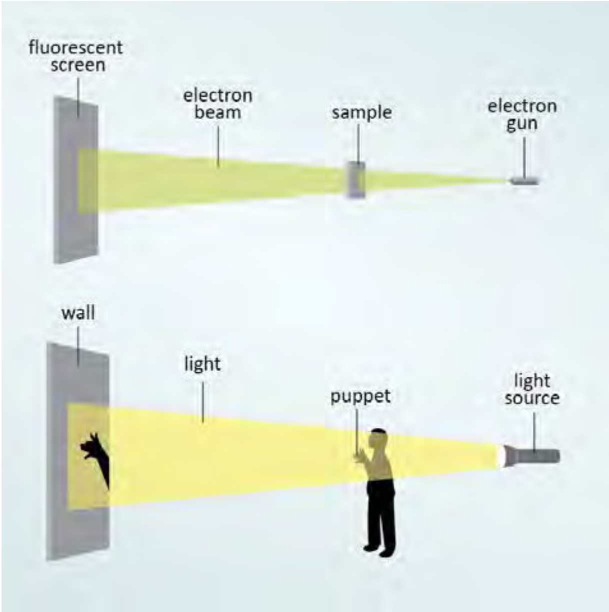


TEM image of silicon dioxide and silicon

How do they work?

TEMs direct an electron beam at a sample and detect the electrons that are transmitted through the sample. A TEM works similarly to a shadow puppet show. In a puppet show, the puppet is illuminated by a bright light and we see the shadow projected onto the wall. In a TEM, the sample is like the puppet and the electron beam is like the bright light. In a TEM, the resulting "shadow"—the transmitted image—is then displayed so that researchers can analyze it.

Unlike in a shadow puppet show, where the puppet blocks the light to create a shadow, in a TEM the electron beam passes through the sample. The "shadow" that's created isn't really from blocking the electrons, but rather from interfering with them. When an electron beam passes through a sample, the atoms can deflect the beam creating a "shadow" in the projection. Heavier atoms deflect the beam more and will appear darker than less heavy atoms.



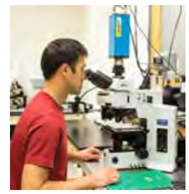
TEMs work similarly to shadow puppets

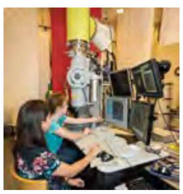
Additional Graphic Resources

Comparing Microscopes Background

Microscope types

Light Microscope: Light microscopes are the cheapest and most common type of microscope. If you've used a microscope at school or at home, you've probably used this type of microscope. In a light microscope, light illuminates the sample and produces a 2D image in the eyepiece. This kind of microscope is great for looking at bugs, flowers, and onion skin. But these microscopes can't identify features smaller than about 200 nanometers. To see features smaller than 200 nanometers, scientists must use an *electron* microscope. Light microscopes have been around since the 16th century! Light microscopes can be as cheap as $50, or they can run into the tens of thousands of dollars for research-grade models!





Transmission Electron Microscope (TEM): TEMs shoot electrons through thin samples and look at the electrons that have reached the other side. Even though TEMs are large and expensive, they are actually similar to overhead projectors, since both produce 2D "shadows" of a sample. TEMs have incredible resolution, so it's possible to image individual atoms with a TEM! TEMs were invented in 1931 by Ernst Ruska and Max Knoll. TEMs cost between $400K and $4M!

Scanning Electron Microscope (SEM): Like TEMs, SEMs shoot electrons at samples. But in SEMs, the samples are thicker so the electrons don't pass through the samples. Scientists get information about the sample by detecting electrons that are reflected or emitted from the sample. SEMs have a very high resolution, but they cannot image individual atoms. The SEM was invented in the 1950s by Charles Oatlev and now cost between $200K and $400K!

Atomic Force Microscope (AFM): AFMs are sensitive instruments that produce height maps of a sample's surface. During an AFM scan, a cantilever with a small tip on the end moves across the sample. This process is similar to how a blind person reads Braille or how a record player converts grooves on a vinyl record into music you can hear. AFMs are so sensitive that they can image individual atoms. And AFMs can do more than just image – they can even *move* atoms! AFMs were developed in the 1980s by Gerd Binning and Heinrich Rohrer. AFMs cost between $50K and $200K.

Challenges

Here are a few challenges scientists and engineers face when using AFMs, SEMs, and TEMs:

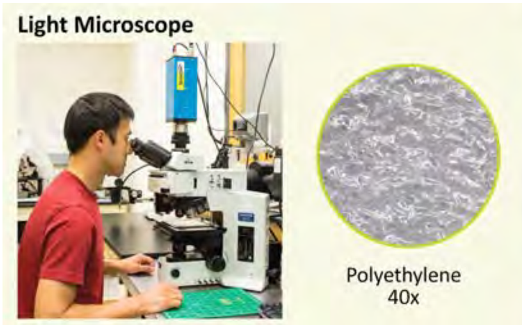
Preparing samples for a vacuum: TEMs and SEMs are operated under a vacuum, which means that the air inside the microscope chambers has been removed. Outer space is also a vacuum! These microscopes have to be under a vacuum so that the electron beam will travel in a straight line and hit the sample. Since the samples are also under a vacuum, they can't be wet or they will release water molecules and destroy the vacuum. This is a problem for biological samples, since they are naturally wet. Scientists have ways of removing the water, but these methods can change or damage the sample!

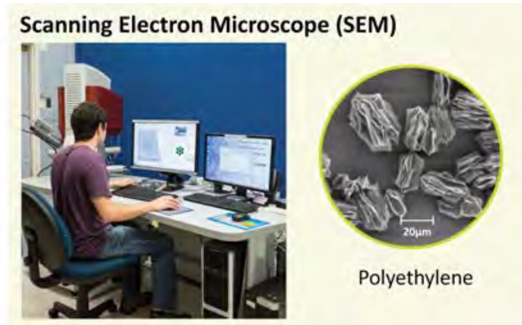
Preventing sample vibrations: Imaging samples with the AFM, TEM and SEM can be tricky, since even tiny vibrations can cause big problems! When scientists are imaging tiny nanoscale features, even small vibrations such as footsteps in the room next door can jiggle the sample too much and ruin the images. To help minimize these effects, these microscopes are placed on special tables called *vibration isolation tables* that minimize vibrations.

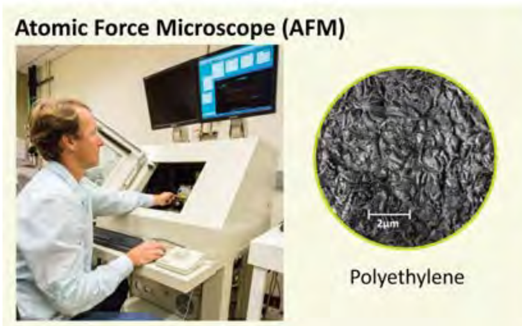
"Comparing Microscopes Background" sheet
8.5 x 11 inches

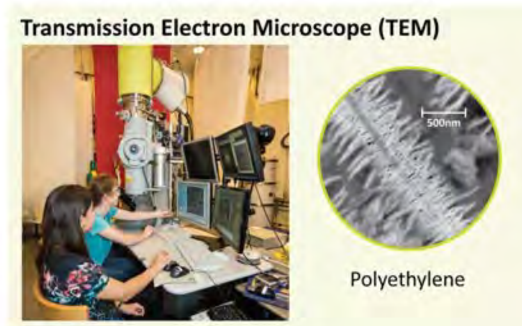
NanoDays
The Biggest Event for the Smallest Science!

Comparing Microscopes









Nanoscientists use many different types of microscopes to study and make tiny things.
The different tools create very different images of the same material—in this case polyethylene, a common plastic.

"Comparing Microscopes" image sheet
11 x 8.5 inches

Exploring Tools—

Dress Up Like a Nanoscientist

Try this!

1. Have a friend stand a few feet in front of you. If they want, have them put on a pair of goggles. Hold up the "Dress Up Like a Nanoscientist" card in your hand and align your friend's face with the cutout.

2. Imagine your friend as a future nanoscientist! If you have a camera (or a phone with a camera), take a picture!

Tip: To keep things in focus, you may need to hold your arm straight out and have your friend move further back away from you.

What's going on?

In a cleanroom, scientists learn about and make things that are too small to see. Special clothing must be worn in cleanrooms. Some of the clothing protects the scientists from harmful things in the cleanroom, but most of it actually protects the lab from harmful things on the scientists!

Scientists wear special clothes to work in a nano lab!

People who work in cleanrooms put on a lot of gear before they enter the lab. They get dressed in a special room called a gowning room. They even get dressed in a special order to keep as clean as possible!

- **Shoe covers** go on over shoes.
- **Hoods** cover heads.
- **Head-to-toe suits** cover the whole body.
- **Booties** go on feet and legs.
- **Goggles and gloves** cover hands and eyes.
- **Badges** identify people.

How is this nano?

Nano labs are clean. To make tiny things, scientists need to work in a very clean place. These special workspaces are called cleanrooms. To keep dust out of cleanrooms, scientists put on special head-to-toe suits that cover everything but their faces. They also use special supplies, like dust-free paper and pens that release fewer chemicals and fibers into the air.
No pencils are allowed—they create too much dust!

Nanoscale devices are so small that even a tiny piece of dust can be much larger than many of the features. A single speck can ruin the whole device! (A nanometer is a billionth of a meter.)

Dust-free paper and pens keep cleanrooms clean

In a cleanroom, scientists and engineers take advantage of special properties at the nanoscale to create new materials and devices.

Learning objectives

To make tiny things, scientists need to work in a very clean place.

Special clothing must be worn in cleanrooms.

Materials

For the activity photo-op:

• "Dress Up Like a Nanoscientist" cards
• Goggles

For the presenter:

• Tyvex™ suit
• Goggles and gloves

The cards can be downloaded from www.nisenet.org/search/nanodays_product. If you print the cards from the digital file, be sure you don't allow page scaling.

Notes to the presenter

Dress up in the enclosed Tyvex suit and wear gloves and goggles to attract visitors and encourage discussion of why nanoscientists wear special clothing to work in a cleanroom. Have visitors take a look at the bottom of their own shoes as a way of understanding the kind of dirt scientists are trying to keep out of the cleanroom.

Encourage visitors to use cameras or camera phones to take a picture of their friend framed in the card. This kind of photography is called perspective photography. If their hand shakes too much to take a picture, they can try to steady the card in the activity sign holder.

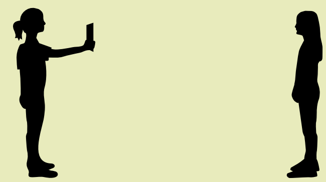
When setting up this activity, make sure the room is big enough so that people can be far enough apart to get a good picture. Try it out yourself to see what works; you can even put tape down on the floor to help guide visitors.

Credits

This activity is adapted from the *NanoLab Dress Up Like a Nanoscientist* exhibit created for the NISE Network by the Sciencenter, Ithaca, NY.

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

Additional Graphic Resources



Try this!

1. Have a friend stand a few feet in front of you. Hold up this card and align your friend's face with the cutout.

2. Imagine your friend as a future nanoscientist! If you have a camera (or phone with a camera), take a picture!

Tip: To keep things in focus, you may need to hold your arm straight out and have your friend move further back away from you.

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"Dress Up Like a Nanoscientist" card
5 x 8 inches, double-sided

Gary Hodges

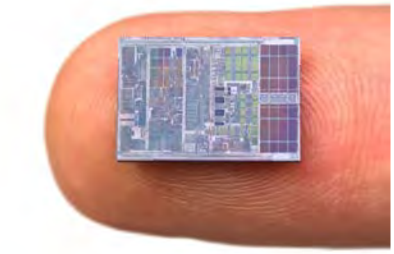
SECTION 4

Nano is new technologies

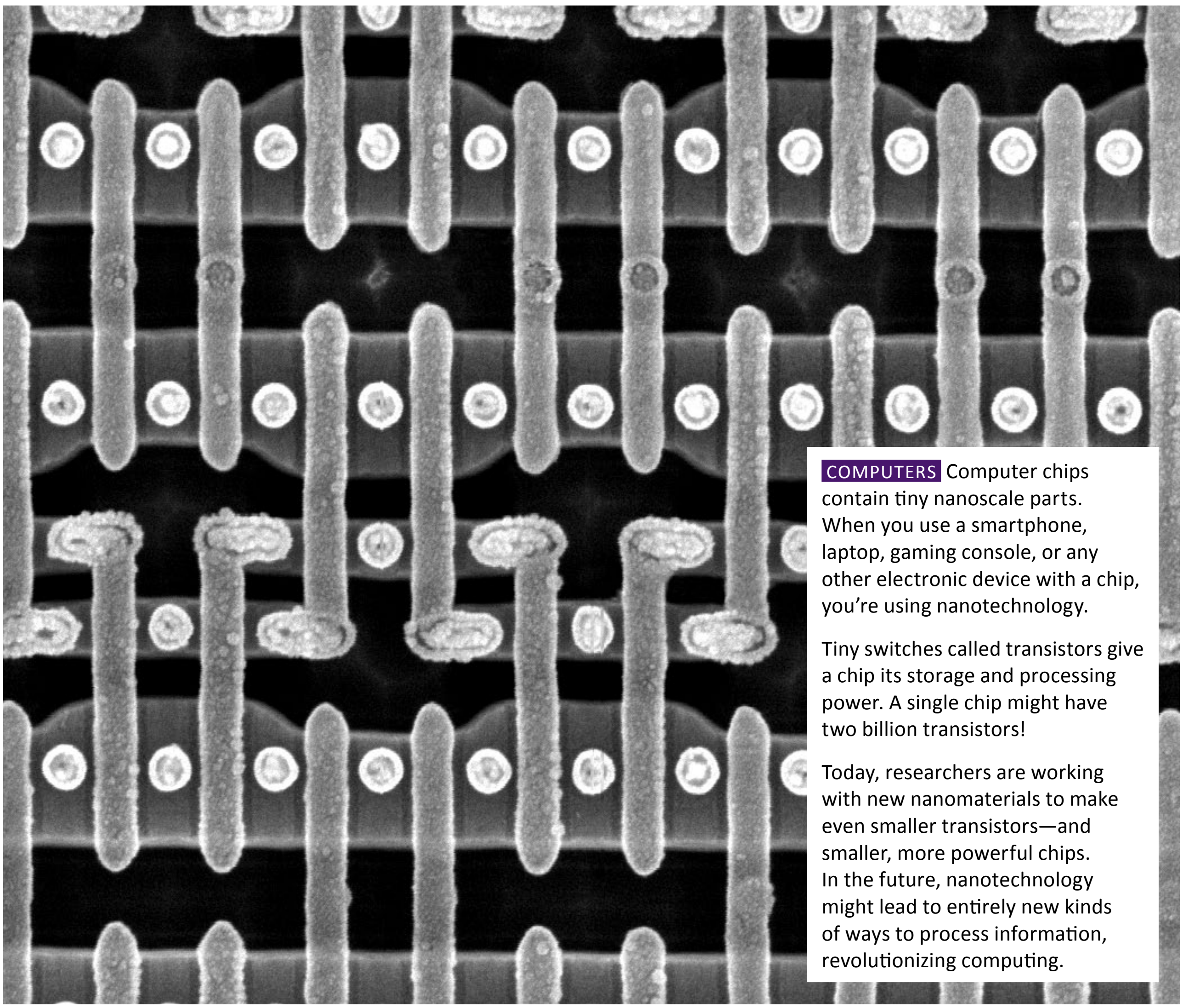
Nanoscale science, engineering, and technology lead to new knowledge and innovations that weren't possible before.

Researchers and engineers use nanoscale properties to improve and create materials, devices, and applications.

Nanotechnology is not all one thing—there are many different nanoscale technologies. Nanotechnology includes a wide range of research and applications in areas such as computing, food science, and medicine. It allows us to improve existing products by reengineering them at the nanoscale. For example, nanotechnology makes sunblock transparent and computer chips faster.



Nanoscale transistors inside a cell phone microprocessor chip



Chipworks, www.chipworks.com

COMPUTERS Computer chips contain tiny nanoscale parts. When you use a smartphone, laptop, gaming console, or any other electronic device with a chip, you're using nanotechnology.

Tiny switches called transistors give a chip its storage and processing power. A single chip might have two billion transistors!

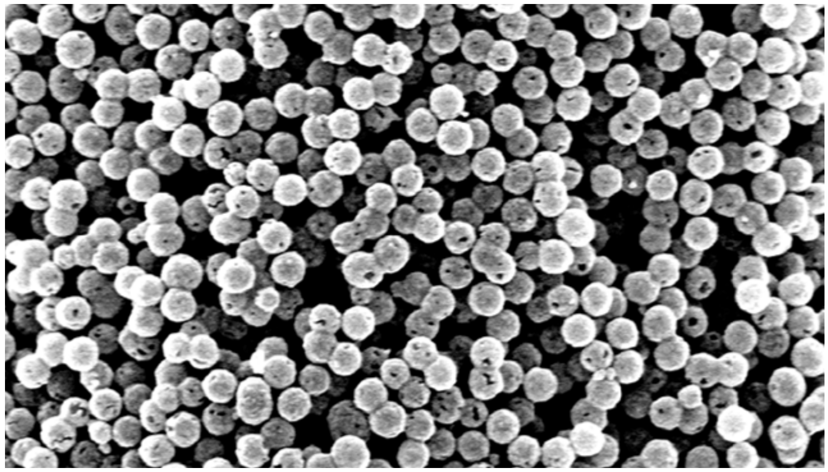
Today, researchers are working with new nanomaterials to make even smaller transistors—and smaller, more powerful chips. In the future, nanotechnology might lead to entirely new kinds of ways to process information, revolutionizing computing.

FOOD Nanotechnology is already on the shelves of your supermarket. Tiny nanostructures make some brands of ice cream look and taste better, while nanoparticles in bottles can keep beer fresh. Supplements contain nanoscale nutrients that are readily absorbed by your body.

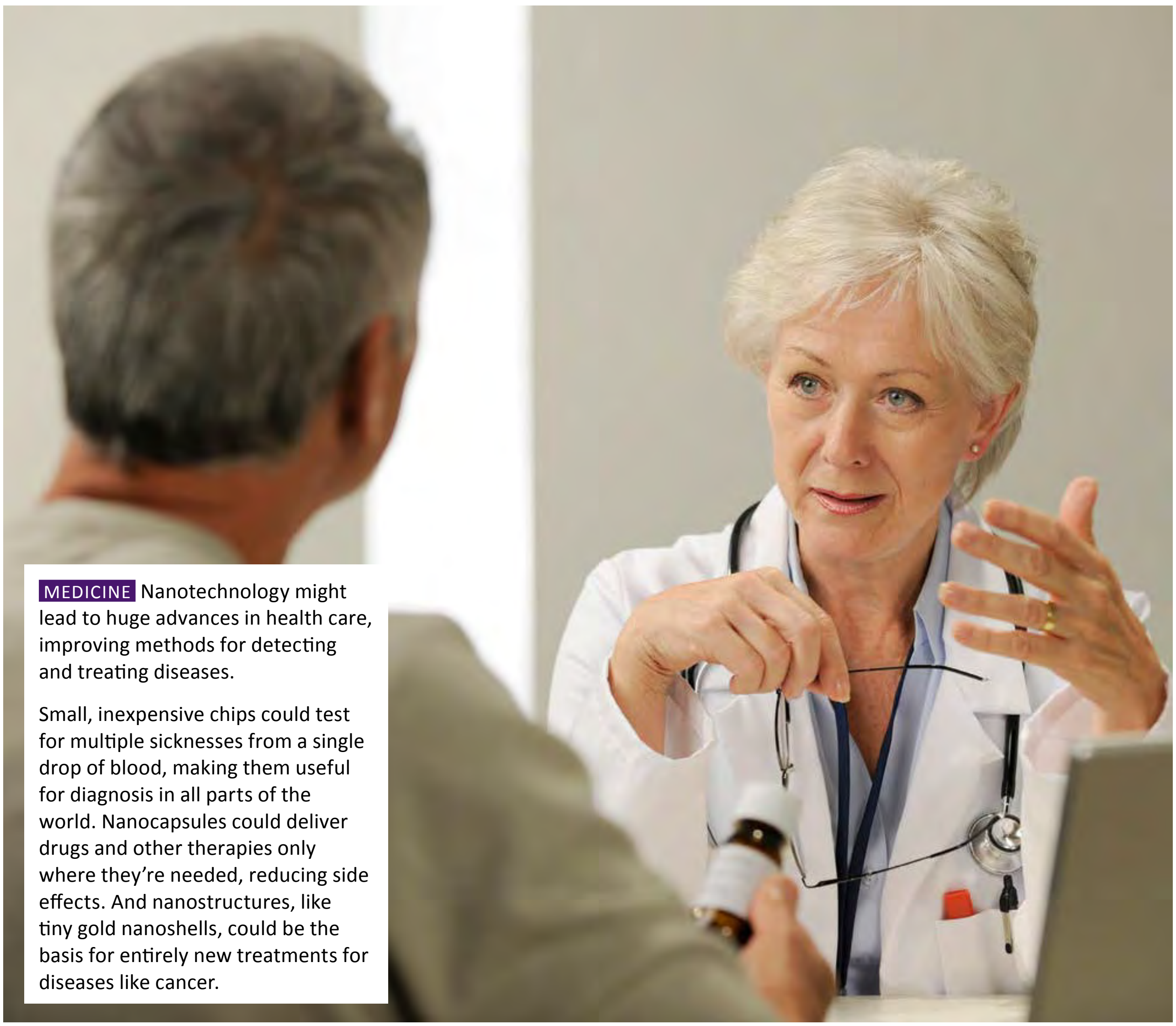
In the future, nanotechnology could be used in all stages of food production, from cultivation to processing to distribution. Nanosensors might be deployed in farm fields, monitoring plant health and dispensing water and nutrients as needed. Other sensors might detect microbes such as salmonella, keeping harmful foods from entering stores.

Nanotechnology also allows us to create entirely new materials and technologies. Right now, most of the nanotechnology you come across is incorporated into certain consumer products. But future applications of nanotechnology will address issues of global importance such as food, water, medicine, and energy.

Gold nanoshells



G.Koeing, University of Wisconsin-Madison



MEDICINE Nanotechnology might lead to huge advances in health care, improving methods for detecting and treating diseases.

Small, inexpensive chips could test for multiple sicknesses from a single drop of blood, making them useful for diagnosis in all parts of the world. Nanocapsules could deliver drugs and other therapies only where they're needed, reducing side effects. And nanostructures, like tiny gold nanoshells, could be the basis for entirely new treatments for diseases like cancer.

ENERGY Nanotechnology could transform the ways we create, transmit, store, and use energy. Some scientists think nanotechnology will allow us to build ultra-efficient transmission lines for electricity, produce more effective and inexpensive solar cells, make cheap, efficient biofuels, and improve the safety of nuclear reactors.

But more research and investment is needed before nanotechnology energy solutions are developed or widely distributed.

Exploring Materials—

Ferrofluid

Try this!

1. Move a magnet around next to the vial of black sand. How does the sand react?

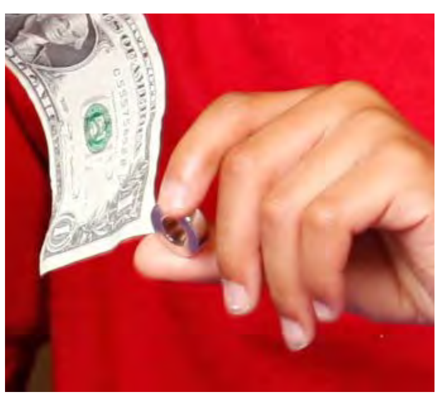
2. Do the same thing with the vial of ferrofluid. Does the ferrofluid act the same way the sand does?

3. Now, hold the magnet next to the crisp dollar bill. What happens to the money?

What's going on?

Ferrofluid is a unique material that acts like a magnetic solid and like a liquid. In contrast, black sand is a regular magnetic solid. Surprisingly, both ferrofluid and black sand are made of magnetite! The difference in their behavior is due to size.

Ferrofluid is made of tiny, nanometer-sized particles of coated magnetite suspended in liquid. When there's no magnet around, ferrofluid acts like a liquid. The magnetite particles move freely in the fluid. But when there's a magnet nearby, the particles are temporarily magnetized. They form structures within the fluid, causing the ferrofluid to act more like a solid. When the magnet is removed, the particles are demagnetized and ferrofluid acts like a liquid again. Black sand is also made of magnetite, but it doesn't have ferrofluid's unusual properties because the grains of sand are much larger.



The dollar bill moves because the ink used in printing contains ferrofluid! This special ink is used to deter counterfeit printing. The ferrofluid used in the ink also helps vending machines know if you've put in $1 or $5 or $50!

How is this nano?

A material can act differently when it's nanometer-sized. (A nanometer is a billionth of a meter.) Nanometer sized magnetite particles suspended in liquid (ferrofluids) behave like paramagnets, meaning that it's magnetic only in the presence of a magnet. But on the macroscale, magnetite is permanently magnetic.

Nanotechnology takes advantage of special properties at the nanoscale—such as paramagnetism—to create new materials and devices.

In addition to the ink used in printing US dollar bills, ferrofluid is used in rotary seals for computer hard drives and other rotating shaft motors, and in loudspeakers to dampen vibrations. In medicine, researchers are looking at ways to use ferrofluid as a contrast agent for magnetic resonance imaging (MRI).

Learning objective

A material can act differently when it's nanometer-sized.

Inside a hard drive

Materials

- Ferrofluid display cell
- Vial of magnetic black sand
- Neodymium magnet wand
- Dollar bill
- Bill sized paper
- 2 giant binder clips (only the black base)
- Ferrofluid Material Safety Data Sheet (MSDS)

Ferrofluid display cells are available from www.teachersource.com (#FF200).

Iron filings can be substituted for magnetic black sand, available from www.teachersource.com (#M-600).

Notes to the presenter

SAFETY: Small fingers can be pinched by magnets! To minimize the pinch hazard, have visitors use caution when holding magnets near magnetic metals.

Before doing this activity, read the MSDS information on the ferrofluid display cell provided by the supplier.

Credits

This activity was adapted from the NanoDays activity Exploring Materials—Ferrofluid supported by the National Science Foundation under Award No. ESI-0532536. The original program is available at: www.nisenet.org/catalog.

And from the "Quick Reference Activity Guide: Ferrofluids," developed by the National Science Foundation-supported Internships in Public Science Education (IPSE) Program at the Materials Research Science and Engineering Center (MRSEC) on Nanostructured Materials and Interfaces at the University of Wisconsin-Madison. The original activity is available at: mrsec.wisc.edu/Edetc/IPSE/educators/ferrofluid.html.

Photo of ferrofluid courtesy of Opoterser. From Wikimedia Commons.

This project was supported by the National Science Foundation under Award No. 0940143. 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.

Ferrofluid Background Information

What is ferrofluid?

Ferrofluid is a colloidal suspension of small magnetic particles in a fluid. In a suspension, solid particles are dispersed. The viscosity of the fluid, the tiny size of the particles, and the particles' constant motion keep the solids from settling out. The magnetic particles in ferrofluid are around 10 nanometers in size. (A nanometer is a billionth of a meter.) Particles this size are known as colloids.

Ferrofluid near a magnet

The magnetic particles in ferrofluids are usually iron oxide (magnetite), synthesized in solution and precipitated as nanoparticles:

- Iron salts (iron II chloride and iron III chloride) are mixed in a basic solution. Tiny particles of iron oxide (Fe_3O_4) precipitate from the solution.
- The iron oxide particles are coated with a surfactant to keep them from sticking to each other.
- The particles are dispersed in a water- or oil-based fluid.

Iron oxide is the same compound as magnetite, a naturally magnetic mineral found in many igneous and metamorphic rocks. The first ferrofluids, developed by NASA in the 1960s, were ground from natural magnetite.

How can it act like a liquid and a solid?

Ferrofluid is superparamagnetic, a property that is found only at the nanoscale. At the macroscale, ferromagnetic materials (like refrigerator magnets) are permanently magnetic. But when ferromagnetic materials are nanometer-sized, they became paramagnetic, which means that they behave like magnets only in the presence of a magnetic field.

When there is no magnet nearby, the magnetite particles in ferrofluid act like normal metal particles in suspension. But in the presence of a magnet, the particles are temporarily magnetized. They form structures within the fluid, causing the ferrofluid to act more like a solid. When the magnetic field is removed, the particles are demagnetized and ferrofluid acts like a liquid again.

Speaker

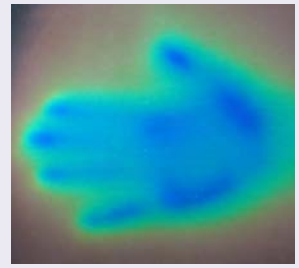
How is ferrofluid used?

Ferrofluid's properties make it useful for many different applications. The US government uses ferrofluid-based ink to print dollar bills as one of many anti-counterfeiting measures. Loudspeakers use ferrofluid to dampen vibrations. It is used in rotary seals for computer hard drives and other rotating shaft motors. In the future, ferrofluid might be used to carry medications to specific locations in the body.

Exploring Materials—

Liquid Crystals

Try this!



1. Place your hand on the tabletop to warm the surface.

2. Remove your hand. Can you see a handprint?

3. Place the large liquid crystal sheet on the table, in the spot where your hand was. Now can you see a handprint?

Now try this!

1. Put a sticker over the black square of a card.

2. Use a paintbrush to spread a thin layer of liquid crystal mixture on top of the sticker.

3. Carefully place the card face down onto the clear side of a self-laminating pouch.

4. Remove the paper on the other side of the pouch and seal it.

5. Warm the card with your hands. Can you get the liquid crystal to change colors?

6. Now cool it against a cool surface. What colors does it turn?

What's going on?

The liquid crystal sheet is temperature sensitive, and can detect where your hand warmed the table!

Liquid crystals represent a phase in between liquid and solid. The molecules in a liquid crystal can move independently, as in a liquid, but remain somewhat organized, as in a crystal (solid).

These liquid crystals respond to changes in temperature by changing color. As the temperature increases, their color changes from red to orange, yellow, green, blue, and purple.

How is this nano?

The way a material behaves on the macroscale is affected by its structure on the nanoscale. Changes to a material's molecular structure are too small to see directly, but we can sometimes observe corresponding changes in a material's properties. The liquid crystals in this activity change color as a result of nanoscale shifts in the arrangement of their molecules.

Nanotechnology takes advantage of special properties at the nanoscale to create new materials and devices. Liquid crystals are used in cell phone displays, laptop computer screens, and strip thermometers. They're also being used to create nanosensors—tiny, super-sensitive devices that react to changes in their environment.

Laptop with liquid crystal display

Learning objectives

The way a material behaves on the macroscale is affected by its structure on the nanoscale.

The liquid crystals in this activity change color as a result of nanoscale shifts in the arrangement of their molecules.

Materials

- Liquid crystal sheet
- Vial of liquid crystal mixture
- Paint brushes
- Printed cards with black squares
- Clear, square stickers
- Self-laminating pouches
- Safety glasses
- Material Safety Data Sheets (MSDS) (3)

Liquid crystal sheets are available from www.teachersource.com (#LC-2530A, 25-30˚C transition).

Instructions for preparing the liquid crystal mixture (26.5-30.5°C transition) are available at mrsec.wisc.edu/Edetc/nanolab/LC_prep/index.html

Chemicals can be ordered from www.sigmaaldrich.com/technical-service-home/product-catalog.html (cholesteryl oleyl carbonate #151157, cholesteryl pelargonate #C78801, and cholesteryl benzoate #C75802).

Self-laminating business card pouches are available at office supply stores (Scotch/3M #LS851G).

The card template can be downloaded from www.nisenet.org. They print on perforated business card sheets (10 per sheet, 2"x 3.5"), from office supply stores.

Clear, square stickers are available from onlinelables.com (#OL6300). You can substitute squares of packing tape.

Notes to the presenter

SAFETY: Visitors must be supervised when doing this activity. They must wear safety glasses to protect their eyes. Before doing this activity, read through the Material Safety Data Sheets.

The liquid crystal mixture must be viscous in order to do this activity. If it has thickened, use a hair dryer or heat gun (on a low setting) to warm the vial until the mixture is the consistency of honey.

The transition range for the liquid crystal mixture is 26.5-30.5°C. If you have difficulty seeing a reaction in the sensor, try cooling the liquid crystal against a cool surface and then warming it with your hands.

Credits

This activity was adapted from "Preparation of a Cholesteryl Ester Liquid Crystal Thermometer," developed by the National Science Foundation-supported Materials Research Science and Engineering Center (MRSEC) on Nanostructured Interfaces at the University of Wisconsin-Madison.
The original activity is available at: mrsec.wisc.edu/Edetc/nanolab/LC_prep/index2.html

Image of liquid crystal courtesy Gary Koeing, University of Wisconsin-Madison. Photo of models of twisted nematic liquid crystals by George Lisensky/Beloit College, courtesy of the Materials Research Science and Engineering Center (MRSEC) on Nanostructured Interfaces, University of Wisconsin-Madison.

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

Liquid Crystals Background Information

What are liquid crystals?

Liquid crystals represent a phase in between liquid and solid. The molecules can move independently, as in a liquid, but remain somewhat organized, as in a crystal (solid).

Why do the colors change?

The liquid crystals used in this activity are thermotropic, which means that they respond to changes in temperature by changing color. As the temperature increases, the color of the liquid crystal changes from red to orange, yellow, green, blue, and purple.

The liquid crystals in this activity are made of mixtures of long, thin molecules stacked in rotating layers, like a spiral staircase (helix).

When light strikes a liquid crystal, some of the light is reflected. The color of the reflected light depends on how tightly twisted the helix is.

More tightly twisted helixes—like the model on the left—reflect wavelengths on the blue end of the spectrum.

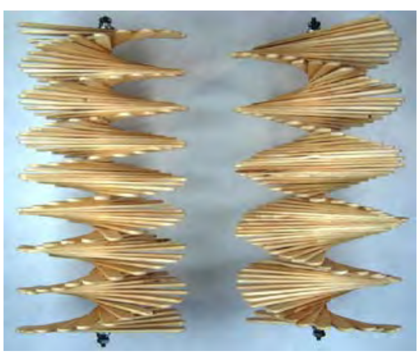
More loosely twisted helixes—like the model on the right—reflect wavelengths on the red end.

As the temperature of the liquid crystal changes, the spacing of the helix changes. This changes the wavelength of light that is reflected and the color that you see.

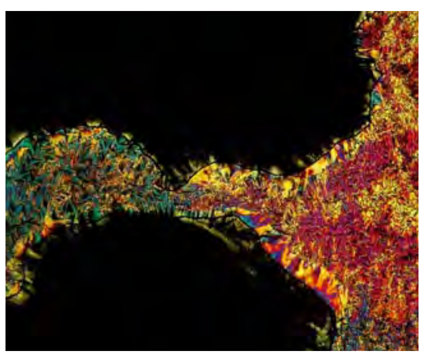
How are liquid crystals used?

The properties of liquid crystals make them useful for many applications. Because the color of a liquid crystal depends on the alignment of its molecules, anything that disrupts that alignment can be detected by a color change.

Liquid crystals are used in displays for cell phones, laptop computers, and other electronics. In these displays, an electric field changes the alignment of the liquid crystal molecules and affects the polarization of light passing through them. Liquid crystal nanosensors can detect certain chemicals, electrical fields, and changes in temperature.



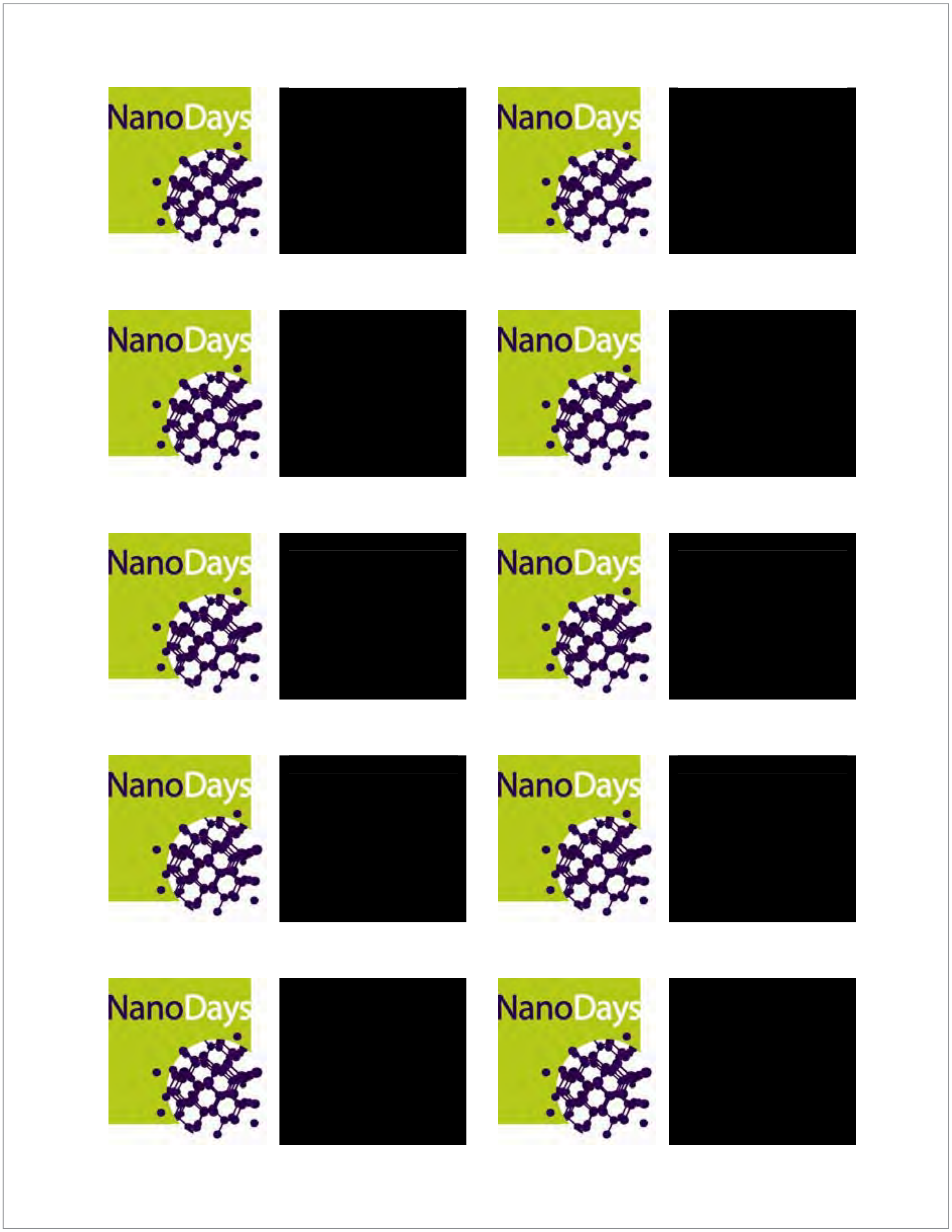
Models of liquid crystals



Liquid crystal

Cell phone with a liquid crystal display

Additional Graphic Resources



“Black Squares” card sheet
8.5 x 11 inches

Exploring Products—

Nano Fabric

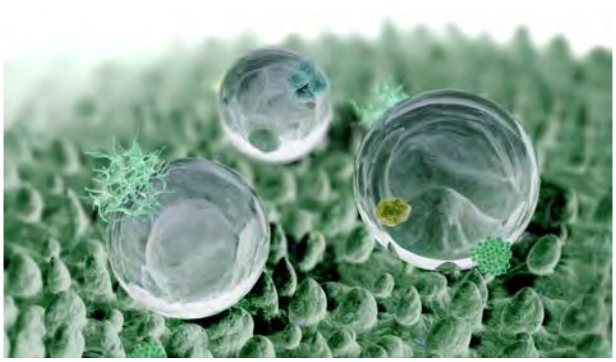
Try this!

1. Use the dropper bottle to squeeze water onto one pair of pants. What happens?

2. Now try dropping some water onto the other pair. Does the same thing happen?

What's going on?

One pair of pants is made of ordinary fabric, so it gets wet. The other pair is made of special fabric that repels water, dirt, and stains. During manufacture, the fabric is dipped into a solution that coats it with tiny, nano-sized "whiskers." The whiskers point outward, like peach fuzz, creating a layer of air next to the fabric. This cushioning layer keeps water and other liquids from soaking into the fabric. Water just beads up and rolls off the pants!



Water droplets collecting dirt as they roll off a lotus leaf

Scientists call this the lotus effect, because it's similar to what happens when water falls on the leaves of some plants, including lotus flowers and nasturtiums. The surfaces of these leaves have nanometer-sized waxy bumps that keep water and dirt from sticking to them.

Other nanotechnology applications mimic the lotus effect, including self-cleaning window glass and paint. These products are all hydrophobic, which means they repel water.

How is this nano?

The way a material behaves on the macroscale is affected by its structure on the nanoscale. Special fabrics are coated with nanometer-sized "whiskers" that protect them from stains. Nano fabrics are an example of nanotechnology—along with self-cleaning paint and windows—that mimic the water-repelling properties of some plant leaves.

Nanotechnology takes advantage of different material properties at the nanoscale to make new materials and tiny devices smaller than 100 nanometers in size. (A nanometer is a billionth of a meter.) Nanotechnology allows scientists and engineers to make things like smaller, faster computer chips and new medicines to treat diseases like cancer.

Learning objectives

The way a material behaves on the macroscale is affected by its structure on the nanoscale.

Special fabrics are coated with nanometer-sized "whiskers" that protect them from stains.

Materials

- Pants made of nanotechnology stain-resistant fabric
- Pants made of ordinary fabric
- Dropper bottle
- Tray

To locate pants made of nano fabric, you can search online for "stain resistant pants," then check for the word "nano" in the garment description.

The NanoDays nano pants were specially made using fabric donated by NanoTex.

Notes to the presenter

Before beginning this activity, fill the dropper bottle with water.

Extension

Visitors can compare how water behaves when dropped onto regular iceberg lettuce and onto hydrophobic plant leaves. Hydrophobic plants include lotus leaves, nasturtium leaves, mustard greens, leafy kale, broccoli, and Chinese cabbage.

Credits

This activity was adapted from "Nano-Tex: Testing New Nano Fabrics" developed by the National Science Foundation-supported Internships in Public Science Education (IPSE) Program at the Materials Research Science and Engineering Center (MRSEC) on Nanostructured Materials and Interfaces at the University of Wisconsin-Madison. The original activity is available at: mrsec.wisc.edu/Edetc/IPSE/educators/activities/nanoTex.html

Fabric for the miniature pants included in the NanoDays kits courtesy of Nano-Tex, Inc.
Computer-generated image of lotus effect courtesy William Thielicke, wthielicke.gmxhome.de/bionik

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

Exploring Products—
Thin Films

Try this!

1. Write your name on a strip of black paper.

2. Slide the paper into the pan. Make sure it's completely under water.

3. Use the brush to drip one drop of nail polish onto the surface of the water. The polish will spread out into a thin film.

4. Hold one end of the paper and lift it up out of the water. The film of nail polish will stick to the paper. Does the nail polish still look clear?

What's going on?

The nail polish spreads out into a super-thin film, which creates iridescent, rainbow colors on the paper. The thin film is only a few hundred nanometers thick, about as thick (or thin!) as a soap bubble. The film is slightly thicker in some places and thinner in others. As the thickness of the film changes, the color changes.

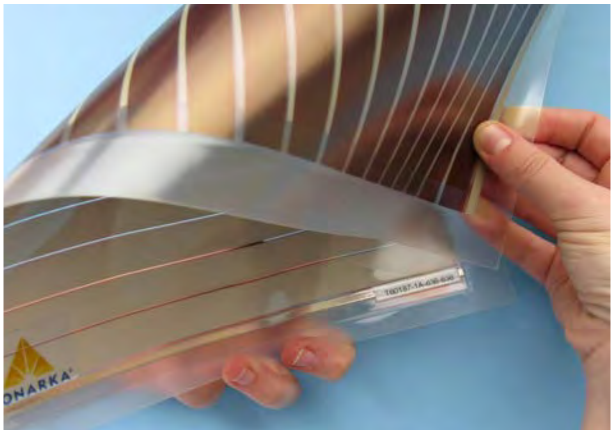
Peacock feathers are iridescent

The film reflects light differently depending on how thick it is, so you see different colors. White light is made up of all wavelengths, or colors, of light. Wavelengths that are in sync, hitting both the front and back of the film, are reflected back to your eyes as bright colors. Different wavelengths are in sync at different parts of the film, depending on its thickness.

Many beautiful things in nature get their iridescent colors this way—through the constructive interference of light. Bird feathers, butterfly wings, shells, and beetle shells all have nano-sized, semi-transparent layers that create an iridescent effect when they reflect light.

How is this nano?

The way a material behaves on the macroscale is affected by its structure on the nanoscale. Thin films can reflect light in special ways, because they're only a



Thin film solar panel

few hundred nanometers thick—in the same size range as the wavelength of visible light.

Nanotechnology takes advantage of special properties at the nanoscale to create new materials and devices. Researchers are creating thin film batteries, solar cells, electronic displays, and coatings for different surfaces.

Learning objectives

The way a material behaves on the macroscale is affected by its structure on the nanoscale.

The thin film reflects light differently depending on how thick it is, so you see different colors.

Materials

- Shallow pan
- Strips of black paper
- Clear nail polish
- Permanent markers in metallic color
- Peacock feather (optional)
- Thin film solar cell sample (optional)

Bristol paper works best for this activity. You can use regular construction paper, but a lot of color will bleed from the paper into the water.

The nail polish should be completely clear (no shimmer or glitter), and regular formula (not fast-drying).

Notes to the presenter

SAFETY: Do this activity in a well-ventilated area.

Before you begin:

- Fill the pans halfway with water.
- Set up an area to let the strips of paper dry.

Black paper is used for this activity because it absorbs all visible light. The colors that appear are created by the interaction of light with the thin film.

Writing their name with the permanent marker helps visitors find their thin film later. The marker doesn't make the colors appear on the black paper—that's the thin film created by the nail polish.

Credits

This activity was adapted from "Create Some Iridescent Art," in the DragonflyTV Nano Educator's Guide, published by Twin Cities Public Television, 2009. The original activity is available at: www-tc.pbskids.org/dragonflytv//web_assets/pdf/dftv_nanoedguide_butterflywings.pdf

Illustration of interfering wavelengths of light by Emily Maletz. Photo of solar panel array in the public domain, from Wikimedia.

This project was supported by the National Science Foundation under Award No. 0940143. 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.

Thin Film Background Information

What are thin films?

A thin film is a layer of material ranging from less than a nanometer (one billionth of a meter) to several micrometers thick. Everyday examples of thin films include soap bubbles, oil slicks on water, and anti-reflection coating on eyeglasses.

Why do some thin films have beautiful colors?

Light travels in waves. Just like water waves, light waves have crests (high points) and troughs (low points). The distance between crests is a *wavelength*. Different colors of light have different wavelengths.

The wavelength of visible light ranges from about 400–700 nanometers. The nanostructures of iridescent feathers, shells, and wings are in this same size range. So are thin films.

Light can interact in special ways with very tiny structures, like those found in nature and in nanotechnology.

White light is made up of all wavelengths, or colors, of light. When white light hits a thin film, some of the light is reflected from the front surface of the film, and some travels through it and is reflected from the back surface.

If the waves reflected from the front and back have crests that overlap, they reinforce each other and the reflected color is bright. This is called *constructive interference.*

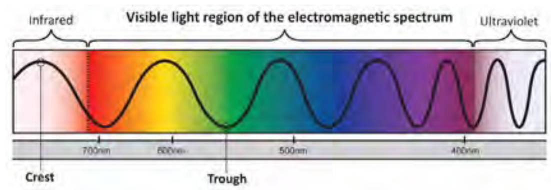
If the waves reflected from the front and back have crests that overlap with troughs, the waves cancel each other out and the reflected color is dim. This is called *destructive interference.*

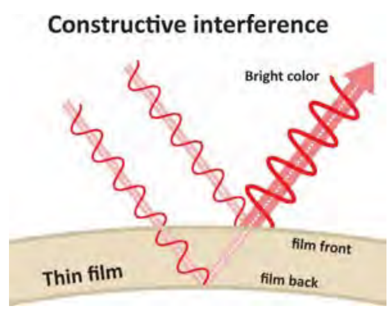
The thickness of the film determines which colors will be bright and which will be canceled out. In a very thin film (less than 400 nanometers thick) all the colors cancel out, and the film appears black.

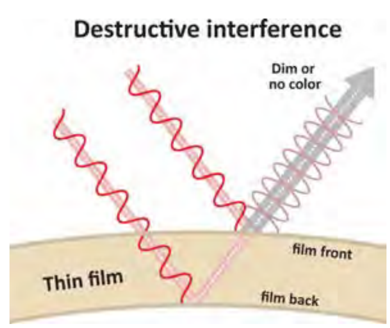
Thin film solar panels

How are thin films used?

Scientists are developing thin films to use as computer memory and in solar cells. Flexible thin film batteries can be made by printing onto plastic, thin metal foil, or paper. Thin films are expected to have cheaper manufacturing and materials costs than conventional materials.







Exploring Products—

Nano Sand

Try this!

1. Use a dropper bottle to squeeze water onto the tray of green sand. Tilt the tray gently. What happens?

2. Now try dropping water onto the tray of purple sand. Does the same thing happen when you tilt the tray?

Now try...

1. Quickly pour purple sand from the small portion cup into the drinking cup of water. What does the sand do?

2. Take a spoon, and scoop the sand back out. Is it wet?

What's going on?

The purple sand is special sand that's been chemically treated to repel water. This hydrophobic ("water-fearing") sand is coated with a silicon compound that makes it repel water. The layer is only one nanometer thick, so the coated sand looks and feels like regular sand—but it behaves very differently.

The green sand is just ordinary sand that's been colored. It acts pretty much like sand you encounter at the beach or playground. Ordinarily, water molecules and sand are attracted to each other, so beach sand gets wet.

Hydrophobic sand was invented to clean up oil spills in water. When the coated sand is poured on a spill, it bonds to the oil (but not the water) and sinks to the bottom, where it can be dredged and treated. Currently, though, hydrophobic sand is too costly to use this way.

Hydrophobic sand was invented to clean up oil spills

Hydrophobic sand has also been used to protect utilities in cold climates. Electrical junction boxes can be covered with a layer of coated sand, then capped with a few inches of soil. The hydrophobic sand can be dug through even when the ground is frozen, making repairs easier.

How is this nano?

The way a material behaves on the macroscale is affected by its structure on the nanoscale. You can't see or feel the nano-layer of silicon compound coating the hydrophobic sand because it's so thin, but you can observe that it makes the sand act differently from ordinary sand.

Nanotechnology takes advantage of different material properties at the nanoscale to make new materials and tiny devices smaller than 100 nanometers in size. (A nanometer is a billionth of a meter.) Nanotechnology allows scientists and engineers to make things like smaller, faster computer chips and new medicines to treat diseases like cancer.

Learning objectives

The way a material behaves on the macroscale is affected by its structure on the nanoscale.

Hydrophobic sand is coated with a nanometer-thick layer of a silicon compound, which makes it repel water.

Materials

- Ordinary, colored sand (green, or another color)
- Hydrophobic sand (purple, or another color)
- Trays (2)
- Dropper bottles (2)
- Small portion cups (2)
- Drinking cups (2)
- Spoons (2)
- "Nano Sand" sheet

Hydrophobic sand is available from www.dunecraft.com (purple #NS-R014 and green #NS-G010).

Notes to the presenter

Before beginning this activity:

- Fill the two trays, one with ordinary sand and one with hydrophobic sand.
- Fill the small portion cups with hydrophobic sand.
- Fill the dropper bottles and drinking cups with water.

To reuse the hydrophobic sand when the activity is over, carefully pour out most the water. Shake the tray and use a sheet of paper towel to absorb the last drops of water. To reuse the ordinary sand, let it dry in the tray.

Extension

Using the spoon, sprinkle nano sand on the surface of the water, so it floats. Gently poke the surface of the sand with your finger. Can you keep your finger dry?

Credits

This activity was adapted from several sources, including:

• Magic Sand, developed by the Materials Research Science and Engineering Center (MRSEC) on Nanostructured Materials and Interfaces at the University of Wisconsin-Madison for the NISE Network. The original program is available at: www.nisenet.org/catalog

• Magic Sand," JCE Classroom Activity #23, Journal of Chemical Education 77(1): 40A-40B, January 2000. The original activity is available at: http://pubs.acs.org/doi/abs/10.1021/ed077p40A

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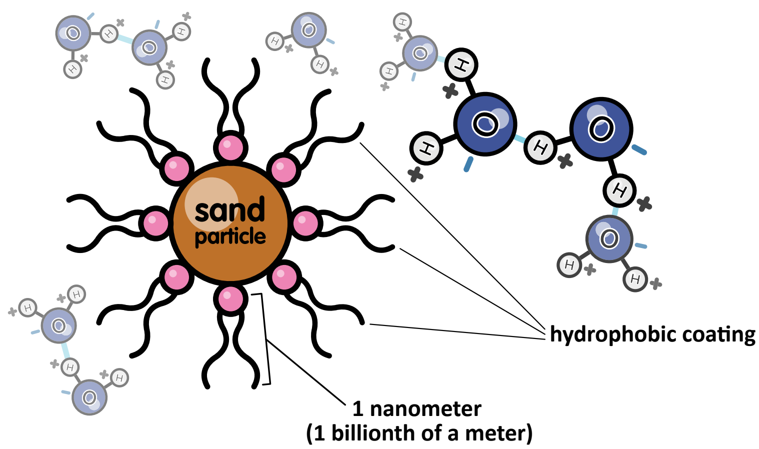
Nano Sand

NanoDays The Biggest Event for the Smallest Science!

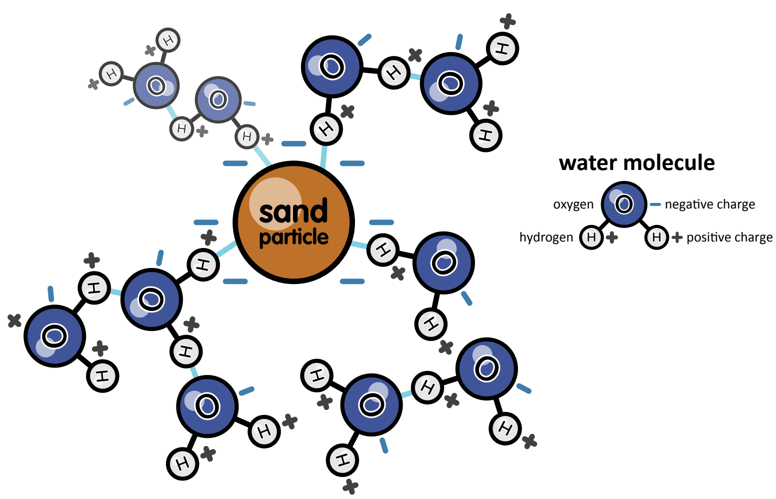
Special sand repels water molecules.

Hydrophobic sand is an example of science on the nanoscale. Treating the surface of individual grains produces a new type of sand that behaves very differently from regular beach sand.



Ordinary sand sticks to water molecules.

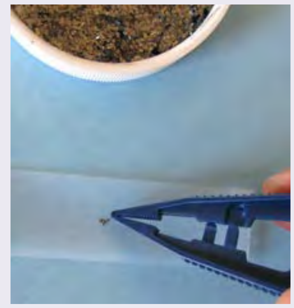
Natural sand is hydrophilic. The surfaces of both sand and water are charged and and are attracted to each other.



"Nano Sand" sheet
8.5 x 11 inches

Exploring Materials—
Graphene

Try this!

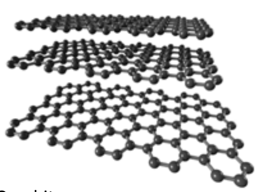


1. Take a piece of tape about 3 inches long. Fold over the two ends so you have small, non-sticky tabs to hold.

2. Use the tweezers to put a flake of graphite on the sticky side of the tape.

3. Fold the tape in half over the graphite and peel it apart again. Do this several more times.

4. Stick your tape onto a white card. What do you see?



Graphite

What's going on?

You've made very thin layers of graphite—and maybe even some graphene, the thinnest material that exists! Graphene is a single layer of carbon atoms arranged in a honeycomb pattern.

You started with a flake of graphite, which is a mineral made of many layers of graphene stacked on top of each other. Graphite is the material in pencils, commonly called "pencil lead." This simple technique for making graphene from graphite and tape—plus very insightful measurements of its properties—won Andre Geim and Konstantin Novoselov a Nobel Prize in Physics in 2010!

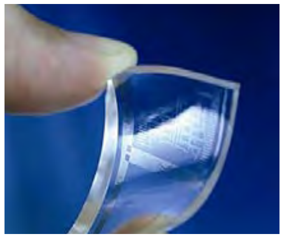
Now try...

1. Use the pencil to color in the box on your card. Be sure to fill it in completely. You're creating a thin layer of graphite.

2. Touch the two wires to the layer of graphite. What happens?

3. Now, take a look at the printed fabric. Do you see any wires? Try touching the two wires to the printed fabric (on the ink!). What happens?

What's going on?



Flexible graphene circuit

The buzzer sounds! The graphite on the card conducts electricity, completing the electrical circuit. The design on the fabric is printed with ink that contains graphene nanoplatelets—tiny stacks of graphene. Just like the graphite, these nano-sized particles of graphene also conduct electricity.

How is this nano?

Graphene is a single layer of carbon atoms arranged in a honeycomb pattern. Graphene is only one atom thick—that's a fraction of a nanometer! (A nanometer is a billionth of a meter.)

In the field of nanotechnology, scientists and engineers make new, nano-sized materials and devices. Graphene has a lot of potential in nanotechnology because of its useful properties: it's flexible, super-strong, nearly transparent, and conducts electricity. The graphene ink on the fabric can be used to make flexible, wearable circuits. Just imagine, you could charge your phone by plugging it into your shirt! Computer chip manufacturers are developing circuits from graphene, by modifying it to make it a semiconductor. One day, graphene could be used to make see-through, bendable electronic displays, and tiny, fast computer chips.

Learning objectives

Graphene is a single layer of carbon atoms arranged in a honeycomb pattern.

Graphene can be a semi-conductor.

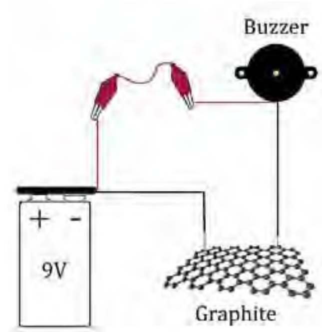
Materials

- Flakes of graphite
- Plastic tweezers with a pointed tip
- Scotch tape
- White activity cards (or index cards)
- Soft drawing pencils (6B is best)
- Pencil sharpener
- Battery and buzzer circuit (9V battery, snap connector, alligator clip, and buzzer)
- "Graphene" image sheet
- Photocopy master for activity cards
- Bag printed with graphene ink

Graphite flakes and bag printed with graphene ink can be purchased from www.graphene-supermarket.com (natural Kish graphite, grade 200, #SKU-NKG-0501).

Battery and circuit materials can be purchased from www.radioshack.com (9v battery #55039849, snap connector #270-324, alligator clip #278-1156).

Buzzer can be purchased from www.newark.com (#89K7985).



Battery and buzzer circuit

Notes to the presenter

When assembling the buzzer and battery circuit use the alligator clip to connect the black wire of the battery to the black wire of the buzzer. Then use the red wires to touch the layer of graphite on the paper. The buzzer will not work if it is connected in the wrong direction to the battery. If the buzzer sound is faint, try putting the wires closer together on the graphite or put down a thicker layer of graphite.

If you have a molecular model set, you can build a model of graphene to supplement the illustrations in this activity.

This project was supported by the National Science Foundation under Award No. 0940143. 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.

Graphene Background Information

What is graphene?

Graphene is a single layer of carbon atoms arranged in a honeycomb pattern. Graphene is only one atom thick—that's a fraction of a nanometer! (A nanometer is a billionth of a meter.)

Andre Geim and Konstantin Novoselov created thin layers of graphite by peeling apart tiny flakes using Scotch tape. When they measured their results, they were surprised to learn they could create layers of a single atom thick! Before their work, scientists didn't think it was possible to create a sheet of carbon only one atom thick.

Graphene has many exciting potential uses, and this simple method makes it possible for many scientists to study and build things from it. Geim and Novoselov won a Nobel Prize in Physics for their work in 2010.

Graphene is just one form of carbon. Carbon atoms can bond together into many different structures that have very different properties.

What other forms can carbon take?

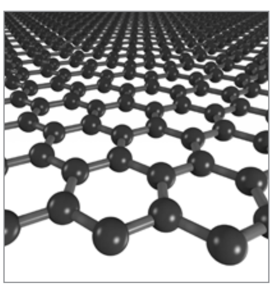
Carbon can form diamond, the hardest natural material known on Earth. But it can also form graphite, a much softer material (commonly known as pencil "lead"). Both diamonds and graphite are made entirely from carbon. They have different properties because the carbon atoms are arranged differently at the nanoscale.

Carbon can also form two other tiny, nanometer-sized structures that are too small to see: buckyballs and carbon nanotubes. Carbon nanotubes are long, hollow tubes. They look like sheets of graphene rolled up. Buckyballs have a soccer-ball shape.

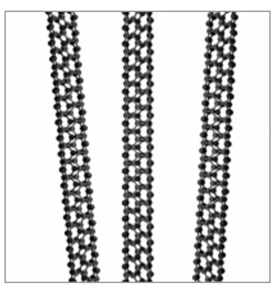
How is graphene used?

Graphene's properties make it potentially useful in many ways. It's 100 times stronger than steel. (A thin sheet of graphene could support an elephant!) It's also flexible and nearly transparent. And it's an excellent conductor of electricity (slightly better than copper).

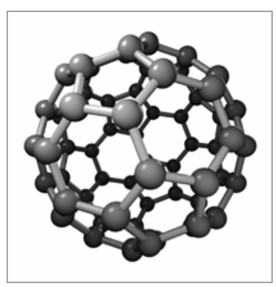
Graphene has a lot of potential in nanotechnology. IBM, Intel, Samsung, and other computer chip manufacturers are researching ways to use graphene in computer chips, by modifying it to make it a semiconductor. Researchers are also using graphene in composite materials, creating plastics that conduct electricity. Eventually, graphene might be in thin, flexible electronic components, transparent touch screens, and organic solar cells.



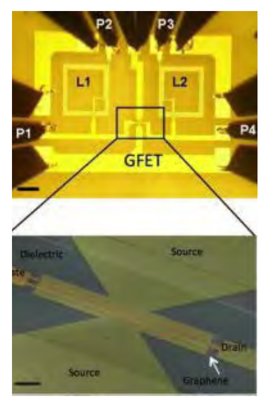
Graphene



Carbon nanotubes



Buckyball



Graphene integrated circuit

Credits

Image of flexible graphene circuit courtesy Ji Hye Hong. Image of graphene integrated circuit courtesy IBM. Image of graphene sheet courtesy Jannick C. Meyer.

The background information presented in this guide was adapted from:

• "Applications Activity: Nanoarchitecture," developed by the National Science Foundation-supported Internships in Public Science Education (IPSE) Program at the Materials Research Science and Engineering Center (MRSEC) on Nanostructured Materials and Interfaces at the University of Wisconsin-Madison. The original activity is available at: mrsec.wisc.edu/Edetc/IPSE/educators/carbon.html

• "Carbon Nanotubes & Buckyballs," developed by the National Science Foundation-supported Materials Research Science and Engineering Center (MRSEC) on Nanostructured Interfaces at the University of Wisconsin-Madison. The original activity is available at: mrsec.wisc.edu/Edetc/nanoquest/carbon/

• "Nanoarchitecture: Forms of Carbon," developed by the National Science Foundation-supported Internships in Public Science Education (IPSE) Program at the Materials Research Science and Engineering Center (MRSEC) on Nanostructured Materials and Interfaces at the University of Wisconsin-Madison. The original activity is available at: mrsec.wisc.edu/Edetc/IPSE/educators/activities/carbon.html

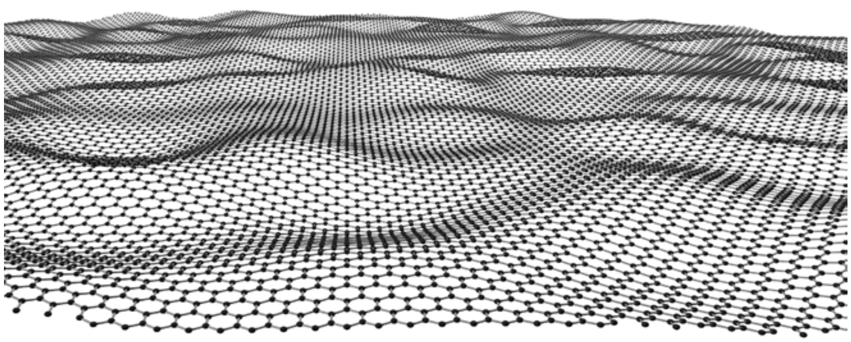
Additional Graphic Resources

NanoDays
The Biggest Event for the Smallest Science!

Graphene

Graphene is a single layer of carbon atoms arranged in a honeycomb pattern. Graphene is only one atom thick—that's a fraction of a nanometer! (A nanometer is a billionth of a meter.)

Graphene has a lot of potential in nanotechnology. Manufacturers are researching ways to use graphene in computer chips, by modifying it to make it a semiconductor. Eventually, graphene might be used in thin, flexible electronic components, transparent touch screens, and organic solar cells.



"Graphene" image sheet
8.5 x 11 inches

NanoDays

Graphene

Graphene is a single layer of carbon atoms in a honeycomb pattern.
It's only one atom thick—a fraction of a nanometer! (A nanometer is a billionth of a meter.)

Scotch tape with graphite and graphene

Use a pencil to color in this box

Graphite conducts electricity!

whatisnano.org

Activity cards
4.25 x 5.5 inches

Exploring Materials—

Hydrogel

Try this!

1. Fill a small cup about half full with water.

2. Put a stir stick in the cup. Place the bottom of the stick about half an inch from the side of the cup, and rest the top of the stick against the side of the cup.

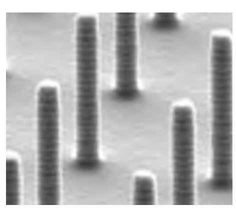
3. Sprinkle in a quarter spoonful of the white powder. What happens?

What's going on?

The powder absorbs all the water, expanding into a gel and moving the stir stick! The powder is a polymer called sodium polyacrylate that can absorb up to 1,000 times its weight in water!

A polymer is a long chain-like molecule made up of many repeating "links." The links of this particular polymer can attract and hold many water molecules. It's used in baby diapers to make them absorbent, and in plantings to help soil retain water.

Researchers are experimenting with similar materials called hydrogels. For example, a group at Harvard University is using hydrogels as "muscles" to control micro-sized structures.



Posts before hydrogel is added. 2,000 nm wide

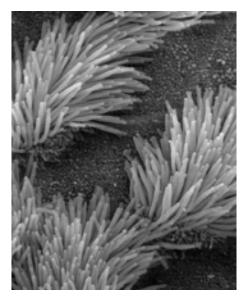
The gels can be designed to respond to changes in their environment, such as pH, temperature, or humidity. When the gels get bigger or smaller, they move tiny structures around them.

Posts moved by hydrogel 2,000 nm wide

How is this nano?

The way a material behaves on the macroscale is affected by its structure on the nanoscale. Some polymer crystals can absorb a lot of water, because they're made of long, chain-like molecules with many smaller "links" that attract water molecules.

Nanotechnology takes advantage of different properties—like super-absorption—at the nanoscale to make new materials and tiny devices smaller than 100 nanometers in size. (A nanometer is a billionth of a meter.)



Cilia keep our lungs clean 300 nm wide

For example, researchers are using hydrogel "muscles" to move tiny structures. This research is inspired by the way muscles move parts of the human body, such as the tiny cilia that help sweep away dust from our lungs.

Nanotechnology allows scientists and engineers to make things like smaller, faster computer chips and new medicines to treat diseases like cancer.

Learning objective

The way a material behaves on the macroscale is affected by its structure on the nanoscale.

Materials

- Sodium polyacrylate powder
- Plastic spoon
- Plastic water bottle
- Small paper cups (3 oz. bathroom size)
- Stir sticks or toothpicks

Sodium polyacrylate powder is available from www.teachersource.com (#GB-6A, #GB-6B, or #GB-620).

Notes to the presenter

SAFETY: Visitors should not ingest the sodium polyacrylate powder. Visitors should be supervised when doing this activity. You may choose to perform this as a demonstration, rather than allowing visitors to do it as a hands-on activity.

Before beginning this activity, fill the bottle with water. You'll need a trash can nearby to dispose of the cups and polymer.

Credits

This activity was adapted from:

• "Diaper Polymers," in You Be the Chemist. Activity Guide: Lesson Plans for Making Chemistry Fun. Grades K-4, published by the Chemical Educational Foundation. The source book is available at: www.chemed.org

• "Super Soakers" polymer activity developed by Lauren Zarzar of the Aizenberg Group at Harvard University and the Strategic Projects Group at the Museum of Science, Boston.

Images of hydrogel and microstructures courtesy Lauren Zarzar and Joanne Aizenberg, Harvard University.

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Exploring Materials—

Nano Gold

Try this!

Look at the three containers. Which one contains gold?

What's going on?

All three containers have gold in them! The difference in their appearance is due to the size of the gold particles.

Large pieces of gold, like the flakes in one of the vials, look shiny and golden. But when gold gets very, very small, it looks different because it interacts differently with light. The containers with red and orange liquids in them have nano gold, tiny particles of gold so small that they're measured in nanometers. A nanometer is a billionth of a meter—smaller than the wavelength of light.

Nano gold can look red, orange, or even blue! The color depends on the size and shape of the nanoparticles, as well as the distance between them. Here, the red nano gold particles are about 20 nanometers across, while the orange nano gold particles are about 80 nanometers across.

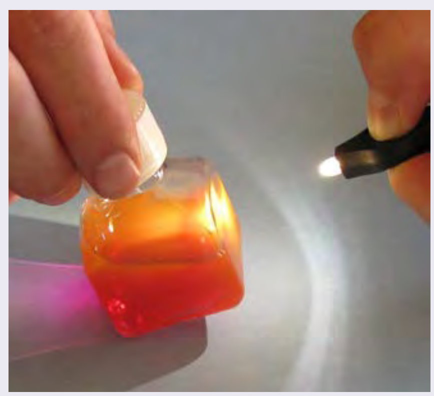
Take a look at the samples of stained glass. Their color comes from real gold! Nano gold has been used to make red stained glass since the Middle Ages. Different colors of glass contain different-sized particles of nano gold.

Now try…

1. Place the container of orange (80 nm) nano gold on the white paper, and tilt the bottle.

2. Shine the light through the bottle. What color do you see on the paper?

Tip: Squeeze the mini-light to turn it on.



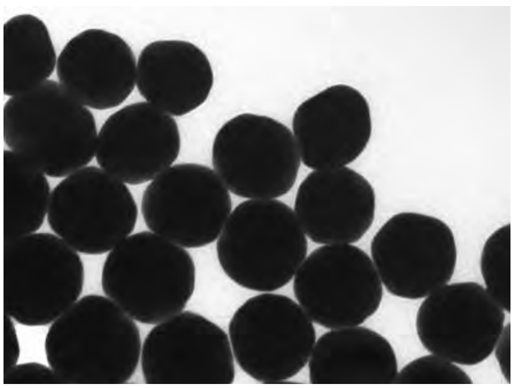
What's going on?

Nano gold interacts with light in surprising ways. When you look at the container of 80 nm gold under regular ambient light, you see the longer, orange wavelengths of light that are scattered by the tiny particles of nano gold. But when you look at the light that shines through the container and onto the paper, you see the shorter, purple wavelengths of light that are transmitted by the suspension of nano gold.

How is this nano?

A material can act differently when it's nanometer-sized. (A nanometer is a billionth of a meter.) Tiny particles of gold look red, orange, or blue—not shiny and golden.

Nanotechnology takes advantage of special properties at the nanoscale to create new materials and devices. Gold nanoparticles can be used as markers to indicate the presence of specific strands of DNA. And gold nanoshells—tiny spheres of glass covered with a thin layer of gold—are being tested as a part of a new cancer therapy.



Nano gold particles 80 nm in diameter

Learning objective

A material can act differently when it's nanometer-sized.

Materials

- Vial of gold flakes
- Vial of red nano gold (20 nm)
- Vial of orange nano gold (80 nm)
- Samples of stained glass made with gold
- Mini-light (very bright white LED)
- Sheet of white paper
- Image of stained glass window

Vials of gold flakes are available from www.amazon.com.

Nano gold is available from www.nanocomposix.com (20 nm and 80 nm spheres are included in the NanoDays kit).

Stained-glass samples made with gold are available from www.bullseyeglass.com (red #001311 and light orange #001823 are included in the NanoDays kit).

Notes to the presenter

SAFETY: Do not let visitors ingest the contents of the vials. Keep vials sealed shut.

SAFETY: Use caution when handling the stained glass samples. Do not remove them from their protective case.

Credits

This activity was developed in consultation with Dr. Dave Sebba, nanoComposix.

Image of 80 nm nano gold particles courtesy nanoComposix. Image of vials of nano gold in suspension courtesy nanoComposix.
Image of gold nanoshells courtesy G. Koeing, University of Wisconsin-Madison.

This project was supported by the National Science Foundation under Award No. 0940143. 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.

Nano Gold Background Information

What is nano gold?

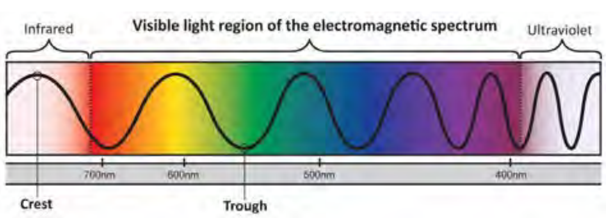
Nano gold is tiny particles of gold that are so small they're measured in nanometers. A nanometer is a billionth of a meter—smaller than the wavelength of light.

When gold is nano-sized, it has some surprising properties. For example, nano gold can look red, orange, or even blue. The color depends on the size and shape of the nanoparticles and the distance between them.

Nano gold

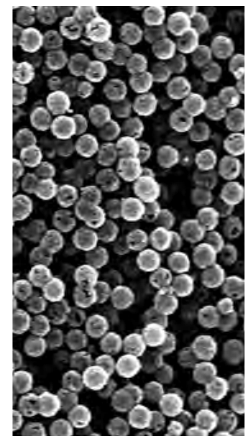
The different colors of nano gold come from a phenomenon called surface plasmon resonance. When light shines on the surface of a metal, it creates a surface plasmon, which is a group of electrons moving back and forth in sync across the surface of the metal. The electrons "slosh" back and forth on the metal surface, similar to the way waves of water move in a pond. When the electrons are moving at the same frequency as the light, the plasmon is said to be in resonance. When they're in resonance, the electrons absorb and scatter light, producing the colors you see.

Nanoparticles of gold resonate at frequencies within the visible spectrum of light. Smaller nano gold particles absorb and resonate with purple, blue, green, and yellow wavelengths of light, so they look red. Larger nano gold particles absorb and resonate with green, yellow, and red wavelengths of light, so they look blue.



How is nano gold used?

Nano gold has been used to create the colors of stained glass since the Middle Ages. Different sizes of nano gold produce different colors of glass. Particles around 20 nanometers across produce red glass. Particles around 30 nanometers across produce pink glass, and particles around 80 nanometers across produce orange glass.



Gold nanoshells

Today, gold nanoparticles can be used as markers to indicate the presence of specific strands of DNA. When strands of marked DNA combine, the gold nanoparticles come closer together, and the solution changes color.

Future cancer treatments might use gold nanoshells to fight tumors. Gold nanoshells are tiny spheres of glass covered with a thin layer of gold.

In an experimental treatment, gold nanoshells are injected into the body and collect in the tumor. Near-infrared light is then shined on the tumor. The light passes safely through healthy tissue, but heats the gold nanoshells and destroys the tumor. Pilot studies indicate that the treatment is successful, with minimal side effects.

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Stained Glass

Nano gold has been the secret ingredient in red stained glass since the Middle Ages!

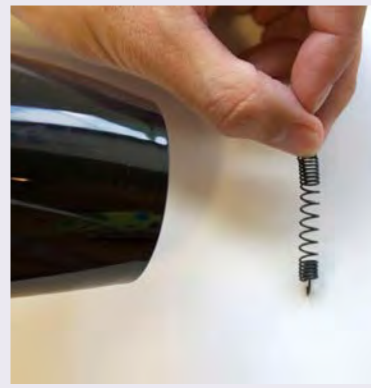
Different sizes of nano gold produce different colors of glass. Red stained glass gets its color from nanoparticles of gold that are only 20 nanometers across! (A nanometer is a billionth of a meter.) Orange glass gets its color from gold nanoparticles that are 80 nanometers across.

Image of stained glass window
8.5 x 11 inches

Exploring Materials—

Memory Metal

Try this!



1. Stretch out the NiTi spring.

2. Hold the stretched-out NiTi spring by one end, and use the "high" setting of the hair dryer to heat it up. What happens?

3. Does the ordinary steel spring do the same thing when it's heated with the hair dryer?

Now try...

1. Stretch out the NiTi spring.

2. Attach it to the handle of the pail.

3. Add a few pennies to the pail.

4. Use the hair dryer to heat the spring again. Can the spring lift the pail?

What's going on?

The NiTi spring returns to its original shape when heated by the hair dryer, but the steel spring doesn't. NiTi is an alloy of nickel and titanium called nitinol, or NiTi, for short. It's also known as "memory metal."

Memory metal changes between two solid structures, a low-temperature phase and a high-temperature phase. The spring changes shape because its atoms rearrange themselves during this phase change. Each atom moves only a tiny bit, but there are so many atoms in the spring that the movement is big enough for you to see.

Some NiTi alloys respond to electricity, rather than temperature, to change shape. For example, the Mars rover Sojourner uses a NiTi wire to shake dust off a solar cell. The NiTi wire is heated, which shortens it and pulls the cover open. This allows the cover to shed accumulated dust, so the solar cell can gather energy from the sun.

The properties of smart metals make them useful for many applications. The most familiar use of NiTi is the dental arch wire and springs used in orthodontic braces. Other commercial products include eyeglass frames, cell phone antennas, and surgical staples.

How is this nano?

The way a material behaves on the macroscale is affected by its structure on the nanoscale. Changes to a material's molecular structure are too small to see directly, but we can sometimes observe corresponding changes in a material's properties. Memory metal changes size and shape as a result of nanoscale shifts in the arrangement of its atoms.

Mars rover

Nanotechnology takes advantage of special properties at the nanoscale to create new materials and devices. Researchers are investigating the use of memory metal in heat engines. Memory metal is already used in a variety of technologies, from orthodontic braces to satellites.

Learning objectives

The way a material behaves on the macroscale is affected by its structure on the nanoscale.

Memory metal changes size and shape as a result of nanoscale shifts in the arrangement of its atoms.

Materials

- Memory metal (NiTi) extension spring with hooks
- Stainless steel extension spring with hooks
- Hair dryer
- Small plastic pail
- Roll of pennies

NiTi springs are available from www.musclewires.com (#3-642) or www.jameco.com (#357835).

Similar stainless steel springs are available from www.mcmaster.com (#9433K44).

Small plastic pails are available from www.orientaltrading.com (#IN-3/341).

Notes to the presenter

Hold the NiTi spring extended for just a moment after stretching it out, so it will hold its distorted shape.

After heating the NiTi spring, don't re-stretch it while it's still warm from the hair dryer. Let it cool thoroughly, to avoid "resetting" it in a distorted shape. After repeated use, the NiTi spring may eventually reset in a distorted shape. At that point, it will need to be replaced.

The ordinary steel spring will become distorted as soon as it's stretched out, and you won't be able to return it to its original shape. This will help visitors see how the memory metal spring is special.

Credits

This activity was adapted from the "Quick Reference Activity Guide: Memory Metal," developed by the National Science Foundation-supported Internships in Public Science Education (IPSE) Educator Resources, Materials Research Science and Engineering Center on Nanostructured Materials and Interfaces at the University of Wisconsin-Madison. The original activity is available at: http://mrsec.wisc.edu/Edetc/IPSE/educators/memMetal.html

Additional information was drawn from:

- Jones, M. Gail, Michael R. Falvo, Amy R. Taylor, and Bethany P. Broadwell. "NanoMaterials: Memory Wire." In Nanoscale Science: Activities for Grades 6-12. pp. 109-114. Arlington, VA: NSTA Press.
- Ramirez, A. "Ainissa Ramirez: Magical metals, how shape memory alloys work." TEDEd video series. http://ed.ted.com/lessons/ainissa-ramirez-magical-metals-how-shape-memory-alloys-work

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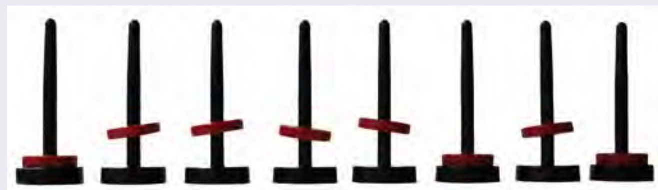
Exploring Products—

Computer Hard Drives

Try this!



1. Place a ring magnet on one of the ring stands.

2. Take the magnet off, flip it over, and put it back on the stand. What happens?

3. Use a row of 8 magnets to make a code! Choose a letter of the alphabet and look it up on the Binary Code sheet.

4. In this code, a magnet that sticks to the stand represents a 0 and a magnet that floats represents a 1.

Now try...

1. Look at the “Data Storage” sheet to compare how much information magnets of different sizes can store in the same amount of space.

2. Make your own binary code! Use a pencil to fill in the circles on the “My Name in Binary Code” sheet.

What’s going on?

You’re using the ring magnets as a model for how computer hard drives store information! The ring magnets either float or stick to the magnet in the base of the stand, depending on which magnetic pole is facing down.

Computers use binary code to store information. Binary code is a series of 1s and 0s. In computer documents like text files, each letter is represented by a particular combination of 1s and 0s. The letter z, for example, is usually stored in computers as 01111010. Each of these 1s and 0s is called a “bit,” so the code for the letter z has eight bits.

Hard drives use magnetic regions on the hard disk surface to represent these 1s and 0s. If the region is magnetized with the north pole facing up, it represents a 1. If the south pole is facing up, it represents a 0.

Hard drives made today store bits in tiny magnetic regions that are about 50 nanometers wide and only a few nanometers thick. (A nanometer is a billionth of a meter.) The smaller the magnetic regions, the more information a hard drive can hold. That's why some new hard drives are the same size as older models but can hold much more.

When we talk about the capacity of hard drives in gigabytes or terabytes we're actually counting the number of magnetic regions they contain. Byte is a word that means "8 bits." Giga- means a billion. Tera- means a trillion. So a hard drive with a terabyte of storage space uses around 8 trillion magnetic regions!

How is this nano?

Computer hard drives are one the most common applications of nanotechnology. Hard drives use tiny, nano-sized magnetic regions on their disks to make the binary code that holds information. The smaller the regions, the more information a hard drive can hold in the same amount of space.

Nanotechnology takes advantage of different material properties at the nanoscale to make new materials and tiny devices smaller than 100 nanometers in size. (A nanometer is a billionth of a meter.)

Learning objectives

Computer hard drives are one of the most common applications of nanotechnology.

Nano-sized magnetic regions allow hard drives to hold a lot of information in a small space.

Materials

- 8 floating ring magnets with stands
- "Binary Code" reference sheet
- "Data Storage" reference sheet
- "My Name in Binary Code" take-home sheets
- Pencils

Floating ring magnets and stands are available from www.teachersource.com (#M-780).

Notes to the presenter

For this activity, you just need one ring magnet per stand. Before you do the activity, remove the extra magnets and set them aside. It's best to use the same color magnet for all eight stands.

The "Binary Code" reference sheet and take-home sheets only have the codes for lowercase letters in the 8-bit ASCII character-encoding scheme. The first three "bits" (or magnets) are the same for all the lowercase letters (011). Uppercase letters, numbers, and symbols can be represented by changing the first three magnets. Uppercase letters start with 010 (instead of 011).

Credits

This activity was adapted from the "Magnetic Mad Libs" activity developed by Ted Gudmundsen of the Ralph Group at Cornell University and Educational Programs Office of the Cornell Center for Materials Research Center. The original activity is available at: http://www.ccmr.cornell.edu/education/educational-resources/lending-library-of-experiments/physics-kits/magnetic-mad-libs/

Image of computer display with "binary data" by W.Rebel, Wikimedia Commons.

This project was supported by the National Science Foundation under Award No. 0940143. 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.

Additional Graphic Resources

NanoDays
The Biggest Event for the Smallest Science!

Binary Code

Computers use binary code to store information. Binary code is a way of representing information in a series of 1s and 0s. Most modern hard drives use magnetic regions on the hard disk surface to represent these 1s and 0s. If the region is magnetized with the north pole facing up, it represents a 1. If the south pole is facing up, it represents a 0.

In this activity, we use a floating magnet to represent a 1 and a sticking magnet to represent a 0. Below are the codes for lower-case letters in the 8-bit ASCII (American Standard Code for Information Interchange) scheme.

Letter	Binary Code
a	01100001
b	01100010
c	01100011
d	01100100
e	01100101
f	01100110
g	01100111
h	01101000
i	01101001
j	01101010
k	01101011
l	01101100
m	01101101
n	01101110
o	01101111
p	01110000
q	01110001
r	01110010
s	01110011
t	01110100
u	01110101
v	01110110
w	01110111
x	01111000
y	01111001
z	01111010


=1


=0

"Binary Code" reference sheet
8.5 x 11 inches

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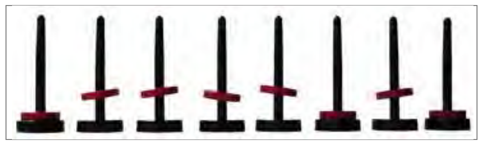
Data Storage

In this activity, the size of the magnets determines how much information can be stored in a given amount of space. We can store 1 byte of information with our eight magnet stands, which is enough for only one letter of the alphabet.

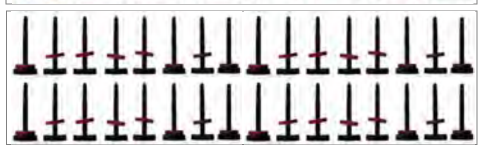
The eight magnets in the first picture below represent 8 bits (or 1 byte) of information. If the magnets were smaller, like in the second picture below, you could store 4 bytes of information (4 letters) in the same amount of space. If you had even smaller magnets, like in the last picture, you could store 16 bytes in the same amount of space.

Imagine how small the magnets would have to be to store enough information for a music file on your computer. A typical mp3 file is about 3.92 MB. That's around 4 million bytes. That's a lot of magnets for just one song!

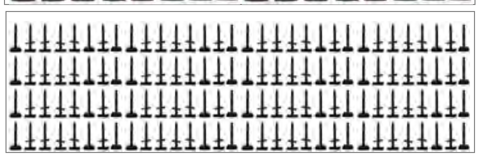
1 byte



4 bytes



16 bytes



"Data Storage" reference sheet
8.5 x 11 inches

NanoDays

My Name in Binary Code

Computers use binary code to store information. Binary code can be represented by any two symbols, such as 1s and 0s or full and empty circles.

Make a binary code representation of your name (or nickname). For each row, fill in a letter and the corresponding binary code. Leave the circle empty for 0 and fill it in for 1.

Name **Binary Code**

___ ○ ○ ○ ○ ○ ○ ○ ○
___ ○ ○ ○ ○ ○ ○ ○ ○
___ ○ ○ ○ ○ ○ ○ ○ ○
___ ○ ○ ○ ○ ○ ○ ○ ○
___ ○ ○ ○ ○ ○ ○ ○ ○
___ ○ ○ ○ ○ ○ ○ ○ ○
___ ○ ○ ○ ○ ○ ○ ○ ○
___ ○ ○ ○ ○ ○ ○ ○ ○

Letter	Binary Code
a	01100001
b	01100010
c	01100011
d	01100100
e	01100101
f	01100110
g	01100111
h	01101000
i	01101001
j	01101010
k	01101011
l	01101100
m	01101101

Letter	Binary Code
n	01101110
o	01101111
p	01110000
q	01110001
r	01110010
s	01110011
t	01110100
u	01110101
v	01110110
w	01110111
x	01111000
y	01111001
z	01111010

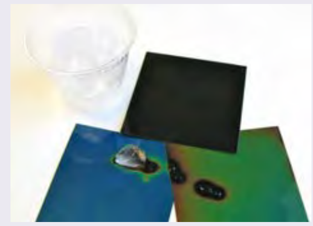
Upper case letters start with 010 (instead of 011).

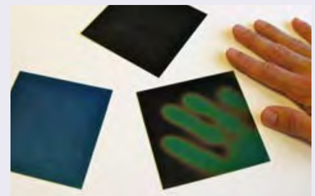
whatisnano.org

"My Name in Binary Code" take-home sheet
5.5 x 8.5 inches

Exploring Materials—
Liquid Crystal Displays

Try this!





1. Place your hand on the liquid crystal sheets. Can you see your handprint? Does it look the same on each sheet?

2. Place the cup of ice on each sheet. Does it leave the same color marks as your hand?

What's going on?

The liquid crystal sheets change color in response to changes in temperature. They can detect where your hand warmed up the sheet or the ice cooled it down. As the temperature increases, the color of the liquid crystals changes from red to orange, yellow, green, blue, and purple. Each sheet senses different range of temperatures.

Liquid crystals represent a phase in between liquid and solid. The molecules in a liquid crystal can move independently, as in a liquid, but remain somewhat organized, as in a crystal (solid).

Now try...

1. Remove the liquid crystal display (LCD) from a calculator.

2. Look closely at the front side of the plastic ribbon attached to the LCD. At the bottom edge, there is an exposed contact area with metallic stripes.

3. Place one of the wires from the battery snap connector on the exposed contact area. Slowly run the other wire along the rest of the contact area. What happens?

What's going on?

Parts of the display light up when you touch them with the wires from the battery. That's because the liquid crystals in the calculator display change color as a reaction to electricity (rather than temperature). The electric field changes the alignment of the liquid crystal molecules and affects the way that light passes through them, which makes them look black to your eyes.

Each thin metallic stripe on the ribbon directs electricity through a small region of the screen, allowing you to control which parts of the display turn black using the battery and wires. When the calculator is assembled, you direct the electricity by pressing the buttons.

Laptop with a
liquid crystal display

How is this nano?

The way a material behaves on the macroscale is affected by its structure on the nanoscale. Changes to a material's molecular structure are too small to see directly, but we can sometimes observe corresponding changes in a material's properties. The liquid crystals in this activity change color as a result of nanoscale shifts in the arrangement of their molecules.

Nanotechnology takes advantage of special properties at the nanoscale to create new materials and devices. Liquid crystals are used in cell phone displays, laptop computer screens, and strip thermometers. The same manufacturing equipment used for making LCDs may in the future be converted to make thin film solar cells.

Learning objectives

The way a material behaves on the macroscale is affected by its structure on the nanoscale.

The liquid crystals in this activity change color as a result of nanoscale shifts in the arrangement of their molecules.

Materials

- Assortment of liquid crystal sheets
- Calculator
- 9v battery
- Snap connector for 9v battery
- Cup of ice

Liquid crystal sheets are available from www.teachersource.com (#LC-ASTX, assortment with different transition temperatures).

The NanoDays physical kit comes with a calculator with the display already removed. To take apart your own calculator, see the instructions below, under "Notes to the presenter." Choose a calculator with a relatively large liquid crystal display. They're available at office supply stores and discount stores.

Snap connectors for 9v batteries are available from www.radioshack.com (#270-324).

Notes to the presenter

SAFETY: The face of the calculator display is glass. Handle it with care. Avoid letting visitors handle it.

Before doing this activity, fill the cup with ice. (If you don't have ice, you can use cool water or eliminate this part of the activity.

The three liquid crystal sheets are sensitive to different temperature ranges: 20°-25°C, 25°-30°C, and 30°-35°C. If you can't see a reaction on one of the sheets, try holding the liquid crystal against a cool surface and then warming it with your hands. (You can warm your hands by rubbing them together.)

The contact area for the liquid crystal display is at the bottom edge of the plastic strip attached to the screen. If you have trouble getting numbers to appear on the screen, be sure the battery wires are touching the exposed part of the display wires on the front side of the plastic ribbon. The exposed part has no coating over the metallic stripes. To get the display to work, the wires need to touch two different metallic stripes. For children and individuals with limited dexterity, you may demonstrate the application of electricity to the LCD.

Do not allow the battery wires to touch each other, as that will drain your battery. When you store the kit, remove the snap connector from the battery.

The display has already been removed from the calculator that is provided in the physical NanoDays kit. To remove the screen from a calculator yourself, use a small screwdriver to remove the screws in back of the calculator. Pull apart the front and back of the calculator case. Carefully lift up the display inside. Peel the plastic ribbon off the circuit board, keeping the ribbon attached to the display. To make it easier to peel off the ribbon, you can try warming it with a hair dryer.

Credits

This activity was adapted from "Disassembly of a Liquid Crystal Watch," developed by the National Science Foundation-supported Materials Research Science and Engineering Center (MRSEC) on Nanostructured Interfaces at the University of Wisconsin-Madison. The original activity is available at: http://mrsec.wisc.edu/Edetc/nanolab/watch/index.html

Image of liquid crystal courtesy Gary Koeing, University of Wisconsin-Madison. Diagram of LCD layers by Ed g2s, from Wikimedia Commons.

This project was supported by the National Science Foundation under Award No. 0940143. 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.

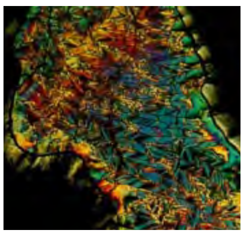
LCD Background Information

What are liquid crystals?

Liquid crystals represent a phase in between liquid and solid. The molecules can move independently, as in a liquid, but remain somewhat organized, as in a crystal (solid).

How do the liquid crystal sheets work?

The liquid crystal sheets used in this activity are *thermotropic*, which means that they respond to changes in temperature by changing color. As the temperature increases, the color of the liquid crystal changes from red to orange, yellow, green, blue, and purple.



Liquid crystal

Liquid crystal

Liquid crystals are made of mixtures of long, thin molecules stacked in rotating layers, like a spiral staircase. This shape is called a helix. When light strikes a liquid crystal, some of the light is reflected. As the temperature of the liquid crystal changes, the spacing of the *helix* changes. This changes the wavelength of light that is reflected and the color that you see.

How does the calculator display work?

The liquid crystal display (LCD) in the calculator has many layers:

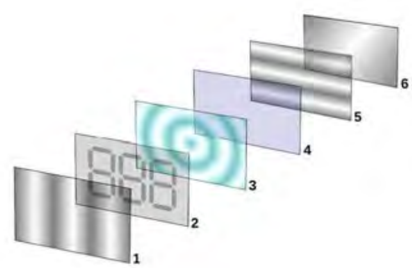
1. Glass plate with polarizing filter oriented vertically
2. Glass plate with electrodes to form the numbers
3. Liquid crystal material
4. Transparent conductive material
5. Glass plate with polarizing filter oriented horizontally
6. Reflective surface to send light back to the viewer

Light passing through the first polarizing filter (1) becomes *polarized*, which means that the light waves are oscillating in one direction only. Polarized light cannot go through the second polarizing filter that is perpendicular to the first (5), because the light waves are not oscillating in the correct direction.

The liquid crystal molecules located between the two polarizing filters (3) are oriented to rotate the polarized light coming through the first filter by 90 degrees so that the light can pass through the second filter. The light is rotated just a little with each step along the liquid crystal helix until it reaches the other filter in the correct orientation.

When electricity is applied to specific regions of the display (2), the liquid crystal molecules line up with the electric field. This disrupts the helical alignment, so the liquid crystal can't rotate the light.

When no electricity is applied, light travels through both polarizing filters, reflects off the mirror (6), and comes back to your eye. When electricity is applied to certain areas of the display, light passes through one filter but not the other, so that part of the screen is black.



How are liquid crystals used?

The properties of liquid crystals make them useful for many applications. Because the color of a liquid crystal depends on the alignment of its molecules, anything that disrupts that alignment can be detected by a color change.

Liquid crystals are used in displays for cell phones, laptop computers, and other electronics. In these displays, an electric field changes the alignment of the liquid crystal molecules and affects the polarization of light passing through them. Liquid crystal nanosensors can detect certain chemicals, electrical fields, and changes in temperature.

Exploring Materials—

Oobleck

Try this!

1. Move the Oobleck around in the plastic bag.

2. Now, try tapping or squeezing the Oobleck. What do you think, is it a solid or a liquid?

What's going on?

When you quickly apply a lot of pressure to Oobleck, like tapping or squeezing, it firms up like a solid. When no pressure is applied, it flows like a liquid. Oobleck is actually a simple mixture made of corn starch and water that has some very surprising properties.

Oobleck is one of many materials called non-Newtonian fluids. Non-Newtonian fluids are fluids that do not follow Newton's 3rd law of motion, "Every action has an equal and opposite reaction." For example, most fluids move faster when they are pushed harder. Oobleck moves slower when more force or pressure is applied. Some other non-Newtonian fluids are ketchup, toothpaste, and paint. In a regular Newtonian fluid, viscosity (resistance to motion) is a constant and only changes if the temperature is changed. Oobleck responds to how fast and how hard a force is applied. Pressure affects Oobleck's viscosity because it changes the way the cornstarch and water interact. When you slowly stir the Oobleck it behaves like a liquid. The same force applied quickly makes it act more like a solid.

Now try...

1. Place a plastic egg into a small bag, and then put that bag into one of the large bags of Oobleck.

2. Hold the large bag and an unprotected plastic egg about 2.5 feet (or roughly chest height) off the ground.

3. At the same time, drop the bag and the egg. What happens?

What's going on?

The Oobleck protects the egg. When it hits the ground, a quick direct force is applied to the Oobleck.

Oobleck experiment

The cornstarch clumps together and hardens like a solid, absorbing the impact and protecting the plastic egg. The Oobleck quickly goes back to acting like a liquid. Researchers are using sheer-thickening fluids (STFs) that behave a lot like Oobleck to make new gels and fabrics. These fabrics are flexible and comfortable when no force is applied, but when struck quickly they harden and provide solid protection.

How is this nano?

The way a material behaves on the macroscale is affected by its structure on the nanoscale. Changes to a material's molecular structure are too small to see directly, but we can sometimes observe corresponding changes in a material's properties.

Nanotechnology takes advantage of properties at the nanoscale to create new materials. Fabrics made with sheer-thickening fluids (STFs) that contain nano-sized particles are used in a variety of technologies, from flexible body armor to protective (and fashionable) winter hats.

STFs make a winter hat more like a helmet

Learning Objectives

The way a material behaves on the macroscale is affected by its structure on the nanoscale.

Nanotechnology takes advantage of special properties at the nanoscale to create new materials.

Materials

- Oobleck
- 2 Large plastic bags
- Small plastic bag
- 2 Plastic eggs
- "Liquid Body Armor" image sheet

Notes to the presenter

Before doing this activity, prepare the Oobleck in each large bag:

- 1 cup cornstarch
- Half a cup water
- 2-3 drops food coloring (optional)

Mix until you reach the desired consistency. You may need to adjust the amount of water. The Oobleck solution should harden when pressure is applied, but otherwise will flow like a liquid. Prepare two bags of Oobleck, one for handling and one for the egg drop experiment. Be sure to not get the mixture in the bag's zipper as it can prevent the bag from sealing. The Oobleck can be mixed in a bowl and then poured into the bag or mixed directly in the bag. To mix in the plastic bag allow some air in the bag and tilt the mixture from side to side.

SAFETY: Although nontoxic, visitors should be careful handling these materials. Visitors should not consume the Oobleck.

Tips: Perform the egg drop experiment on a hard surface. If done on carpet, the unprotected egg may not break. If the unprotected egg does not break on the first try, repeat the experiment from a higher starting point. Also, try to orient the eggs so they land on their sides. They tend to break more reliably if the seam hits the ground.

Cleanup: If visitors do get messy with the Oobleck, advise them to dunk their hands into a tub of water before washing in a sink. Empty all Oobleck directly into the trashcan, NOT the sink. Oobleck can clog a sink if too much is put down the drain. If saved for more than a few days Oobleck can begin to smell, so throw it out promptly.

Name: Oobleck gets its name from the Dr. Seuss book *Bartholomew and the Oobleck* where a gooey green substance, Oobleck, fell from the sky and wreaked havoc in the kingdom.

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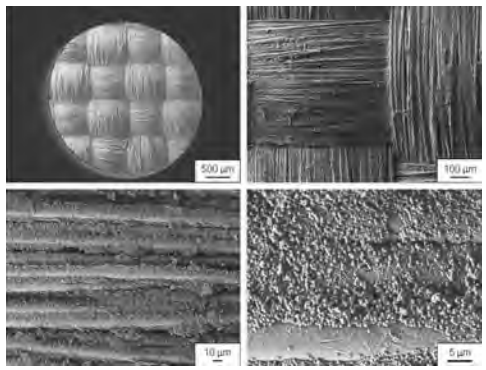
Liquid Body Armor

Researchers at the University of Delaware and the U.S. Army Research Laboratory have developed a new material called Liquid Body Armor. Liquid Body Armor is created by saturating traditional Kevlar, a protective fabric commonly used by police officers and soldiers, with a special sheer thickening fluid of nano-sized silica particles suspended in polyethylene glycol. Sheer thickening fluids (STFs) display non-Newtonian behavior, similar to Oobleck. In a liquid state, the tiny silica particles stay evenly separated in the mixture due to a weak molecular repulsion. If the saturated Kevlar is forcefully hit or punctured, the energy of the sudden impact overrides the molecular repulsion and forces the particles into small groups called hydroclusters. The hardening process occurs in milliseconds, but once the force is removed the material returns to its original flexibility. Still in the experimental phase, STF-treated fabric could replace military flak jackets or be used for prison guard uniforms. Other companies are also using STF-treated fabrics to make personal protective equipment such as ski hats, football pads, point shoes, and motorcycle jackets.



Scanning Electron Microscope image of STF treated Kevlar

“Liquid Body Armor” image sheet
11 x 8.5 inches

Credits

STF treated Kevlar images courtesy of Norman J. Wagner, University of Delaware.

This activity was adapted from Liquid Body Armor, developed by the Children’s Museum of Houston for the NISE Network. The original program is available at: www.nisenet.org/catalog.

This project was supported by the National Science Foundation under Award No. 0940143. 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.

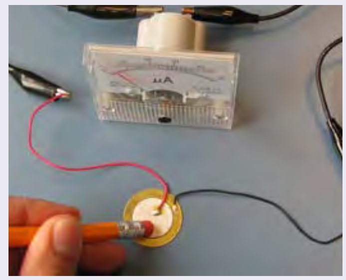
Exploring Properties—
Electric Squeeze

Try this!

1. Attach the piezo disk (gold-colored disk) to the ammeter and tap on the disk with a pencil eraser.

2. What happens to the ammeter?

3. Now, attach the piezo buzzer to the battery pack. What happens?



What's going on?

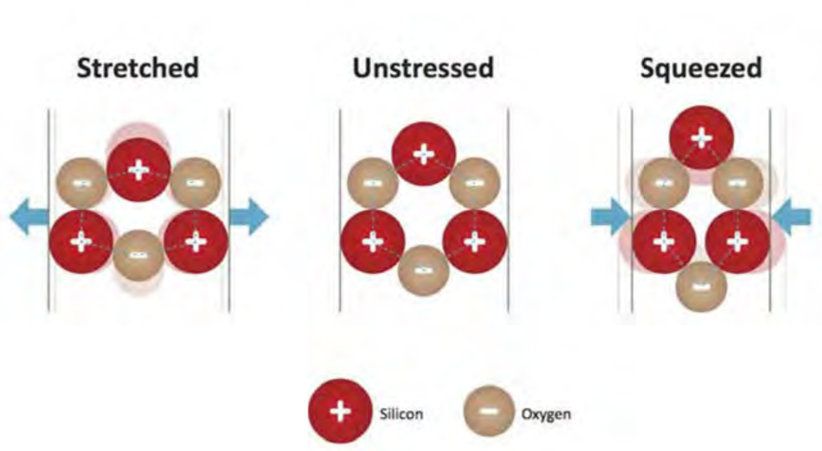
Both the disk and the speaker are made with a special piezo ceramic material. When this ceramic is hit, or squeezed, it produces electricity. The ammeter, which measures electric current flowing through a circuit, allows us to detect this. When a pulse of electricity runs through the ceramic it produces vibrations—by squeezing it together and stretching it out. This vibration creates sound in the speaker. We call this reversible process the *piezoelectric effect.*

Piezoelectric materials produce electricity when they change their shape (by being stretched or squeezed) and they change their shape (by stretching or squeezing) when electricity is run through them.

Scientists are able to make piezoelectric ceramics and polymers. Naturally occurring piezoelectric materials include topaz and quartz.

How is this nano?

The way a material behaves on the macroscale is affected by its structure on the nanoscale. When you squeeze a piezoelectric crystal, the length of the crystal may only change a few nanometers, or even less (a nanometer is a billionth of a meter), but that small change is enough to make the material generate electricity.



Piezoelectric effect in quartz

Piezoelectric materials are now used in a wide range of products, from speakers and microphones to sensors and switches. Some companies, like Pavegen Systems in the UK, are using piezoelectric materials in floor tiles. When people walk on these tiles the compression they cause is converted into electricity. Can you imagine other ways to make electricity through movement?

Floor tiles generate electricity by walking on them

Learning objectives

The way a material behaves on the macroscale is affected by its structure on the nanoscale.

Nanotechnology takes advantage of special properties at the nanoscale to create new materials.

Materials

- Piezoelectric disc with leads
- Ammeter
- Alligator clips
- Pencil with eraser
- Piezoelectric buzzer with leads
- Battery holder for 2 AA batteries
- 2 AA Batteries
- "Piezoelectric Effect" image sheet

The piezoelectric disk is somewhat fragile so we recommend tapping on it with a pencil eraser, but visitors can use their fingers as well.

If you find the buzzer to be too loud, you can place a piece of transparent tape over the hole. This will dampen the sound slightly.

Credits

Image of piezoelectric tiles courtesy of Pavegen Systems.

This project was supported by the National Science Foundation under Award No. 0940143. 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.

Additional Graphic Resources

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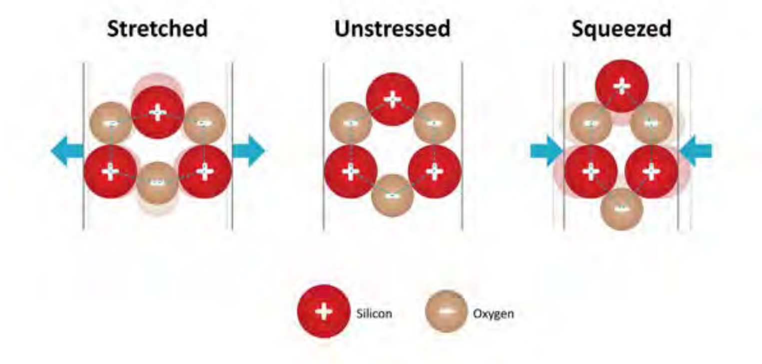
Piezoelectric Effect

Piezoelectric materials can turn mechanical stress into electricity, and electricity into mechanical vibrations. Quartz is an example of a naturally occurring piezoelectric crystal. Quartz crystals are made of silicon and oxygen atoms in a repeating pattern. In quartz, the silicon atoms have a positive charge and oxygen atoms have a negative charge. Normally, when the crystal is not under any external stress, the charges are dispersed evenly in the molecules throughout the crystal. But when quartz is stretched or squeezed, the arrangement of the atoms changes slightly. This change causes negative charges to build up on one side and positive charges to build up on the opposite side. When you make a circuit that connects one end of the crystal to the other you can use this potential difference to produce current. The more you squeeze the crystal the stronger the electric current will be. Conversely, sending an electric current though the crystal changes its shape.



"Piezoelectric Effect" image sheet
11 x 8.5 inches

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Using a multimeter with Exploring Properties—Electric Squeeze

What is a multimeter?

A **multimeter** is a device that can measure current, voltage, and resistance in electrical circuits. Your multimeter comes with a red and black wire. These wires are called **test probes** or **leads**. Plug the black probe into the COM port and the red probe into the port labeled VΩMA.

In the Exploring Properties—Electric Squeeze activity a multimeter can be used in place of the analog ammeter. Use the alligator clips to connect the piezo disk to the multimeter test probes. When the piezo disk is hit or squeezed, the multimeter will measure the electric current produced.

What setting should the multimeter be on?

For the Exploring Properties—Electric Squeeze activity, you'll need to measure current in microamps (μA). The dial should be on the 200μA setting. This range is sensitive enough for the multimeter to measure the small amount of current generated by hitting the piezo disk.

How to care for your multimeter

Always **turn off the multimeter** when not in use to conserve battery life.

If the battery in your multimeter dies, you'll need a small screwdriver and an A23 battery. Remove the screws from the back of the case and replace the old battery.

"Using a Multimeter" reference sheet
8.5 x 11 inches

Exploring Materials—
Polarizers

Try this!

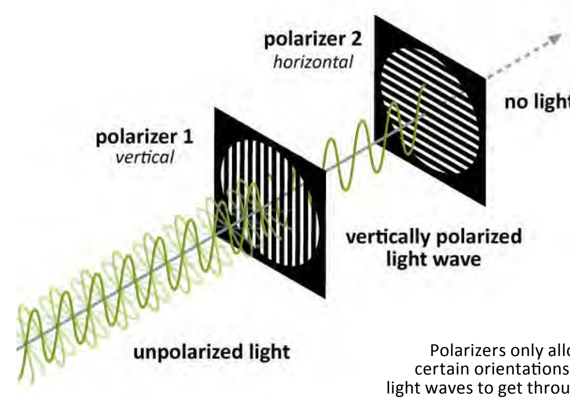
1. Use strips of transparent tape to make designs on a clear plastic sheet. Put down lots of overlapping pieces of tape!

2. Place your design between two polarizing filters and hold everything up to a diffuse light source—a window during daylight or an overhead light.

3. Try rotating one of the filters. What happens to your design?

What's going on?

Polarizing filters block light. The light they block depends on the polarizer's orientation. When two polarizers are rotated the same way, most of the light gets through. When they're rotated 90 degrees to each other, the filters block all the light waves, and are known as "crossed polarizers."



Polarizers only allow certain orientations of light waves to get through

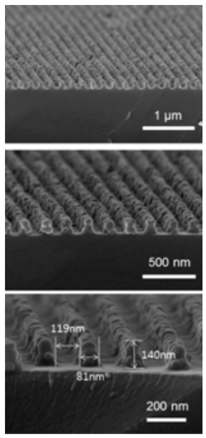
Certain materials like mica, Plexiglas®, corn syrup, and transparent tape exhibit beautiful colors when placed between two crossed polarizers. These materials produce colors because they are *birefringent*. In birefringent materials, light passes through the material at different speeds.

The transparent tape interacts with polarized light in a special way because of the structure of the tape. The tape consists of long polymer molecules that are stretched along the length of the tape. As a result, light moves through the tape at different speeds, depending on whether it's oriented parallel or perpendicular to these long polymer molecules. Once the light makes it through the tape, the light components that were moving quickly recombine with the ones that were moving more slowly, producing waves with new properties. The second polarizing filter blocks most of these waves, which filters the white light and produces the different colors we see. The color of the tape is determined by the direction the light moves and the thickness of the tape. So we can produce different colors by placing the tape at different angles or by stacking pieces of tape on top of each other.

How is this nano?

The way a material behaves on the macroscale is affected by its structure on the nanoscale. Researchers are studying ways to make polarizers out of aligned metal nanowires. The nanowires they use are less than 100 nm wide, much too small for us to see with our eyes! In these nanowire grid polarizers (NWGPs), light that is oriented parallel to the NWGP interacts with the metal wires and is reflected from the surface. However, light perpendicular to the wires transmits through.

NWGPs show a lot of promise and have many advantages over more conventional polarizers. For example, NWGPs are more compact and have wide viewing angles, making excellent polarizers. However, like many new technologies, there are still manufacturing and performance challenges that engineers must solve before these polarizers can become widely used.



Nanowire Grid Polarizers (NWGPs)

Learning objectives

The way a material behaves on the macroscale is affected by its structure on the nanoscale.

Nanotechnology takes advantage of special properties at the nanoscale to improve existing materials.

Materials

- Polarizing filters (2) in cardboard holders
- Overhead transparency sheets
- Transparent tape
- Diffuse light source (a window during daylight hours or an overhead light)
- "How polarizers block light" image sheet

Polarizing filters are available at www.teachersource.com (Item # PF-4).

Transparent tape can be found at office supply stores such as www.staples.com (Item # 609009).

Be sure to use "transparent" tape, not "invisible" or "magic" tape. It should have a clear, non-matte finish. Test the tape before you try this with visitors to ensure that it works for this activity.

Notes to the presenter

SAFETY NOTE: Visitors should not be looking at direct sunlight. If you are doing this activity outside or near a window, be careful not to ask visitors to look directly into the sun.

Ask visitors to hold the polarizers by the holders to avoid fingerprints on the polarizers.

Visitors can take home the clear plastic sheets with tape on them, but not the polarizing filters. Since visitors will not be allowed to take the polarizing filters with them, you can suggest one way that they can continue their experimenting at home using a computer screen and some polarized sunglasses. Filters inside the screen polarize the light coming out of the computer and the sunglasses act as the second filter. They can also look at materials such as plastic silverware, plastic wrap, or other molded clear plastics by placing them in front of the computer screen and looking through the sunglasses.

Credits

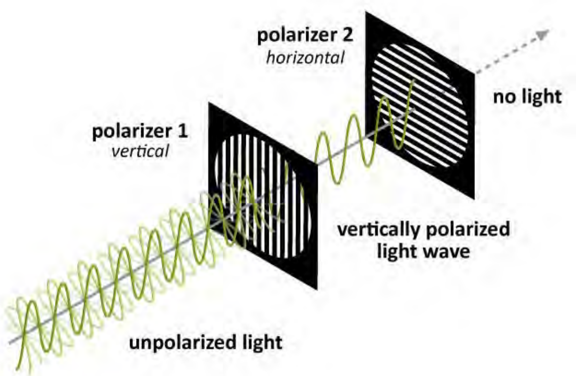
Image of Nanowire Grid Polarizer courtesy Kyung S. Park, Hanyang University, Seoul, Korea.

This project was supported by the National Science Foundation under Award No. 0940143 and 0937591. 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.

Polarization Background Information

How do polarizers work?

To understand how polarizers work, we need to think about light behaving like a wave. Every light wave has a particular orientation. Most light sources, like light bulbs or the sun, produce light waves oriented in all directions. We call this type of light randomly polarized light, meaning it doesn't have a preferred orientation. A polarizer affects light by blocking certain orientations of light. Once light goes through, it is plane polarized, meaning that all of the light waves are now parallel to each other.

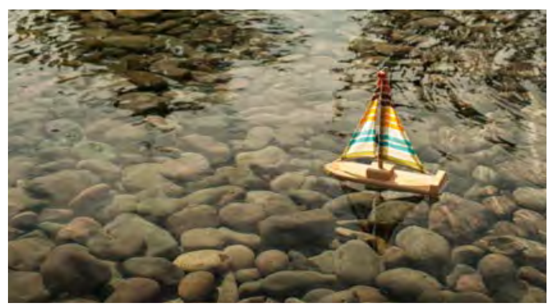


When you look through two (or more) polarizer films, the brightness depends on how the polarizer films are aligned. So when you rotate the polarizer films, the brightness changes. When you have two polarizers that are aligned parallel to each other, the light that makes it through the first polarizer will make it through the second polarizer. Parallel polarizers like this let the most light through and look the brightest. Conversely, when you have two polarizers that are perpendicular to each other, the light that makes it through the first polarizer is oriented perpendicular to the second polarizer, so it will be blocked. Polarizers that are perpendicular to each other, called crossed polarizers, let the least light through and look the darkest. The quality of a polarizer is often measured by the difference in brightness between the brightest (parallel) and darkest (perpendicular) orientations.

How are polarizers made?

Polarizers are made in many ways. One of the most common polarizers is known as a Polaroid and consists of iodine crystals embedded in a polymer. To create the polarizer, the polymer film is stretched, which causes the polymers to align. Then the film is dipped in a solution of iodine and the iodine molecules attach themselves to the polymer. The Polaroid's ordered structure allows it to absorb light that is parallel to the polymer chains and transmit light that is perpendicular to the chains. Researchers are trying to create even better polarizers using aligned nanowires instead of iodine-coated polymer chains.

Without polarized lens



With polarized lens

Where do we use polarizers?

Polarizers are all around us! We use polarizers in liquid crystal displays, in telescopes, and in sunglasses. Polarized sunglasses are especially helpful when we're looking at water or snow, because the glare from these surfaces is extremely polarized. Polarizers can very efficiently reduce the glare. Polarizers are even used in some of the glasses worn to make 3D movies come to life.

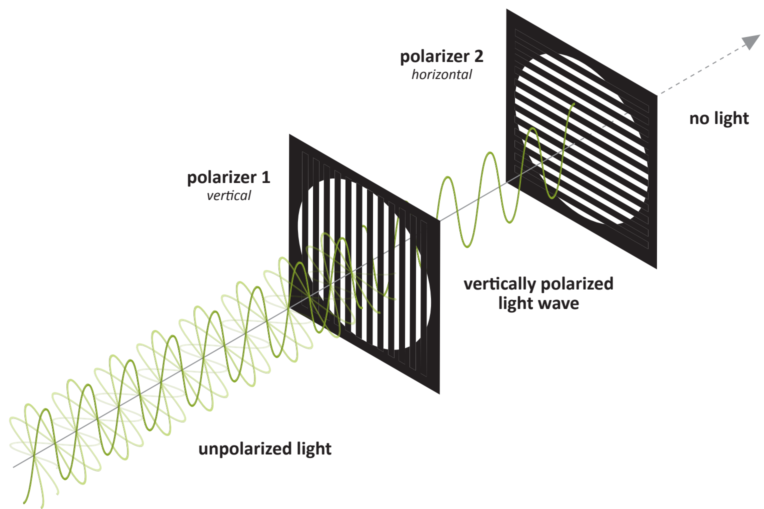
Additional Graphic Resources

NanoDays
The Biggest Event for the Smallest Science!

How polarizers block light

Most light sources, like light bulbs or the sun, produce light waves that are oriented in all different directions. Polarizers work by blocking certain orientations of light. Once light goes through a polarizer, it is *plane polarized*, meaning that all of the light waves passing through are parallel to each other.

When you look through two (or more) polarizers, the brightness depends on how the polarizers are aligned. So when you rotate the polarizers, the brightness changes. When two polarizers are aligned parallel to each other, the light that makes it through the first polarizer will make it through the second polarizer. Parallel polarizers like this let the most light through and look the brightest. Conversely, when two polarizers are perpendicular to each other, the light that makes it through the first polarizer is oriented perpendicular to the second polarizer, so it will be blocked. Polarizers that are fully perpendicular to each other are called *crossed polarizers*, let the least light through, and look the darkest.



"How polarizers block light" image sheet
8.5 x 11 inches

Exploring Products—

Kinetic Sand

Try this!

1. Play with the sand in both trays. Poke it. Pick it up. Let it fall slowly from your fingers. What happens? What do you notice about these different sands?

2. Use the tools to make small sand sculptures. Do your sculptures hold their shapes? What happens if you leave them alone for a little while? How do the two sands behave differently?

What's going on?

One of the sands (the Kinetic Sand™) has been coated with a thin polymer layer. The polymer layer is so tiny that an individual grain of sand looks and feels just like regular sand, but a container of it behaves very differently! The polymer coating that gives the Kinetic Sand these unique properties is polydimethylsiloxane (PDMS).

The PDMS coating makes the Kinetic Sand behave more like wet sand. You can sculpt and build with it, but over time, Kinetic Sand creations flow apart and the sand moves in some interesting and surprising ways. We think this odd behavior happens because the polymer coating makes the sand stick to itself. So as a grain of sand moves—even a little—it pulls other grains along with it.

PDMS isn't just used in Kinetic Sand—it's used in many commercial products, including water repellants, lubricating oils, and even anti-gas drops for babies!

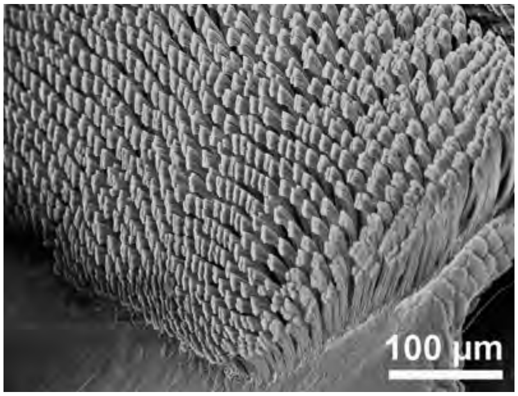
How is this nano?

The way a material behaves on the macroscale is affected by its structure on the nanoscale. You can't see or feel the nano-layer of PDMS on the sand because it's so thin, but you can observe that the Kinetic Sand behaves differently from ordinary sand.

Polymers are important in nanoscale research. For example, scientists at the University of Massachusetts Amherst have used PDMS, as well as other soft polymers, to make a material known as Geckskin™.

The amazing, sticky properties of Geckskin were inspired by real geckos in nature. Geckos are able to walk on walls and cling to ceilings because of the tiny nano-sized hairs on their feet. Geckskin mimics these tiny hairs. Geckos must also be able to lift their toes up and put them back down. Strong tendons in their feet allow them to do this. Geckskin also uses strong stiff, fabrics that act as synthetic tendons to pull on the soft polymer.

Scientists and engineers often try to mimic nature when they're developing new products—we call this *biomimicry*. Biomimicry is especially important in nanotechnology, where engineers are using it to create new electronic displays, drugs, tiny robots, and protective coatings.



Gecko toes have tiny nano-sized hairs that allow them to walk on walls and cling to ceilings

Learning objectives

The way a material behaves on the macroscale is affected by its structure on the nanoscale.

Nanotechnology takes advantage of special properties at the nanoscale to create new materials.

Materials

- Play sand
- Kinetic Sand™
- 2 trays
- Sand toys

Kinetic Sand is available from Waba Fun, www.wabafun.com.
Play sand is available through home improvement stores, such as Lowe's, www.lowes.com.

Notes to the presenter

Kinetic Sand was originally developed by a Sweden-based arts and crafts company called Delta of Sweden. The process for making this product is proprietary. We know that the special sand is coated with a nano-thin layer of polydimethylsiloxane (PDMS), but we don't know the exact recipe or procedure.

Before beginning this activity, fill one of the two trays with play sand and the other with Kinetic Sand. You can reuse the Kinetic Sand and the play sand when the activity is over, just carefully transfer them into storage containers or plastic bags. When visitors are playing with the sand, and during cleanup, minimize cross-contamination between the two sands!

Important: Don't let the Kinetic Sand get wet! It won't ruin the sand, but it will change its properties. If it does get wet, just be sure to leave it out to dry.

Credits

Image of Geckskin courtesy of A. Crosby and D. Irschick, University of Massachusetts Amherst.

This project was supported by the National Science Foundation under Award No. 0940143. 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.

Exploring Products—

Nano Food

Try this!

1. Roll the large cube of connected blocks into the tray.

2. Count how many squares the cube is touching.

3. Now take the cube apart and re-roll the eight small blocks in the tray.

4. Count how many squares the blocks are touching. How does this compare with the number of squares the large cube touched?

What's going on?

We taste things when they come into contact with the taste buds on our tongues. In this demo, the cube and blocks represent salt crystals, the playing surface represents your tongue, and the squares represent your taste buds. Even though there is the same total amount of "salt" in both cases, the smaller "crystals" (the broken-apart blocks) cover more area and touch more "taste buds."

Some food scientists believe we can use much less salt but still get the same taste and experience just by using smaller crystals. So nano-sized salt crystals might help us make foods like potato chips lower in sodium and healthier—but with the same big flavor!

How is this nano?

Nanotechnologies may improve existing products. Nano-sized particles are already being used in many foods, both natural and processed. Mayonnaise, for example, is created by dispersing nanometer-sized globules of fat in water.

Salt crystals

Researchers are devising new ways to manipulate food on the nanoscale in order to create specific tastes and properties. By controlling the size and structure of salt, fat, and sugar, food scientists can create healthier food that still has yummy tastes and textures.

While nano-sized particles of salts, fats, or sugars are thought to be safe—since the body will metabolize them in the same way as larger particles—the same may not be true for other foods. As a result, more research may be needed on the long-term impact of nano-sized ingredients that aren't traditionally eaten but are finding their way into our foods, such as silver, titanium and silica.

Learning objective

Nanotechnologies may improve existing products.

Materials

- Tray with "Tongue Cutout" taped to the inside
- Snap cubes (16)

Snap cubes are available through education supply stores, such as www.learningresources.com (Item # LER 7586).

Tongue image can be downloaded from www.nisenet.org.

Notes to the presenter

SAFETY NOTE: Do not allow visitors to put the snap cubes in their mouths as they pose a potential choking hazard.

Each time you begin the activity with a different visitor group, piece together eight of the snap cubes to create a large cube. Encourage visitors to count every little black square that a block touches (even partially) when they're comparing the large cube with the broken-apart blocks.

You can use this activity to further explore conversations about how nanotechnology is being used in food and food production. Nano-sized salt crystals are just one example of how nanotechnology may change our food. There are also new techniques that reduce fat content but maintain taste and texture. For example, one chocolate shake product uses silica nanoparticles coated in cocoa instead of solid pieces of cocoa, and some mayonnaises use nano-sized water droplets coated in fat instead of solid droplets of fat.

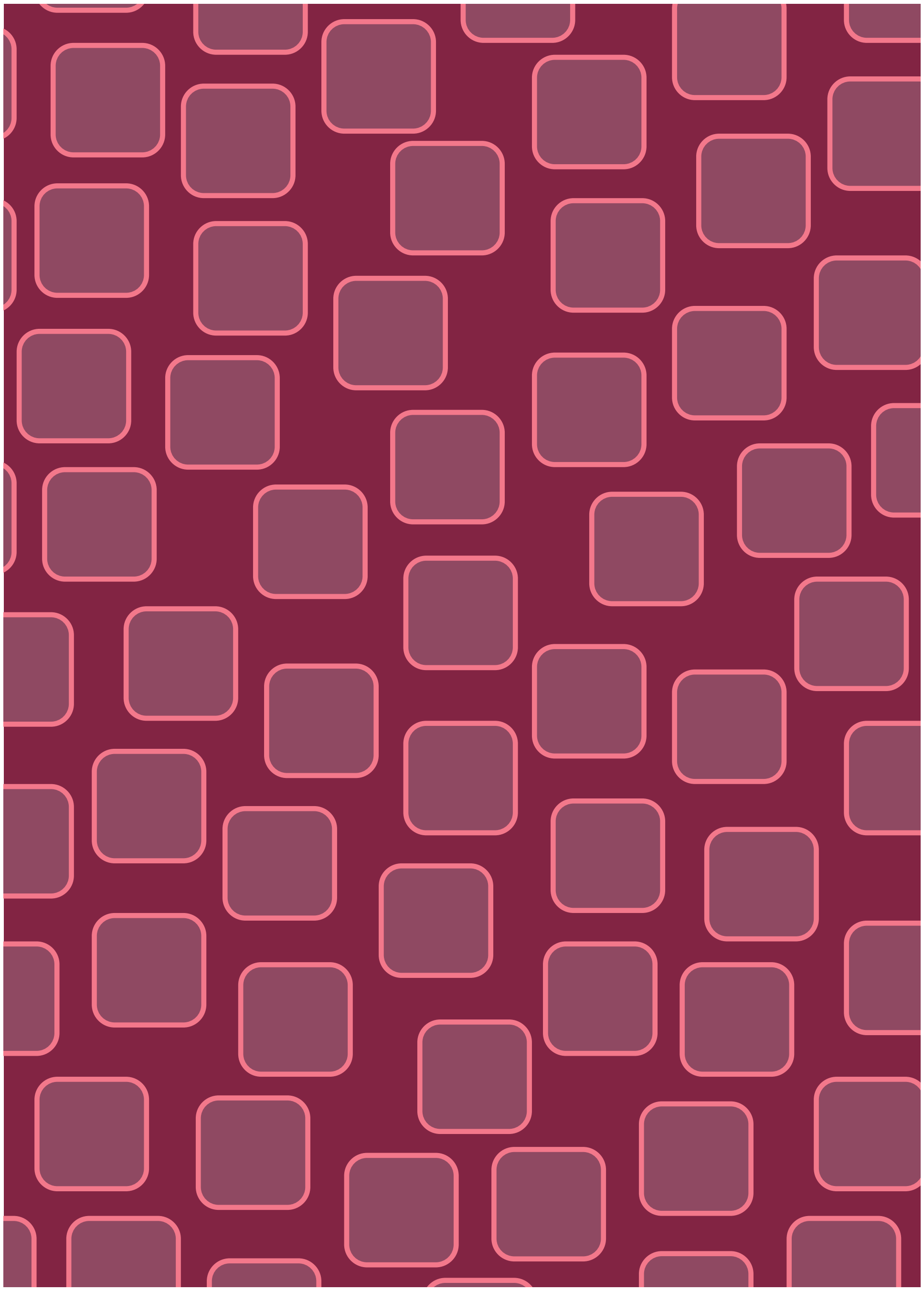
Nanotechnology is also used in food packaging. Nano-thin wax-like coatings can be used on fruit and vegetables to keep them fresher longer. Nanosilver is currently used in some food storage containers because it has powerful antimicrobial properties. And some plastic bottles have nano-particles of clay in them to keep oxygen from getting through the plastic.

Credits

Salt crystal image by John Hunt, Cornell Center for Materials Research, with support from NSF Award No. DMR-1120296.

This project was supported by the National Science Foundation under Award No. 0940143 and 0937591. 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.

Additional Graphic Resources



“Tongue Cutout”
5 x 7 inches


Gary Hodges

SECTION 5

Nano is part of our society and our future

Nanotechnologies have costs, risks, and benefits that affect our lives in ways we cannot always predict.

Nanotechnology will affect our economy, environment, and personal lives.

Some scientists think that nanotechnology could transform our lives just as much as cars or computers! As individuals and communities, we'll need to balance the costs, risks, and benefits of different nanotechnologies. Citizens, scientists, government agencies, and companies can work together to maximize the benefits of nanotechnology and minimize the risks.

HEALTH AND BEAUTY PRODUCTS

Certain shampoos, cosmetics, toothpaste, and other personal care products contain nanotechnology.

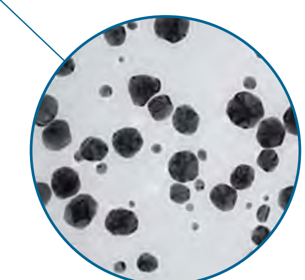
For example, many sunblocks contain nanoparticles of zinc oxide and titanium dioxide. Cosmetic products aren't regulated by the Food and Drug Administration (FDA), and their labels don't have to indicate if they contain nanoparticles. This concerns some advocates for consumers and the environment.

Materials can act differently when they're nanoscale, so an ingredient that's safe on the microscale isn't necessarily safe on the nanoscale.

NANOSILVER Nanosilver is one of the most common nanomaterials found in consumer products today. Silver is naturally antimicrobial, and nanoscale particles of silver are especially effective at killing germs. Bandages, washing machines, cutting boards, doorknobs, and even socks can contain nanosilver.

There are tradeoffs to using nanosilver products, and many people feel differently depending on the product. Nanosilver equipment in hospitals can help prevent dangerous infections, but overuse of nanosilver could lead to highly bacteria-resistant "superbugs." Nanosilver socks can keep feet from smelling, but their washwater could contaminate water supplies, harming fish and other wildlife.

Antibacterial silver nanoparticles

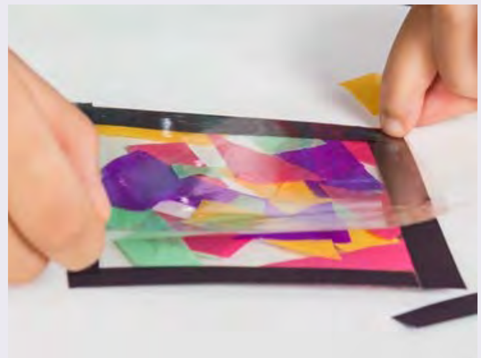


Everyone has a role in shaping nanotechnology. Companies and governments decide which technologies to invest in and how to regulate them. Individuals can help shape nano research and development by deciding whether to use products containing nanotechnology. As we develop and use new nanomaterials and technologies, we need to consider how to do so in a way that's equitable and responsible.

Exploring Materials—

Stained-Glass Windows

Try this!



1. Peel the backing off of one piece of contact paper.

2. Place pieces of colored tissue paper on the exposed adhesive side to create a design. Use the black construction paper strips to create a border.

3. Peel the backing off the other piece of contact paper and stick both adhesive sides together. Trim your artwork. You can even cut out a special shape.

4. Now hold your design up to the light or window. What do you notice?

What's going on?

In your artwork, the different pieces of tissue paper have different colors because they contain different dyes. These dyes were added to the paper pulp during the paper production process.

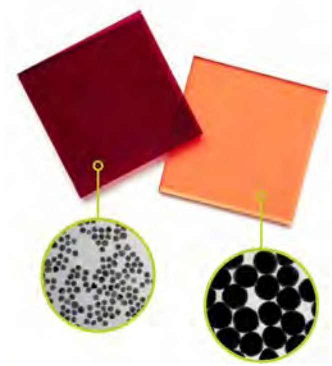
Now, take a look at the samples of real stained glass. Large pieces of gold usually look golden and metallic, but when gold gets very small its color can change because it interacts differently with light. The red glass contains gold nanoparticles around 30 nanometers across, while the orange glass contains gold nanoparticles around 90 nanometers across.

Nano-sized gold and other metals have been used to color stained glass since the Middle Ages. Different materials produce different colors. For example, the yellow-colored stains can come from nano-sized silver particles.

How is this nano?

Medieval stained-glass windows are an early example of nanotechnology. The artists didn't know it at the time, but **a material can act differently when it's nanometer-sized.** (A nanometer is a billionth of a meter.)

Many nano materials behave differently as they change size. This seems odd because it doesn't happen at the macroscale. For example, we can't change the flavor of ice cream just by changing the scoop size. No matter what the size, vanilla ice cream always tastes like vanilla ice cream. A big scoop of vanilla ice cream and a small scoop still taste the same. But at the nanoscale, properties can change when the size changes. For example, as particles of gold get smaller, their color changes. This is like the flavor suddenly changing from vanilla to chocolate, just because the scoop got smaller!



Changing the size and shape of gold nanoparticles changes their color

Learning objective

A material can act differently when it's nanometer-sized.

Materials

- Samples of nano gold stained glass (2)
- Sample of gold flakes
- Precut pieces of clear contact paper
- Small pieces of multicolored tissue paper
- Precut strips of black construction paper
- Scissors
- "Stained-glass Art" image sheet

Gold flakes are available from www.amazon.com.

Stained glass samples made with gold are available from www.bullseyeglass.com (red #001311 and light orange #001823.)

Notes to the presenter

SAFETY NOTE: Take care using scissors with small children.

Before you begin:

- Have small pieces of multicolored tissue paper available.
- Precut the contact paper to the desired size and cut strips of black construction paper for the borders.

Peeling off the backing of the contact paper can be challenging. Sometimes it is hard to get the peel started. One tip is to bend and crease one of the corners. This sometimes helps to get the peeling started. During slow times, or before the activity begins, you may want to peel the corner of the backing off some pieces of contact paper to aid visitors who might have difficulty doing it themselves.

Credits

This activity was adapted by the Children's Museum of Houston from NISE Network's Exploring Materials—Nano Gold. The original activity is available at: www.nisenet.org

Image of nano gold particles courtesy of nanoComposix. Image of different stained-glass squares by Emily Maletz. Image of stained glass, www.istockphoto.com. Images of stained-glass art, commons.wikimedia.org

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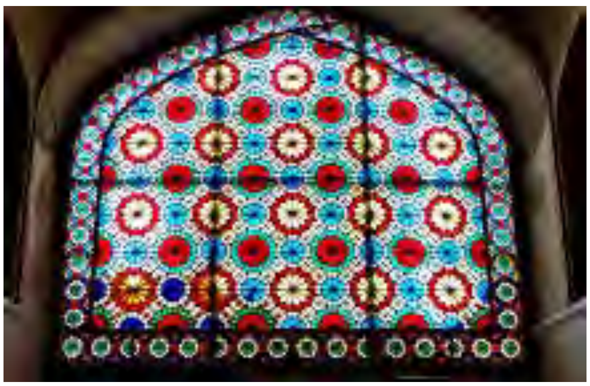
NanoDays
The Biggest Event for the Smallest Science!

Stained-glass Art

Nano-sized gold and other metals have been used to color stained glass since the Middle Ages. Although traditionally made in flat panels and used in windows (often in culturally or religiously important buildings), modern stained-glass artists also create abstract panes, structures, and sculptures.



Stained-glass window in a mosque, Yazd, Iran

Modern stained-glass art, Corning Museum of Glass, Corning, NY

DragonFly TV video clip on the process of making stained-glass:
http://www.youtube.com/watch?v=kaRLAbiF-VQ

"Stained-glass Art" image sheet
11 x 8.5 inches

Exploring Nano & Society—Space Elevator

Try this!

1. What if it were possible to take an elevator into space? Imagine what our world would be like.

2. Draw a picture of the future world you're imagining. What would we need in space? What kinds of plans would we have to make?

Think about it...

How would the space elevator work? What would power it?

Who would get to use the space elevator? Where would you get on?

When you got up in space, what would be there? What would you need to bring with you?

What's going on?

It's fun to imagine what our lives might be like in the future—and it's also important. We have the things we do today because in the past, people thought about the kind of world they wanted and invented technologies to help make their dreams real.

Researchers really are working on creating a space elevator, including scientists at NASA and Google. They think that new materials like carbon nanotubes will make this technology possible.

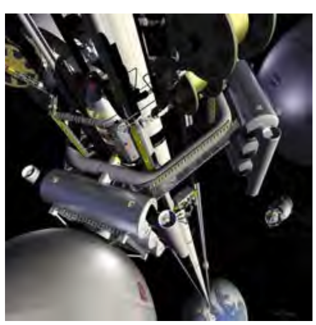


Illustration of a space elevator by NASA

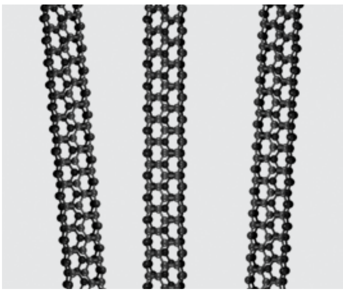
If these scientists are successful, someday it might be cheap and easy to bring people and materials into space. And if it were possible for ordinary people to go into space, that could mean big changes to our lives.

We all need to think about the kind of world we want in the future, and begin planning for it. Do you think exploring and developing space is important? If so, what kind of society should we create there? Or do you think we should spend our time and money on something else, instead of a space elevator?

How is this nano?

Technologies and society influence each other. People's values shape how nanotechnologies are developed and adopted.

Researchers think about the future world they would like to live in when they create new technologies. And when people decide to use new technologies, those technologies can change their lives in ways that are big and small.



Carbon nanotubes

New nanomaterials are making new technologies possible. For example, super strong, lightweight carbon nanotubes might allow us to make a cable that can support a space elevator. The space elevator is an old dream—people have been imagining the possibilities of taking an elevator into space since at least 1895!

Learning objectives

Technologies and society influence each other.

People's values shape how nanotechnologies are developed and adopted.

Materials

- Large sheets of paper
- Markers
- "Space Elevators" sheet

Notes to the presenter

This activity is designed as an open-ended, conversational experience. Some visitors (such as adults) may prefer to talk about their ideas, rather than draw them.

You can use the "Think about it" questions to get visitors started. Once they've begun, you can ask them to explain what they're drawing, and ask questions to help them think about the kinds of technologies and systems they'd need to support their vision of the future. In your conversation, consider how a space elevator would change our lives and how it would be connected to other things, rather than focusing on the elevator itself.

For larger groups, such as classes or camps, visitors can work collaboratively on a large sheet of butcher paper.

Credits

This activity was created as a collaboration of the NISE Network and the Center for Nanotechnology in Society at Arizona State University.

Image of space elevator concept by NASA, public domain. Image of space elevator concept copyright Dan Roam 2012. Image of space elevator concept courtesy Mondolithic.

This project was supported by the National Science Foundation under Award No. 0940143 and 0937591. 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.

Additional Graphic Resources

NanoDays
The Biggest Event for the Smallest Science!

Space Elevators

Space elevator designs often include a base station on Earth, an orbiting station in space, and a cable stretching between the two. The elevator car moves up and down on the cable between Earth and space. Some researchers think that super strong, lightweight carbon nanotubes might allow us to create a cable that can support its own weight plus that of the elevator car—making the dream of a space elevator possible.

Mondolithic

Dan Roam, © 2012

Artist illustrations of space elevator concepts

NOVA video about space elevators:
http://www.pbs.org/wgbh/nova/space/space-elevator.html

“Space Elevators” sheet
8.5 x 11 inches

Exploring Nano & Society—
You Decide!

Try this!

1. Look at the green cards with different technologies. If you got to decide, which ones would you make sure people had?

2. Place the technologies in order of importance, in your opinion. Which ones are the most useful? Which are less useful?

3. Choose one of the yellow cards with different people on them.

4. Pretend you're the person on the card. Do you think they would decide that the same technologies are important? Or would they change the order of the technology cards?

What's going on?

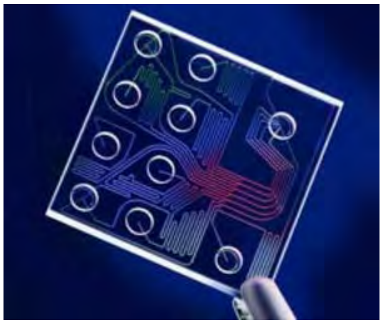
Different people think different technologies are important. You might put the technologies in a different order from someone else in your family, or someone else in a different part of the world. Sometimes, it's hard for us to know which technologies another person might value.

People's values determine which technologies are made and used. We all make decisions related to technologies—as individuals and as a society.

For example, security is a priority for the US government, so a lot of our national budget goes toward military funding. Safety is also a priority for many parents, who might pay for alarm systems for their home or cell phones for their children.

How is this nano?

Technologies and society influence each other. People's values shape how nanotechnologies are developed and adopted. In our country, a lot of our work developing new nanotechnologies goes toward computing, energy, medicine, and military applications. These efforts reflect what we collectively think is important. In other countries, people choose to invest in different kinds of technologies.



Lab-on-a-chip
screens for diseases

Nanotechnology takes advantage of the different physical forces at the nanoscale to make new materials and tiny devices smaller than 100 nanometers in size. (A nanometer is a billionth of a meter.) Nanotechnology allows scientists and engineers to make things like smaller, faster computer chips and new medicines to treat diseases like cancer.

Learning objectives

Technologies and society influence each other.

People's values shape how nanotechnologies are developed and adopted.

Materials

• Playing cards

Notes to the presenter

This activity is designed as an open-ended, conversational experience. There is no right or wrong way for visitors to sort the cards. To help visitors think about how to prioritize the technologies, you can ask them to think about which ones might be most useful or important and explain why they think so. After they chose a character card, you can ask them which technologies they think that person would find important, suggesting some factors the character might consider.

You can adjust this game to work for different audiences. For families with young children, try starting with 3–5 technologies. (Good choices include the space elevator, the teabag water filter, the invisibility cloak, the solar cells, and the mini drone robots.) Young children may have a hard time understanding the different perspectives represented by the character cards, but they often can recognize that they would sort the cards differently from other people in their family.

This activity is easy to facilitate with a little practice—but before doing it with visitors, become familiar with the cards and try it out a few times with a friendly audience.

Credits

This activity was created as a collaboration of the NISE Network and the Center for Nanotechnology in Society at Arizona State University.

Image of thin film solar cell courtesy of Konarka Technologies. Image of lab-on-a-chip courtesy of Agilent.

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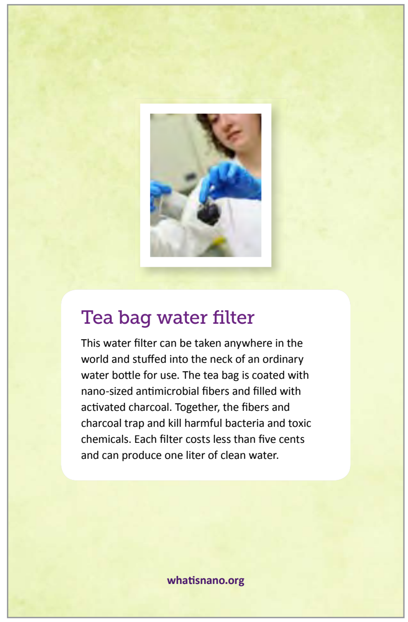
Additional Graphic Resources



Technology Cards
Set of 10 double-sided cards
5.5 x 8.5 inches

People Cards
Set of 5 single-sided cards
5.5 x 8.5 inches

Exploring Properties—
Invisibility

Try this!

1. Look in the glass beakers.
What do you see?

2. Gently lift the craft stick out of one beaker, then the other.
What's on the end of the line?

What's going on?

One of beakers has **two** glass objects in it! Before you lifted the objects out of the water, you might have thought each beaker had only one object—one red and one colorless. The beaker with two objects in it is filled with baby oil, while the beaker with one object is filled with plain water. The colorless object can be hidden in the oil because it's made of borosilicate glass, which has a similar *refractive index* to baby oil. It can't be hidden in the water, because borosilicate glass has a different refractive index from water.

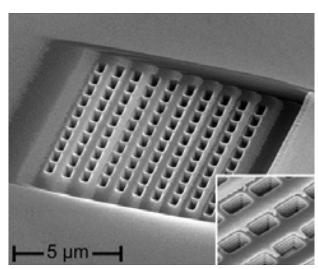
The refractive index indicates how fast light can travel through a material. The higher a material's refractive index, the slower light travels in that material. If two materials have a different refractive index, the speed of the light changes as it moves from one material to the other. This causes some of the light to *reflect*, or bounce off an object, and some of it to *refract*, or bend as it goes through an object.

You can't see the colorless object in the oil, because light traveling from baby oil to glass doesn't change speed very much. It doesn't refract or reflect when it hits the glass, so you don't see the object. It's almost invisible!

In everyday life, you see refraction at work when a straw submerged in a glass of water appears to bend. The light interacts differently with the air outside the glass than the water inside the glass, creating the illusion that the straw is bent.

How is this nano?

The way a material behaves on the macroscale is affected by its structure on the nanoscale. Using nanotechnology, it is possible to engineer new materials that can interact with light in special ways. Engineers have created special coatings that control reflection and refraction, improving the energy efficiency of windows and making better solar cells.



Metallic nanostructures that bend light backwards

Researchers are even experimenting with ways of bending light to cloak objects—making them invisible to the human eye or to surveillance devices. For example, scientists at the University of California at Berkeley have created a tiny "carpet" that makes a three-dimensional object appear flat by reflecting the surface beneath it. Thin, metallic nanostructures create negative refraction, bending light "backwards" in directions it couldn't go in nature.

Think about it…

1. What would you do if you had an invisibility cloak? What do you think other people might do?

2. Would you make rules for how people could use invisibility cloaks?

Technologies and society influence each other. When we use a new technology—whether it's a cell phone or an invisibility cloak—we create new ways of interacting with each other. We work together to figure out when, where, and how it's ok to use the new technology. Eventually, we create norms, rules, and laws that influence how we use it. New nanotechnologies will affect our social relationships, just like any other technology does.

Learning objectives

The way a material behaves on the macroscale is affected by its structure on the nanoscale.

Technologies and society influence each other.

Materials

- Glass beakers (2)
- Baby oil
- Water
- Borosilicate glass objects
- "Nanotechnology Mirage" sheet
- Sheet of "oil-resistant" white paper (laminated or synthetic)

The NanoDays physical kit includes two colorless glass pendants and one colored glass pendant. You can substitute other glass objects, but it's important that they be borosilicate glass. (Some other kinds of glass don't have the same refractive index, and won't "disappear" in the baby oil.) Borosilicate glass stir rods are available from scientific suppliers, such as www.sciencelab.com (#22-1900-6-DZ).

Notes to the presenter

SAFETY: Visitors should be careful handling the glass objects. Visitors should not drink the liquids. Visitors should be supervised at all times while doing this activity.

Before doing this activity:

- Fill one beaker with baby oil and one beaker with water. Suspend the stick with two glass objects (red and colorless) in the beaker with baby oil. Suspend the stick with one glass object (colorless) in the beaker with water. Place the beakers on the sheet of laminated paper.

- Check the lighting in your demonstration space. In some spaces, you may still be able to see the "invisible" object because of the way the lights are placed. If this happens, try a different spot.

This activity is based on a demonstration about the refraction of light, but it provides an opportunity to engage visitors in conversation about the potential for an invisibility cloak.

The red object provided in the NanoDays kit is made from a kind of glass known as "Red Elvis." The color comes from nanoscale particles of gold! Gold has been used to create red glass since the Middle Ages.

NanoDays
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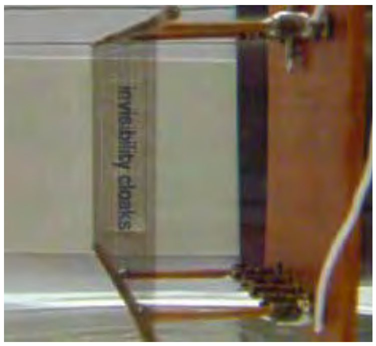
Nanotechnology "Mirage"

Researchers are experimenting with ways of bending light to cloak objects. For example, scientists at the University of Texas at Dallas have created a transparent curtain made out of millions of carbon nanotubes, which can hide objects underwater. When an alternating electric current is run through the curtain, it quickly becomes very hot. The temperature difference between the curtain and the surrounding water causes light rays to bend away rather than be reflected to your eye. This creates a mirage that hides whatever is behind the curtain.



Carbon nanotube screen in front of text that says "invisibility cloaks." Here, the screen is turned off.

Now the screen is turned on. Electricity creates a mirage effect, hiding the words.

Think about it…

1. What would you do if you had an invisibility cloak? What do you think other people might do?
2. Would you make rules for how people could use invisibility cloaks?

Video of the nanotechnology "mirage" in action:
http://www.youtube.com/watch?v=Nfnbj9r1-2I

"Nanotechnology Mirage" sheet
11 x 8.5 inches

Credits

This activity was created as a collaboration of the NISE Network and the Center for Nanotechnology in Society at Arizona State University.

Image of metallic nanostructures courtesy Jason Valentine, Vanderbilt University. Images of "nanotechnology mirage" courtesy Ali Aliev, Alan G. MacDiarmid NanoTech Institute, University of Texas at Dallas.

This project was supported by the National Science Foundation under Award No. 0940143 and 0937591. 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.

Exploring Nano & Society—

Tell a Nano Story

Try this!

1. Select a card to begin a story inspired by the picture.

2. Continue to add cards as you tell your story. You can use as many or as few cards as you need—but remember, every story has a beginning, middle, and end!

3. Something missing from your story? Draw your own technology, character, or place card!

Think about it…

1. Who is the main character of your story? What new technologies might they need in their adventure?

2. What do you think the future will look like if all these new technologies are developed?

3. How will a future society be the same or different compared to our current society?

What's going on?

Nobody knows what the future will bring, but most of us think about the future all the time. It's fun to imagine what our lives might be like in the future—and it's also important. We have the things we do today because in the past, people thought about the kind of world they wanted and invented technologies to help make their dreams real.

Science fiction storytelling is just one place people write down and capture their vision for what the future might look like.

"Trying to predict the future is a discouraging and hazardous occupation," science fiction author Arthur C. Clarke said in 1964, and yet he got it remarkably right in his own predictions, including his 1968 vision for a tablet. He wasn't alone. Isaac Asimov, another famous author, predicted online education, Douglas Adams predicted e-books, and Ray Bradbury predicted that we would reach Mars (though, so far, we've only done so with robotic extensions of ourselves). What do you predict the future will look like? We can all think about the kind of world we want in the future and begin planning for it. Are there new technologies we'll need to develop and adopt? How might society change as these become more available and commonplace?

How is this nano?

Technologies and society influence each other. New technologies will open up new possibilities, shape our relationships, promote the values of those who build them, and through a variety of systems affect many different parts of our society and communities. Likewise, our own society will have a dramatic effect on what technologies are developed and adopted.

New nanomaterials will have a significant impact on our lives in the coming years, so it is very important that we engage in open conversations about what nanotechnology is, what is possible, and where we would like it to go.

Learning objectives

Technologies and society influence each other.

People's values shape how technologies are developed and adopted.

Technologies affect social relationships.

Technologies work because they are part of larger systems.

Materials

• "Tell Me A Nano Story" cards and "Draw Your Own Story" cards

• Crayons

Notes to the presenter

Getting started: Lay out a selection of cards on the table—face-up. We've found it works well to start with somewhere between 9 and 15 cards. You can use the "Think about it" questions to get visitors started telling a story, and while they are telling the story. Visitors can start a story with just one card and add cards as they continue, or they can tell a story around a selection of cards. You can pick a card to get them going, or let them choose their own.

Game play is flexible. This activity is designed as an open-ended, conversational experience. Listen carefully to the nano story that visitors create. A nice way to reinforce the storytelling aspect of this activity is to tell the story back to the visitors or suggest that they tell the story again to other members of their group.

Additional "Think about it..." questions:

• How do your own values, or the values your characters, influence what technologies were used?

• How do the technologies affect the social relationships in the story? Are friendships impacted? Family relationships?

• What larger systems were required for the technologies in their story? Will we need new or additional infrastructure to make technologies safe, accessible, or affordable?

Game play modifications: For larger groups, such as classes or camps, visitors can work collaboratively to develop a story together by taking turns choosing a card and adding a plot twist or a new character to the collective narrative. For very young visitors, you can use the cards to tell them a custom story. Allow the child to pick a certain number of cards and use the illustrations as prompts for your own science fiction story.

Credits

This activity was created as a collaboration of the NISE Network and the Center for Nanotechnology in Society at Arizona State University.

Artwork by Emily Maletz.

This project was supported by the National Science Foundation under Award No. 0940143 and 0937591. 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.

Additional Graphic Resources

"Tell Me a Nano Story"
set of 27 cards
4 x 5 inches

"Draw Your Own Story" cards
4 x 5 inches

Exploring Products—Sunblock

Try this!

1. Take a piece of black paper.

2. Use a cotton swab to put a small dab of ointment on the paper. Try rubbing it in.

3. Now use a swab to rub in a dab of sunblock. Is it easier to rub in than the ointment?

What's going on?

The sunblock rubs in better than the ointment, because it contains tiny, nanosized particles of zinc oxide. (A nanometer is a billionth of a meter.) The nanoparticles of zinc oxide are so small that they don't reflect visible light, making the sunblock transparent on skin.

The ointment also contains zinc oxide, but the particles are much bigger. These larger zinc oxide particles reflect visible light, so they create a white film. (To see how this works, look at the pictures of white dots on a black background.)

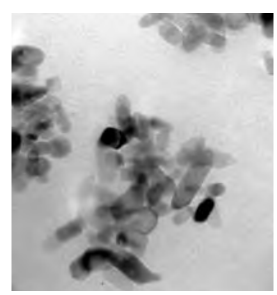
Both products are equally effective at absorbing UV radiation and keeping it from reaching your skin, but many people prefer sunblock that rubs in clear.

Research shows that sunblocks containing nanoparticles of zinc oxide and titanium dioxide are safe to use. The zinc and titanium minerals in the sunblock don't go through the outer later of healthy, adult skin. Still, some people have concerns about the use of nanoparticles in sunblock and other products.

Many other health and beauty products contain nanosized particles, including hair products, cosmetics, and toothpaste. These products are not regulated by the U.S. Food and Drug Administration (FDA), and are not required to indicate whether their formulations include nanosized particles.

How is this nano?

Sunblocks containing nanoparticles are one of the most common applications of nanotechnology. Nanotechnology takes advantage of special properties at the nanoscale. For example, the nanoparticles in sunblock are invisible to the human eye because they're smaller than the wavelength of visible light.



Titanium dioxide nanoparticles
Less than 100 nm long

Some people are concerned that the particle size of the ingredients may make a difference in how safe they are. That's because materials can act differently when they're nanosized—so just because something is safe on the microscale doesn't necessarily mean it's safe on the nanoscale. More research is needed before we can know for sure.

Learning objectives

Sunblocks containing nanoparticles are one of the most common applications of nanotechnology.

Nanoparticles in sunblock are invisible to the human eye because they're smaller than the wavelength of visible light.

Materials

- Sunblock with nanoparticles of zinc oxide
- Zinc oxide ointment
- Black construction paper
- Cotton swabs
- "Particle Size" sheet

Notes to the presenter

SAFETY: To avoid potential reactions due to allergies or sensitivities, do not allow visitors to apply the ointment or sunblock to their skin.

Visitors may wonder how they can tell if their sun protection contains nanoparticles. Here are some guidelines:

- If a product includes zinc oxide or titanium dioxide, it's a mineral sunblock that works by absorbing UV rays. If a mineral sunblock rubs in clear, it probably contains nanoparticles.

- Products that contain avobenzone, oxybenzone, or PABA are chemical sunscreens that do not contain mineral nanoparticles.

More information on potential health concerns related to nanoparticles in sunblock can be found in the "Invisible Sunblock" program, available at www.nisenet.org/catalog/programs/invisible_sunblock

Credits

This activity was adapted from "Invisible Sunblock," developed by The Franklin Institute for the NISE Network. The original program is available from: www.nisenet.org/catalog

This project was supported by the National Science Foundation under Award No. ESI-0940143. 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.

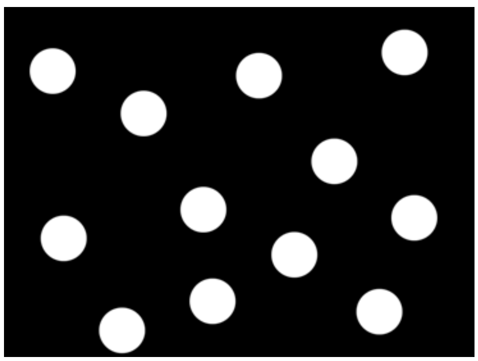
Additional Graphic Resources

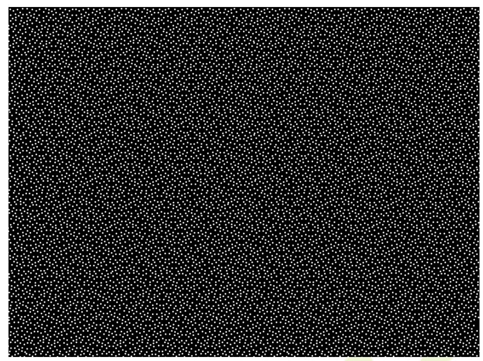
NanoDays
The Biggest Event for the Smallest Science!

Particle Size—Sunblock

These pictures help explain why larger zinc oxide particles are easier to see on the black paper (or your skin). Both pictures have the same ratio of white to black. The large white dots are much easier to see than the small dots, because each large dot reflects more light than a small dot.

The nanoparticles of zinc oxide in the sunblock are much, much smaller than the dots in these pictures. They're smaller than the wavelength of visible light! The nanoparticles don't reflect visible light to our eyes, so we don't see them once the sunblock is rubbed in. But they're still big enough to absorb UV light and protect our skin.





"Particle Size" sheet
8.5 x 11 inches

PROGRAM

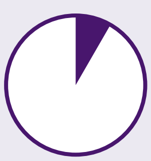
Robots & People

Stage Presentation Plus Facilitated Activity

In the first part of the *Robots & People* program, visitors learn what robots and nanobots are, what they can do, and how they affect our lives. In the second part of the program, visitors imagine and draw a robot, designing it to do a particular task.

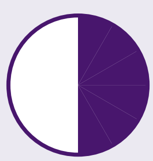
Time Required

Setup



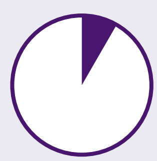
5 min

Program



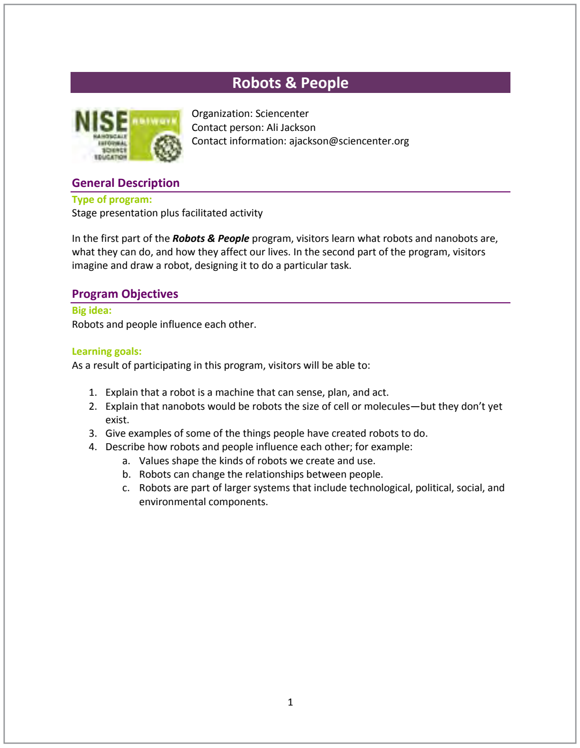
30 min

Cleanup



5 min

Program Resources


Robots & People

Organization: Sciencenter
Contact person: Ali Jackson
Contact information: ajackson@sciencenter.org

General Description

Type of program:
Stage presentation plus facilitated activity

In the first part of the ***Robots & People*** program, visitors learn what robots and nanobots are, what they can do, and how they affect our lives. In the second part of the program, visitors imagine and draw a robot, designing it to do a particular task.

Program Objectives

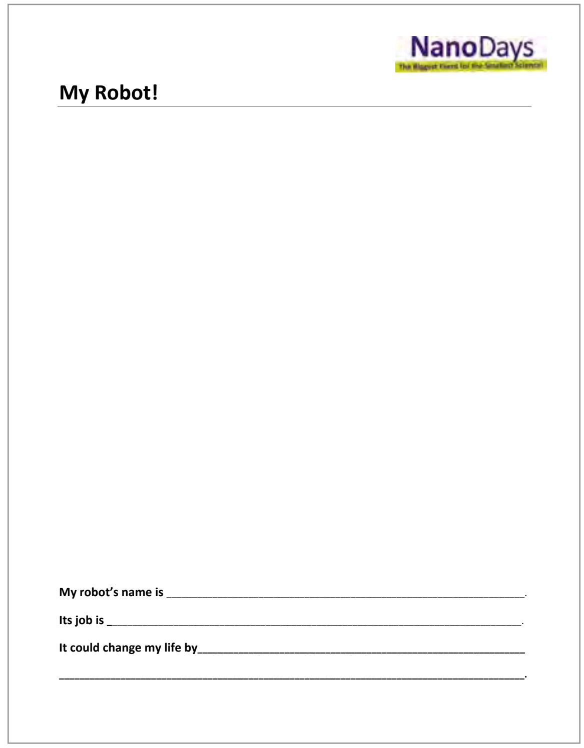
Big idea:
Robots and people influence each other.

Learning goals:
As a result of participating in this program, visitors will be able to:

1. Explain that a robot is a machine that can sense, plan, and act.
2. Explain that nanobots would be robots the size of cell or molecules—but they don't yet exist.
3. Give examples of some of the things people have created robots to do.
4. Describe how robots and people influence each other; for example:
   a. Values shape the kinds of robots we create and use.
   b. Robots can change the relationships between people.
   c. Robots are part of larger systems that include technological, political, social, and environmental components.

1

"Robots & People" lesson plan
20 pages


NanoDays

My Robot!

My robot's name is ______________________.

Its job is ______________________.

It could change my life by______________________
______________________.

"My Robot!" drawing sheet
8.5 x 11 inches

"Robots & People" presentation
35 slides

PROGRAM

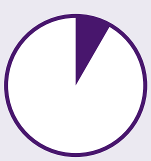
Would You Buy That?

Stage presentation

Like all new technologies, nanotechnology has costs, risks, and benefits we cannot always predict. The *Would You Buy That?* stage presentation examines and explores ways our consumer behavior both impacts and is impacted by new technology. By looking at historical examples and current and future nanotechnologies, audience members weigh the risks versus the benefits and make group purchase decisions. Sometimes we need to stop and think more about a consumer decision. By engaging in this dynamic, interactive presentation, the audience and the presenter discuss their choices and learn more about nano products they could buy (or not buy) for themselves, their families, and their communities.

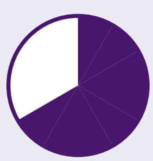
Time Required

Setup



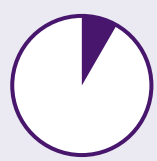
5 min

Program

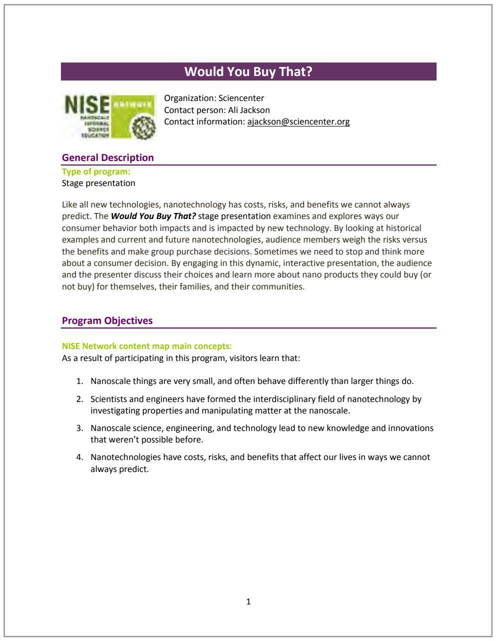


40 min

Cleanup



5 min



Would You Buy That?

Organization: Sciencenter
Contact person: Ali Jackson
Contact information: ajackson@sciencenter.org

General Description

Type of program:
Stage presentation

Like all new technologies, nanotechnology has costs, risks, and benefits we cannot always predict. The ***Would You Buy That?*** stage presentation examines and explores ways our consumer behavior both impacts and is impacted by new technology. By looking at historical examples and current and future nanotechnologies, audience members weigh the risks versus the benefits and make group purchase decisions. Sometimes we need to stop and think more about a consumer decision. By engaging in this dynamic, interactive presentation, the audience and the presenter discuss their choices and learn more about nano products they could buy (or not buy) for themselves, their families, and their communities.

Program Objectives

NISE Network content map main concepts:
As a result of participating in this program, visitors learn that:

1. Nanoscale things are very small, and often behave differently than larger things do.
2. Scientists and engineers have formed the interdisciplinary field of nanotechnology by investigating properties and manipulating matter at the nanoscale.
3. Nanoscale science, engineering, and technology lead to new knowledge and innovations that weren't possible before.
4. Nanotechnologies have costs, risks, and benefits that affect our lives in ways we cannot always predict.

1

"Would You Buy That?" lesson plan
17 pages

"Product Cards"
Set of 9 double-sided cards
8.5 x 11 inches

"Would You Buy That?" presentation
28 slides

Gary Hodges

APPENDIX I

Additional educational graphics and resources

Giant Puzzle Blocks

NanoDays
The Biggest Event for the Smallest Science!

Build a Giant Puzzle!

Put the pieces together to discover the nano connection!

You can make 6 different puzzles out of these blocks.

Stained glass

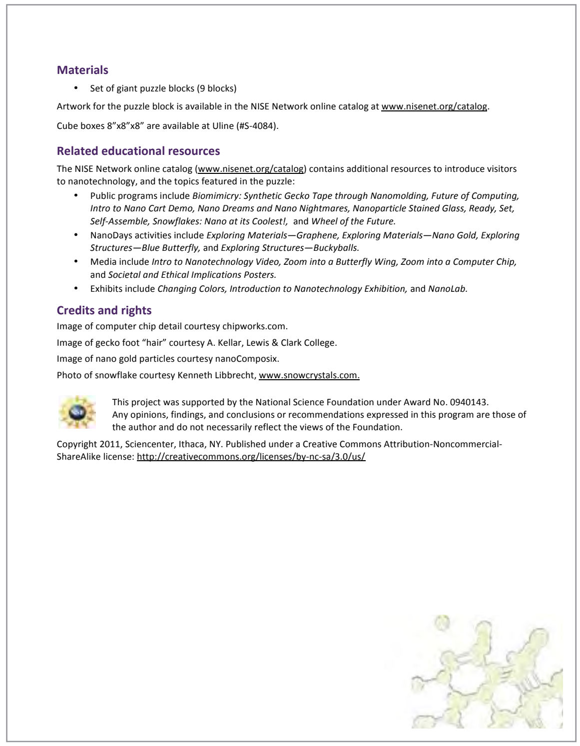
Snowflake

Blue Morpho Butterfly

Gecko

Computer chip

Boy and buckyball



Materials

- Set of giant puzzle blocks (9 blocks)

Artwork for the puzzle block is available in the NISE Network online catalog at www.nisenet.org/catalog.

Cube boxes 8”x8”x8” are available at Uline (#S-4084).

Related educational resources

The NISE Network online catalog (www.nisenet.org/catalog) contains additional resources to introduce visitors to nanotechnology, and the topics featured in the puzzle:

- Public programs include *Biomimicry: Synthetic Gecko Tape through Nanomolding, Future of Computing, Intro to Nano Cart Demo, Nano Dreams and Nano Nightmares, Nanoparticle Stained Glass, Ready, Set, Self-Assemble, Snowflakes: Nano at its Coolest!,* and *Wheel of the Future.*
- NanoDays activities include *Exploring Materials—Graphene, Exploring Materials—Nano Gold, Exploring Structures—Blue Butterfly,* and *Exploring Structures—Buckyballs.*
- Media include *Intro to Nanotechnology Video, Zoom into a Butterfly Wing, Zoom into a Computer Chip,* and *Societal and Ethical Implications Posters.*
- Exhibits include *Changing Colors, Introduction to Nanotechnology Exhibition,* and *NanoLab.*

Credits and rights

Image of computer chip detail courtesy chipworks.com.

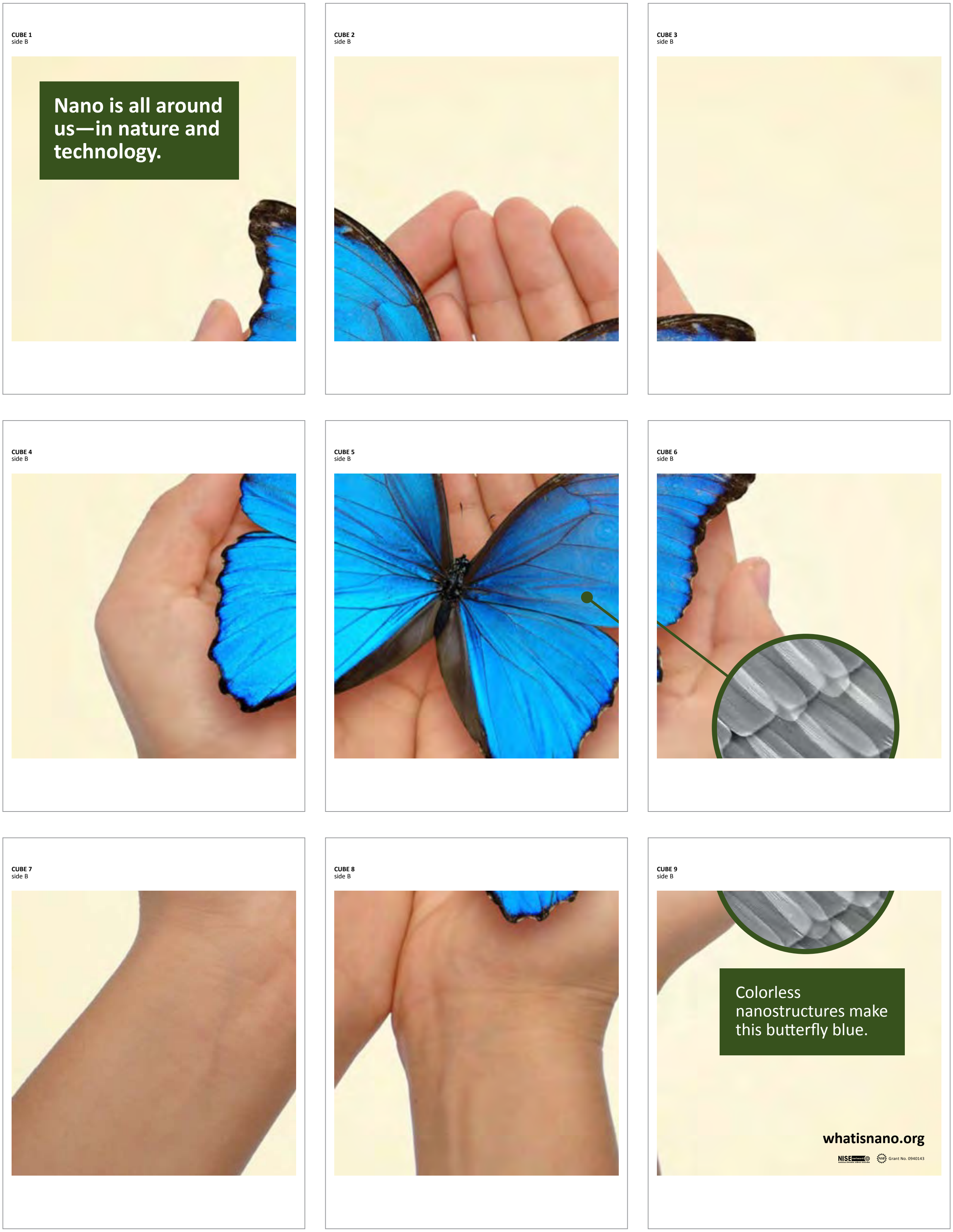
Image of gecko foot “hair” courtesy A. Kellar, Lewis & Clark College.

Image of nano gold particles courtesy nanoComposix.

Photo of snowflake courtesy Kenneth Libbrecht, www.snowcrystals.com.

This project was supported by the National Science Foundation under Award No. 0940143.
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.

“Build a Giant Puzzle” guide
2 pages
8.5 x 11 inches



"DIY Puzzle Blocks"
54 pages
8.5 x 11 inches

I Spy Nano Game

“I Spy Nano” game boards
9 x 11 inches
set of 6

NanoDays
The Biggest Event for the Smallest Science!

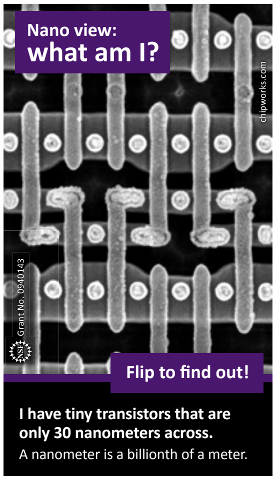
I Spy Nano!

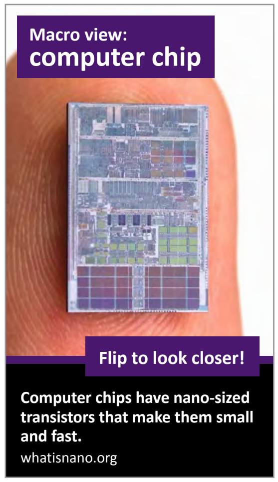
1. Each player chooses a game board.
2. Place the deck of playing cards in the center, purple side facing up (picture side down).
3. Read the statement on the back (purple) side of each card, then turn it over.
4. Look at the objects on the front of the card. Each game board has <u>one</u> of these objects on it.
5. All players search their boards to find an object that’s <u>identical</u> with an object on the card.
6. The first person to find their object says “Nano!” and takes the card.
7. Play continues with the next card in the deck, until no cards remain in the center pile.
8. Whoever has the most cards wins!

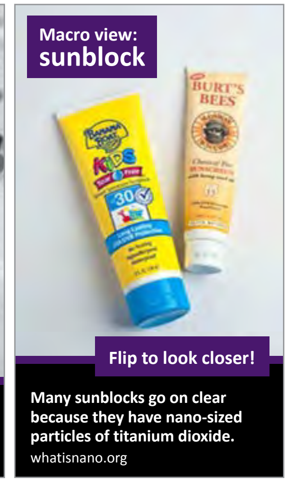
“I Spy Nano” guide
8.5 x 11 inches

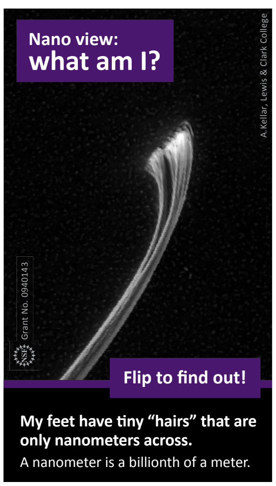
“I Spy Nano” cards
4.75 x 3.73 inches,
set of 24 double-sided cards

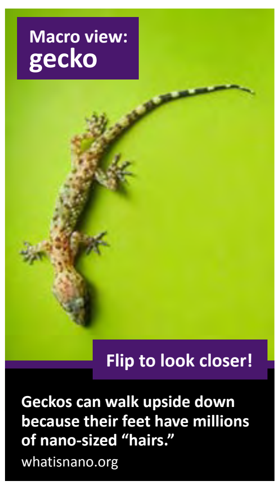
What am I?

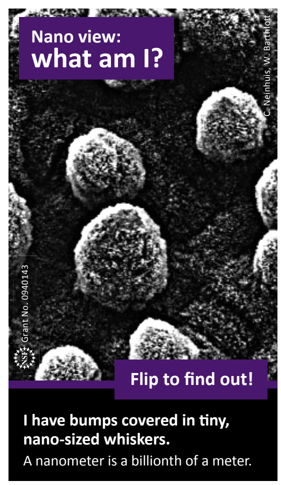


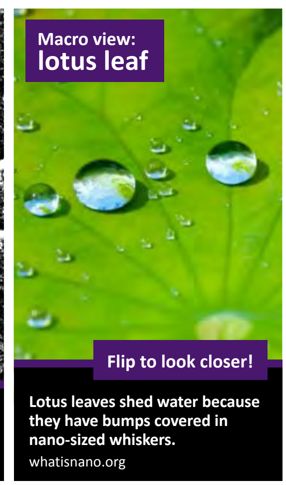


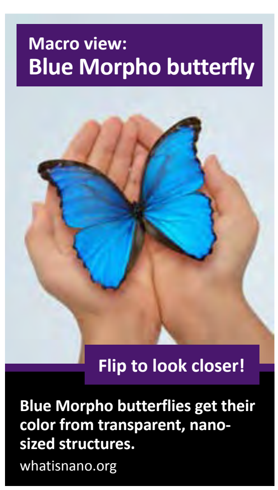






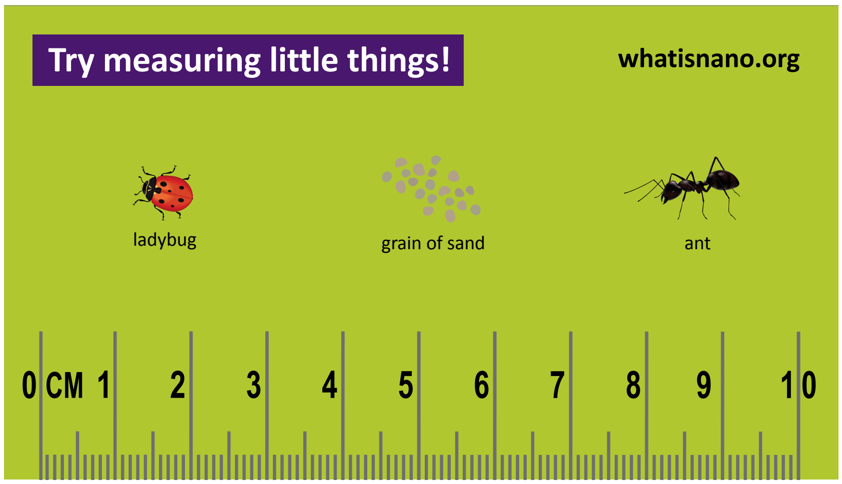


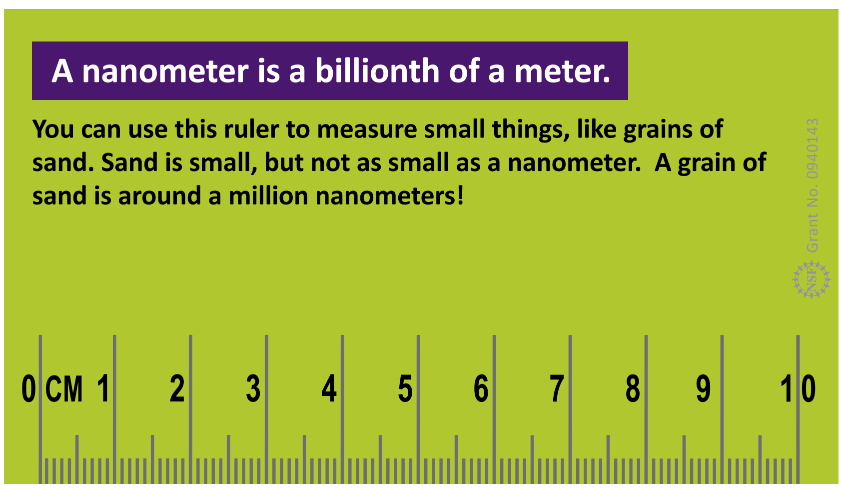




"What Am I" cards
5.75 x 10 inches
set of 5 double-sided cards

Measuring Tiny Things

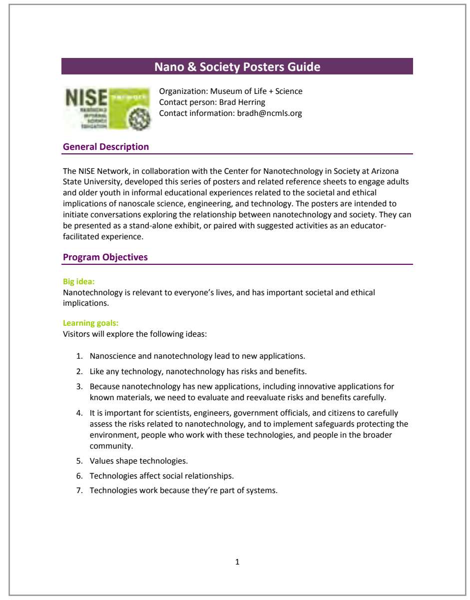




“Measuring Tiny Things” card
4.375 x 2.5 inches, double-sided

Nano and Society Posters

"Nano and Society" info sheets
8.5 x 11 inches
set of 6 double-sided sheets



"Nano and Society" posters guide
8.5 x 11 inches, 8 pages

"Nano and Society" poster 1 of 10
24 x 30 inches

"Nano and Society" poster 2 of 10
24 x 30 inches

"Nano and Society" poster 3 of 10
24 x 30 inches

"Nano and Society" poster 4 of 10
24 x 30 inches

"Nano and Society" poster 5 of 10
24 x 30 inches

"Nano and Society" poster 6 of 10
24 x 30 inches

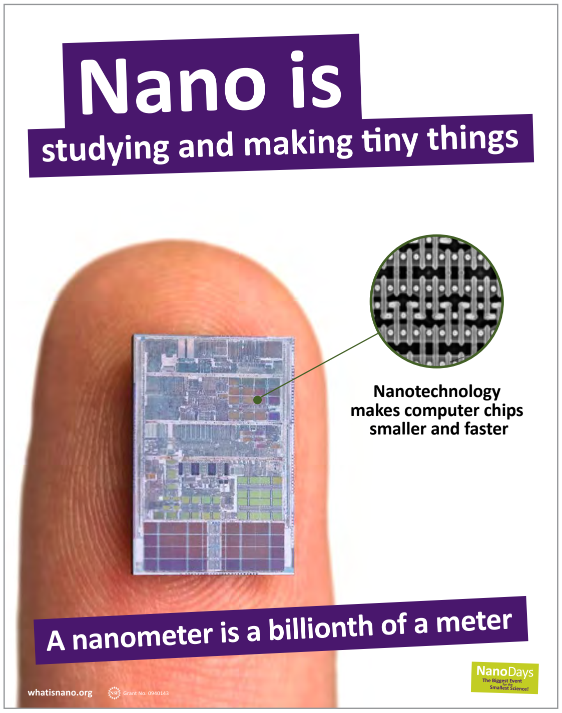
"Nano and Society" poster 7 of 10
24 x 30 inches

"Nano and Society" poster 8 of 10
24 x 30 inches

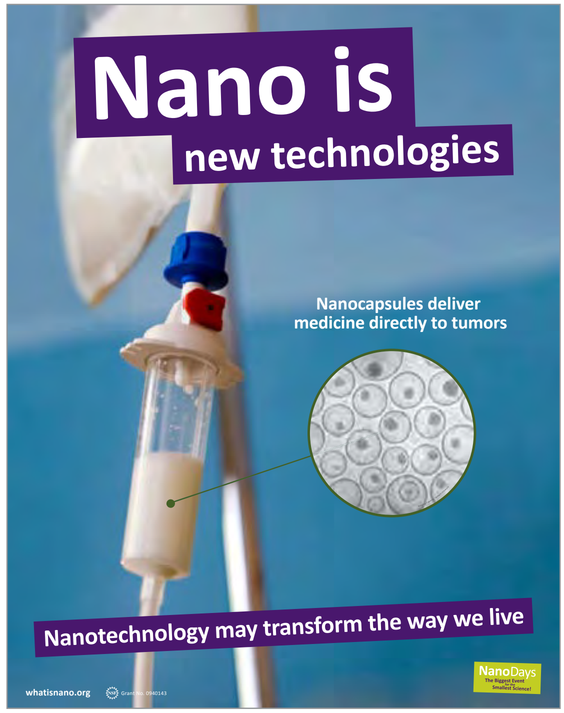
"Nano and Society" poster 9 of 10
24 x 30 inches

"Nano and Society" poster 10 of 10
24 x 30 inches

Key Concepts Posters

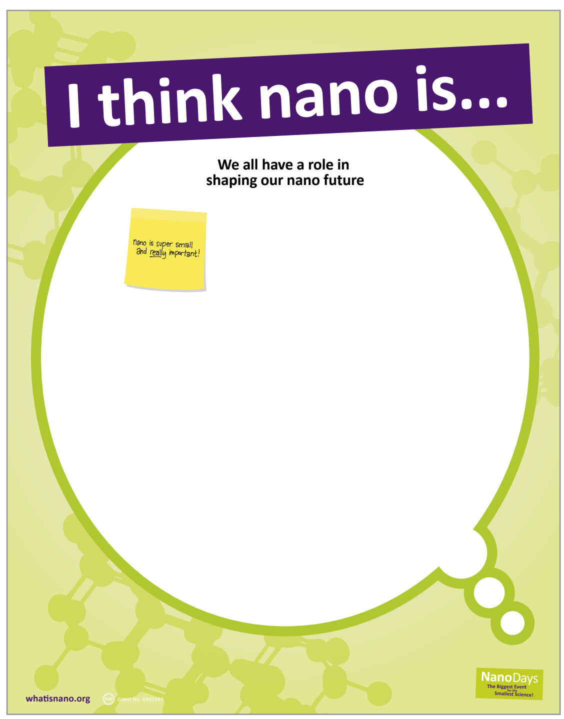


“Key Concepts” poster 1 of 5
23 x 29 inches



“Key Concepts” poster 2 of 5
23 x 29 inches

“Key Concepts” poster 3 of 5
23 x 29 inches



“Key Concepts” poster 4 of 5
23 x 29 inches

How small is nano?

The world is full of things of all different sizes! In your everyday life, you come across things in at least three different size scales: the *macroscale*, the *microscale*, and the *nanoscale*.

Child
A child is about 1 meter tall
1 meter = 1,000,000,000 nm (1 billion nanometers)

Hand
A hand is about 1 decimeter wide
1 decimeter = 100,000,000 nm (100 million nanometers)

Pinky Finger
A pinky finger is about 1 centimeter wide
1 centimeter = 10,000,000 nm (10 million nanometers)

Freckle
A freckle is about 1 millimeter wide
1 millimeter = 1,000,000 nm (1 million nanometers)

Strand of Hair
A hair is about 0.1 (one tenth) of a millimeter wide
0.1 millimeter = 100,000 nm (100 thousand nanometers)

Macroscale
The macroscale includes things we can see with our eyes, from big to small. There are lots of ways to measure macroscale things, including *meters*. Meters are about the same size as a yard.

Kids around six years old are about a meter tall. A strand of hair is just a fraction of meter, 0.1 millimeters.

Red Blood Cell
A red blood cell is about 10 micrometers wide
10 micrometers = 10,000 nm (10 thousand nanometers)

Bacteria
A bacteria cell is about 1 micrometer wide
1 micrometer = 1,000 nm (1 thousand nanometers)

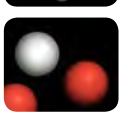
Virus
A virus is about 0.1 (one tenth) of a micrometer wide
0.1 micrometer = 100 nm (1 hundred nanometers)

Microscale
The microscale is smaller than the macroscale. To see microscale things clearly, we need tools like microscopes. We measure them using *micrometers*.

A micrometer is a millionth of a meter. Red blood cells are about 10 micrometers wide.

Cell Membrane
A cell membrane is about 10 nanometers wide
10 nanometers = 10 nm

Sugar Molecule
A sugar molecule is about 1 nanometer wide
1 nanometer = 1 nm



Atom
An atom is about 0.1 (one tenth) of a nanometer wide
0.1 nanometer = 0.1 nm

Nanoscale
There's an even smaller scale, the nanoscale! Nanoscale things are so tiny, we can't see them with just our eyes, or even with light microscopes. We need special tools to make images of them. We measure nanoscale things using *nanometers*.

A nanometer is super small—a billionth of a meter! DNA is just two nanometers wide.

What's a nanometer? **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 parts of a cell or DNA.

whatisnano.org

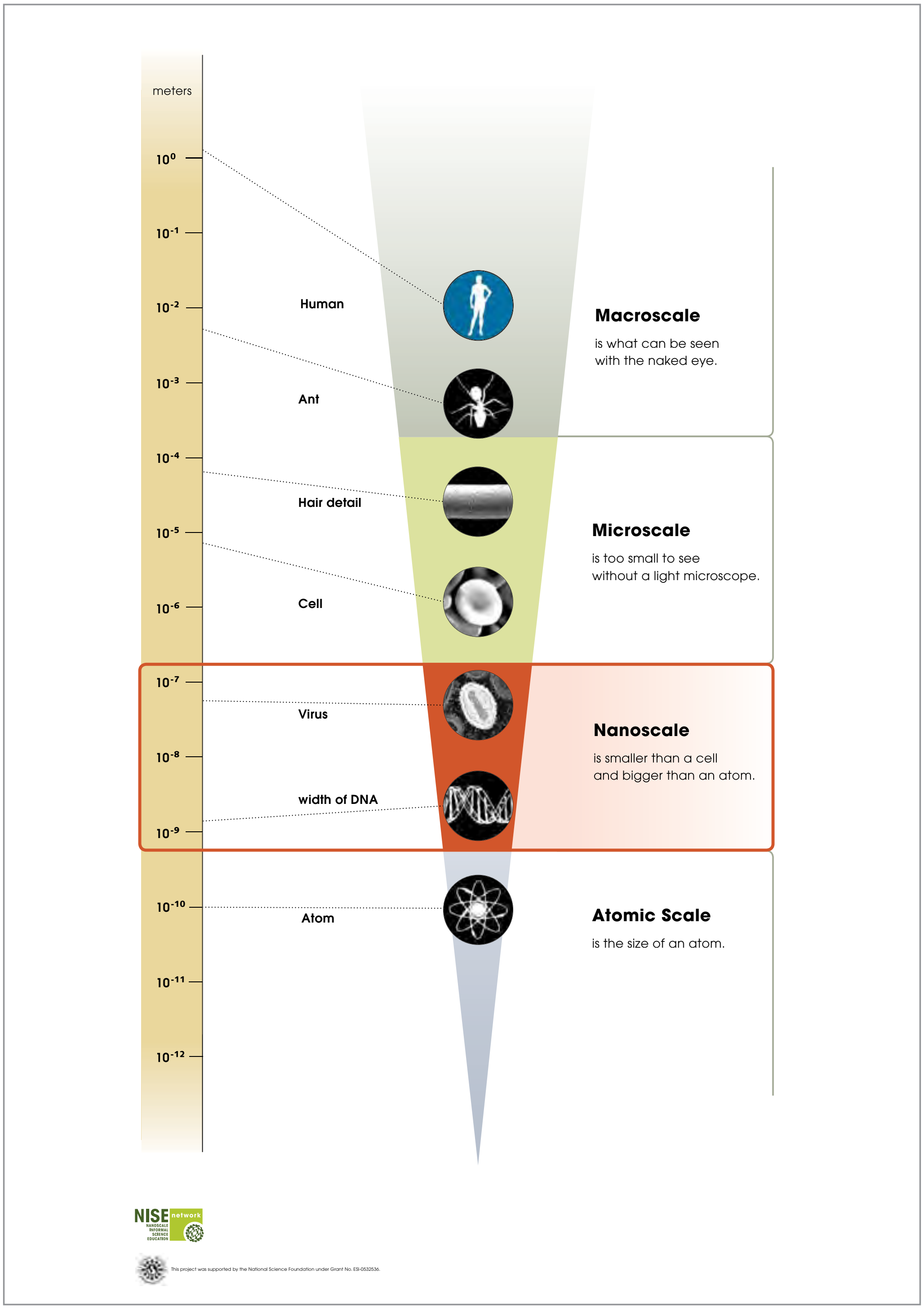
Grant No. 0940143

"Key Concepts" poster 5 of 5
23 x 29 inches

Nano Museum Lables

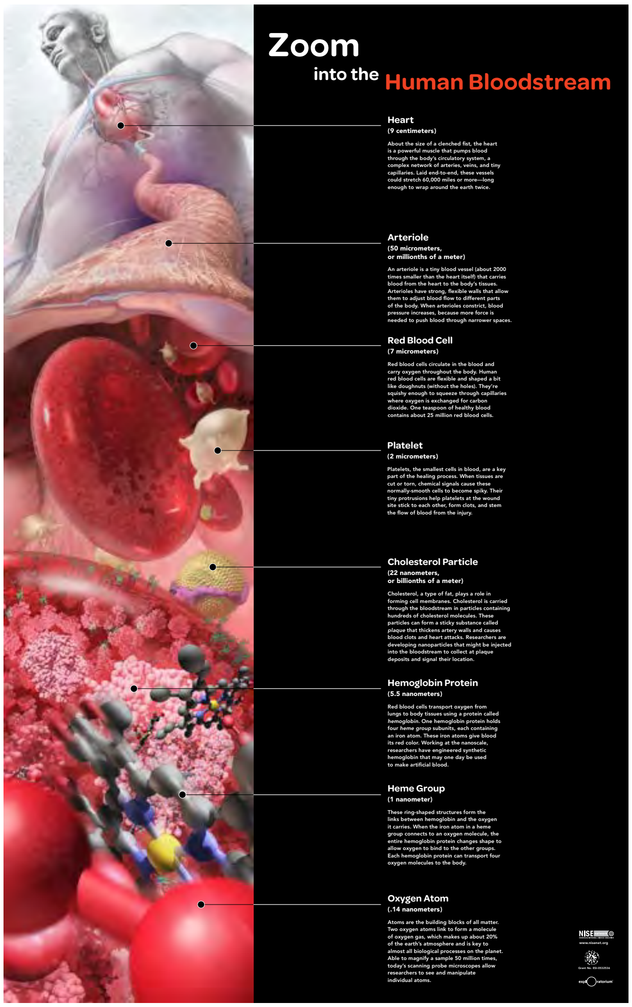
"What's Nano About?" labels
11 x 8.5 inches, set of 15

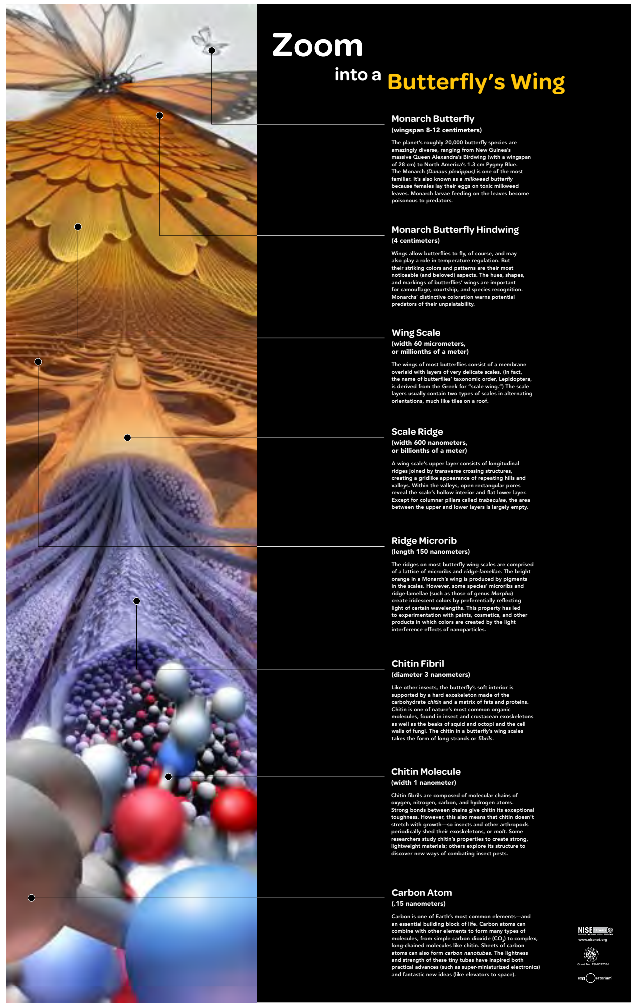
Scale Ladder



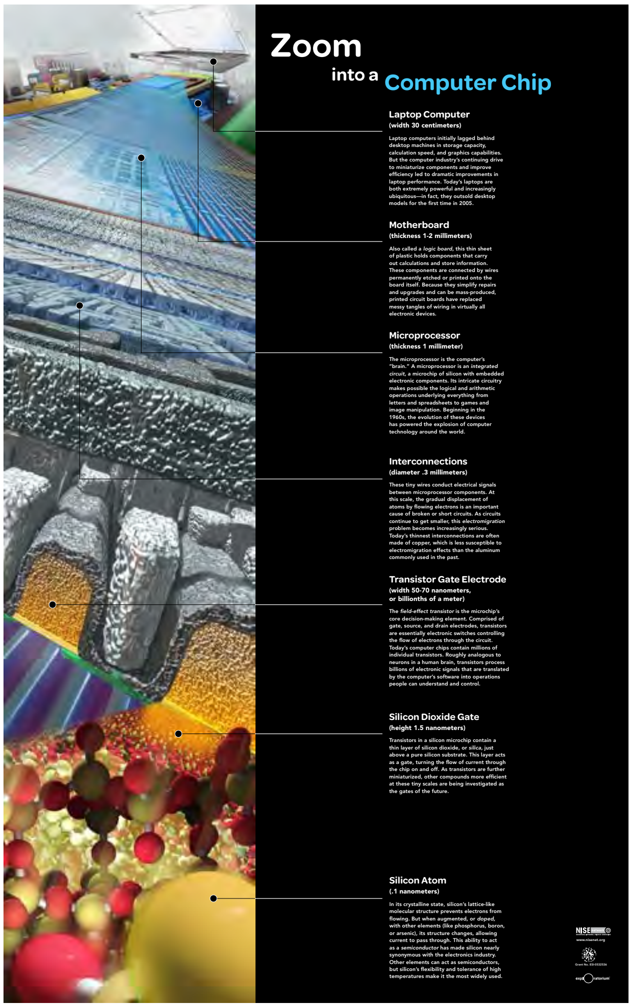
"Scale Ladder" poster
31 x 44 inches

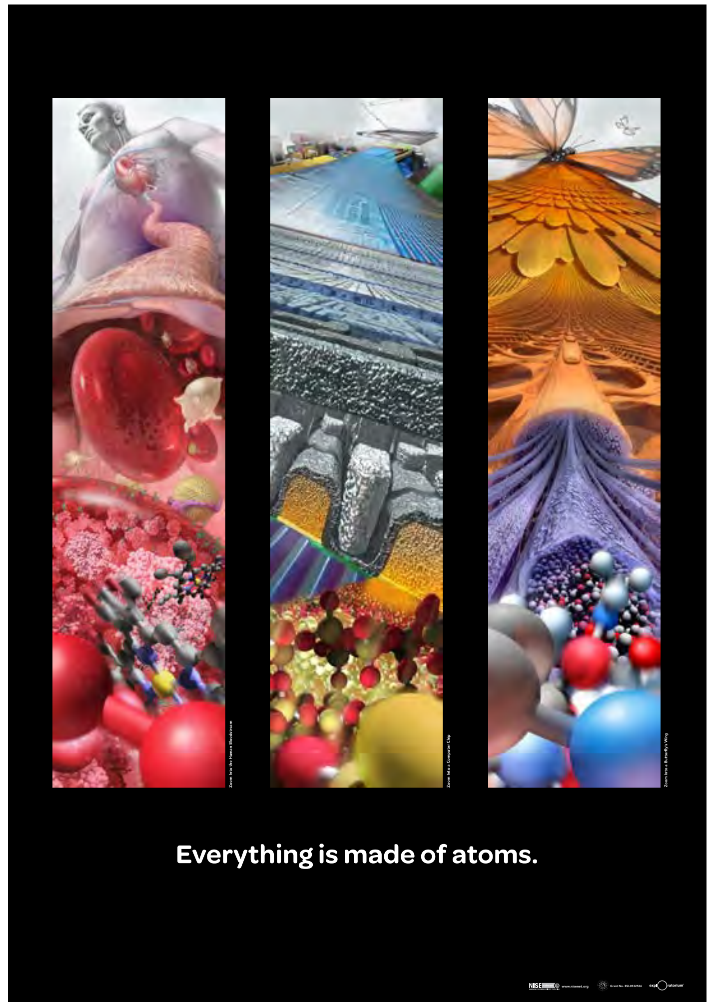
Zoom Into Posters





"Zoom In" posters
24.25 x 38.75 inches, set of 3





"Everything Is Made of Atoms" poster
27.25 x 38.75 inches

Gary Hodges

APPENDIX II

Training resources and marketing materials

Tips for Engaging Visitors

Greet visitors
Say “hello,” make eye contact, and smile. Simply looking like you’re available and friendly will bring visitors to your station.

Let visitors do the activity
As much as possible, let visitors do the hands-on parts of the activity, and let them discover what happens. (If your activity has a surprise, don’t give it away!)

Share what you know
Use clear, simple language. Focus on one main idea—don’t feel that you need to tell visitors everything at once! Keep the information basic for starters, and be willing to expand on an idea for interested learners.

Use examples from everyday life
Familiar examples can help explain abstract concepts. Be aware of visitors’ abilities, keeping in mind that children do not have the same skills or vocabulary as adults.

Ask questions
Help visitors observe and think about the activity. Try to use questions that have more than one answer, such as:
- What do you see happening?
- Why do you think that happened?
- What surprised you about what you saw?
- Does this remind you of anything you’ve seen before?

Be a good listener
Be interested in what visitors tell you, and let their curiosity and responses drive your conversation forward.

Offer positive and encouraging responses
If visitors haven’t quite grasped a concept, you might say, “That’s a good guess,” or “Very close, does anyone else have something to add?” Don’t say, “No” or “Wrong” in response to visitors’ observations or explanations.

Share accurate information
If you aren’t sure about something, it’s OK to say, “I don’t know. That’s a great question!” Suggest that visitors go to whatisnano.org to learn more about nanoscale science, engineering, and technology.

Remain positive throughout the interaction
Remember that nonverbal communication is important, too. Try to maintain an inviting face and body language.

Thank visitors
As your interaction ends, suggest that visitors explore other NanoDays activities.

HAVE FUN! ☺ A positive experience will lead to learning.

Tips for Visitor Conversations

Greet visitors

Say “hello,” make eye contact, and smile. Simply looking like you’re available and friendly will invite visitors to interact with you.

Let visitors do the talking

As much as possible, let visitors’ interests guide the conversation. You can help them reflect on their own ideas and form their own opinions. If visitors aren’t interested in an extended conversation, that’s fine.

Keep the conversation open-ended

In a conversation about individual values and perspectives, there’s no right and wrong answer. Your contributions can provide interesting things to think about, but shouldn’t suggest a conclusion.

Use examples from everyday life

Familiar examples can help explain abstract concepts. Be aware of visitors’ abilities, keeping in mind that children do not have the same skills or vocabulary as adults.

Ask questions

Help visitors observe and think about the activity. Try to use questions that have more than one answer, such as the ones included in the activity guide.

Be a good listener

Be interested in what visitors tell you, and let their curiosity and responses drive your conversation forward.

Offer positive and encouraging responses

When visitors are having trouble articulating their thoughts, you might say, “That’s an interesting idea. Why do you think that?” or “Have you thought about…?” Offer them an opportunity to reflect further.

Share accurate information

You can provide additional information or a different perspective, but maintain a neutral position on issues. If you aren’t sure about something, it’s OK to say, “I don’t know. That’s a great question!” Suggest that visitors go to whatisnano.org to learn more about nanoscale science, engineering, and technology.

Remain positive throughout the interaction

Keep things upbeat and positive. Remember that nonverbal communication is important, too. Maintain an inviting face and body language.

Thank visitors

Wrap up the conversation whenever it has run its course. A brief interaction is fine! As your interaction ends, suggest that they explore other NanoDays activities.

HAVE FUN! ☺ A positive experience will lead to learning.

tips for ENGAGING GIRLS at NanoDays

USE INCLUSIVE LANGUAGE

Watch the pronouns you use. When speaking about a scientist, do you say “he” or “his”? Make pronouns gender neutral whenever possible.

FEATURE FEMALE ROLE MODELS

Feature images and stories about women in the information you share while facilitating the activity. Showcase real female nanoscientists. Learning about women role models is inspiring for girls, and it’s also important for boys and parents to see female scientists. Have female facilitators when possible—seeing women leading the activity can help empower girls to participate.

MAKE IT SOCIAL

Encourage sharing and discussion of the activity with friends or family. Set up activities so that more than one person can participate at a time. Consider assigning roles so that every visitor has an active role to play.

ENGAGE THE SENSES

Promote a multisensory experience with a variety of colors, sounds, smells, and textures. Take time to make sure the activity table remains aesthetically pleasing and inviting.

TELL A STORY

Engage participants during the activity by telling a story they can relate to. This could be the story of the person who discovered the technology in the activity or a story of someone who might use this technology. Encourage visitors to tell their own stories.

HIGHLIGHT ALTRUISM

Feature ways the nanotechnology in the activity has been used to help people, or ways that it may one day be used to help others. Encourage visitors to brainstorm ways they think the technology might be useful, or even express concern about ways it could do harm.

MAKE IT PERSONAL

Find common connections between the activity and the everyday lives of girls. Ask girls where they would see or experience a similar phenomenon. Encourage them to tell you about a time they saw something similar, or where they might imagine using a related product in the future.

ENCOURAGE CREATIVITY

Find ways to allow for creative self-expression in the activity. Invite girls to draw, paint, make, or act!

MAKE SURE THERE ARE MANY “RIGHT” ANSWERS

Encourage open-ended investigations by finding ways for girls to explore, discover, and try ideas without any one single “right” answer.

tips for ENGAGING GIRLS at NanoDays

Exploring Products—Nano Fabric

MAKE IT PERSONAL

• Invite visitors to **imagine** other places in their lives where nano fabric might be useful (such as a table cloth, on couches, or as carpet).

TELL A STORY

• Tell a **funny story** (real or made up) about a time when nano fabric could have saved you from staining your clothing, carpet, furniture, or similar. Be careful to use inclusive language and not give examples that reinforce stereotypical gender roles (i.e., a wife washing her husband's clothing).

tips for ENGAGING GIRLS at NanoDays

Exploring Materials—Thin Films

ENCOURAGE CREATIVITY

• Participants may choose to **create** a greeting card, bookmark, or similar item out of the black paper. Encourage visitors to draw a design or write a special message and to cut their paper into a shape of their choosing.

Plan ahead: To promote creativity provide larger pieces of black paper. In addition to the activity materials, you'll also need to provide scissors for this extension. We suggest using Bristol paper as the dye in the paper doesn't bleed when it gets wet the way regular black construction paper does.

MAKE IT PERSONAL

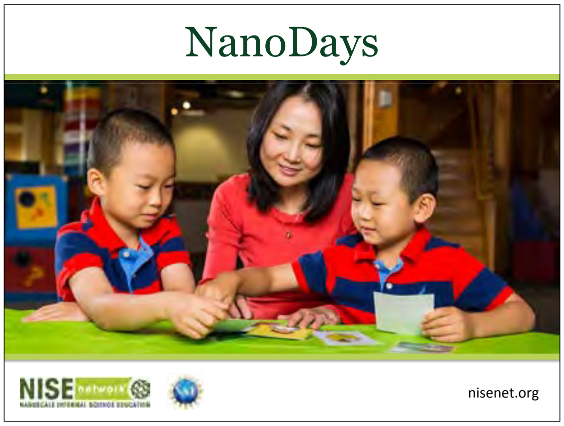
• Encourage participants to **brainstorm** places they have seen iridescent colors before. Some examples are soap bubble, an oil slick on water, and even butterfly wings; all of which are examples of thin films.

HIGHLIGHT ALTRUISM

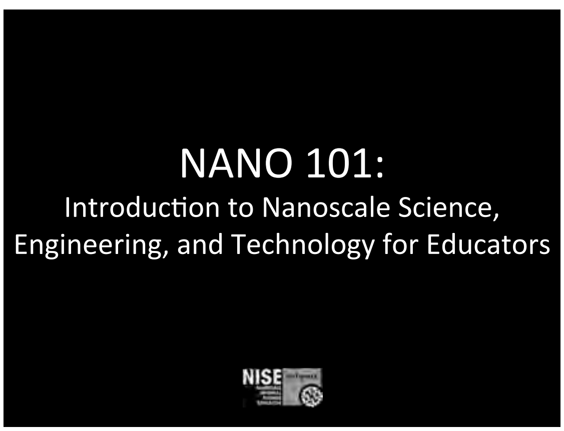
• **Oil spills** are a big problem for ocean life and the health of our planet. You saw how quickly one drop of nail polish could spread and create a nanofilm on the surface of water. How did the size and shape of the droplet change when it came in contact with the water's surface? Can you measure it? Imagine you were tasked with cleaning up

(continued on reverse)

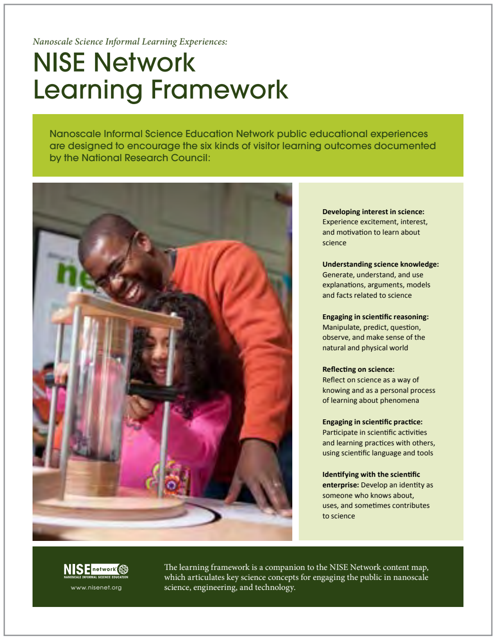
Tips for Engaging Girls Cards
8.5 x 5.5 inches
8 pages



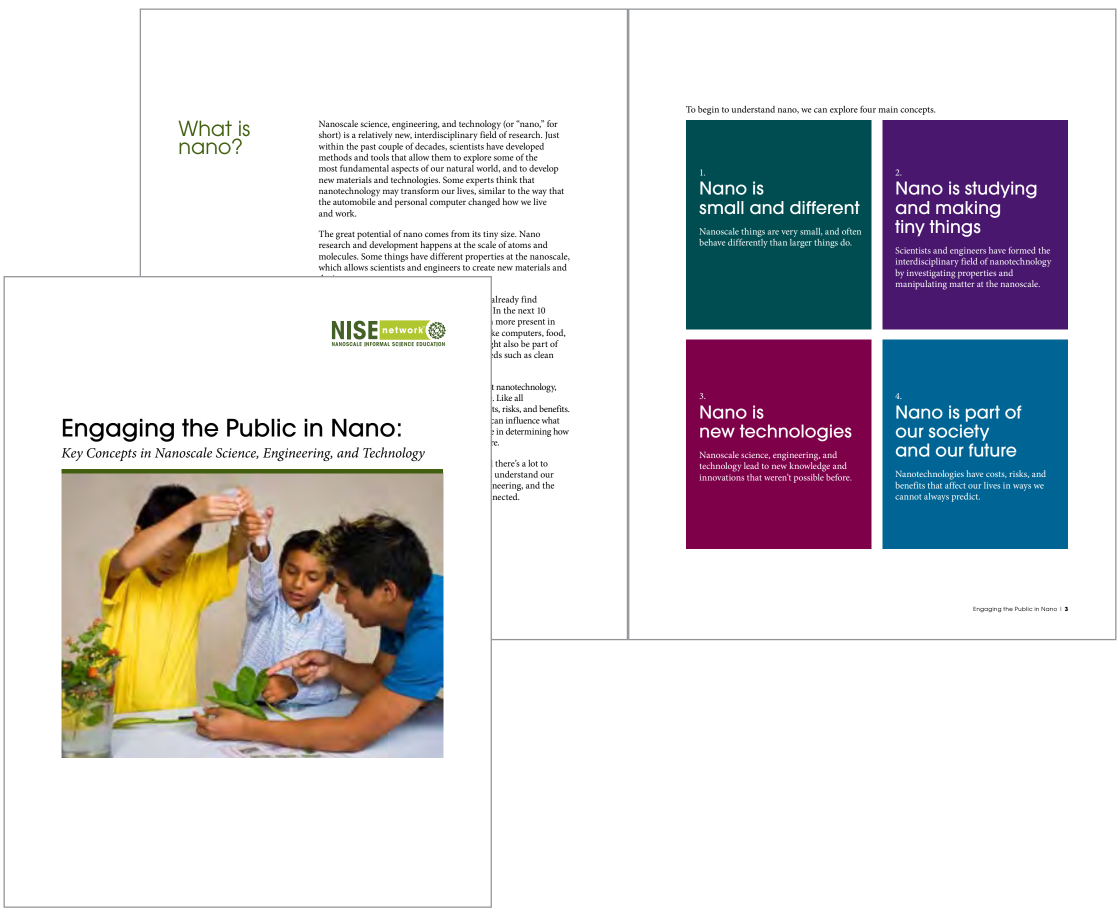
NanoDays Orientation Presentation
19 slides



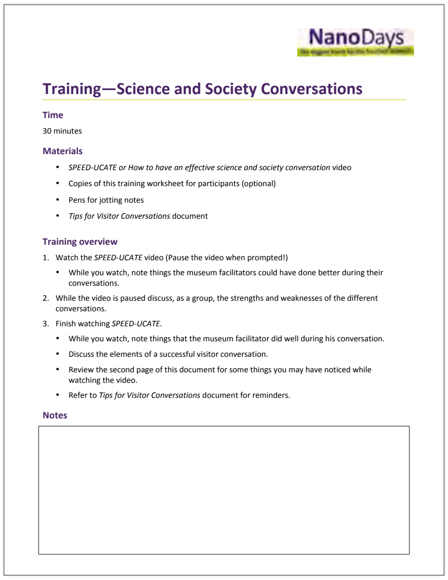
Nano 101 (for staff)
24 slides



Learning Framework
2 pages



NISE Net Key Concepts
32 pages



NanoDays

Training—Science and Society Conversations

Time

30 minutes

Materials

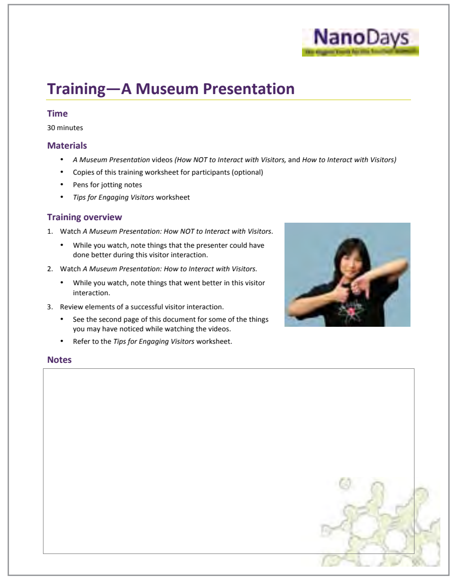
- *SPEED-UCATE or How to have an effective science and society conversation* video
- Copies of this training worksheet for participants (optional)
- Pens for jotting notes
- *Tips for Visitor Conversations* document

Training overview

1. Watch the *SPEED-UCATE* video (Pause the video when prompted!)
   - While you watch, note things the museum facilitators could have done better during their conversations.
2. While the video is paused discuss, as a group, the strengths and weaknesses of the different conversations.
3. Finish watching *SPEED-UCATE.*
   - While you watch, note things that the museum facilitator did well during his conversation.
   - Discuss the elements of a successful visitor conversation.
   - Review the second page of this document for some things you may have noticed while watching the video.
   - Refer to *Tips for Visitor Conversations* document for reminders.

Notes

Conversations Training Video Guide
2 pages



NanoDays

Training—A Museum Presentation

Time

30 minutes

Materials

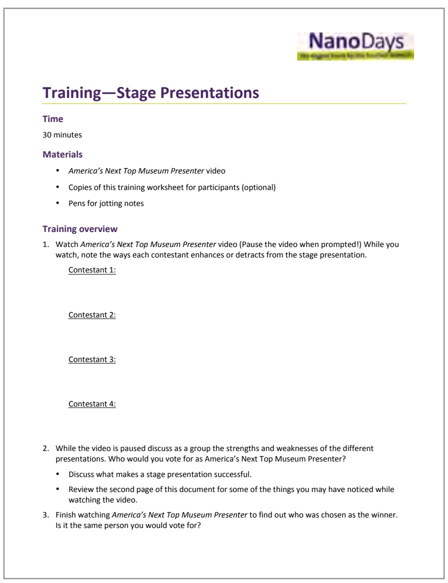
- *A Museum Presentation* videos *(How NOT to Interact with Visitors,* and *How to Interact with Visitors)*
- Copies of this training worksheet for participants (optional)
- Pens for jotting notes
- *Tips for Engaging Visitors* worksheet

Training overview

1. Watch *A Museum Presentation: How NOT to Interact with Visitors.*
   - While you watch, note things that the presenter could have done better during this visitor interaction.
2. Watch *A Museum Presentation: How to Interact with Visitors.*
   - While you watch, note things that went better in this visitor interaction.
3. Review elements of a successful visitor interaction.
   - See the second page of this document for some of the things you may have noticed while watching the videos.
   - Refer to the *Tips for Engaging Visitors* worksheet.

Notes

How To / Not To Video Guide
2 pages



NanoDays

Training—Stage Presentations

Time

30 minutes

Materials

- *America's Next Top Museum Presenter* video
- Copies of this training worksheet for participants (optional)
- Pens for jotting notes

Training overview

1. Watch *America's Next Top Museum Presenter* video (Pause the video when prompted!) While you watch, note the ways each contestant enhances or detracts from the stage presentation.

   Contestant 1:

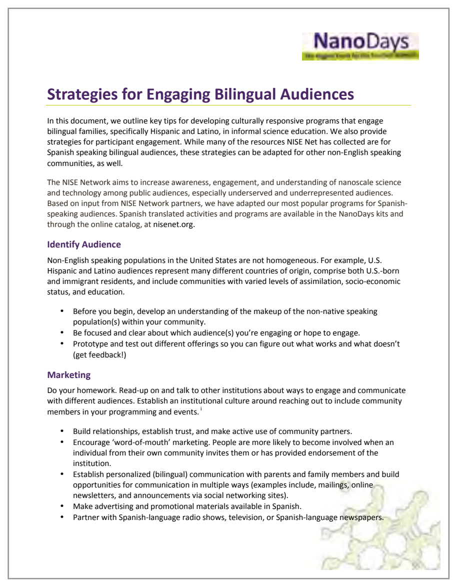
   Contestant 2:

   Contestant 3:

   Contestant 4:

2. While the video is paused discuss as a group the strengths and weaknesses of the different presentations. Who would you vote for as America's Next Top Museum Presenter?
   - Discuss what makes a stage presentation successful.
   - Review the second page of this document for some of the things you may have noticed while watching the video.
3. Finish watching *America's Next Top Museum Presenter* to find out who was chosen as the winner. Is it the same person you would vote for?

Stage Presentations Training Video Guide
2 pages



NanoDays

Strategies for Engaging Bilingual Audiences

In this document, we outline key tips for developing culturally responsive programs that engage bilingual families, specifically Hispanic and Latino, in informal science education. We also provide strategies for participant engagement. While many of the resources NISE Net has collected are for Spanish speaking bilingual audiences, these strategies can be adapted for other non-English speaking communities, as well.

The NISE Network aims to increase awareness, engagement, and understanding of nanoscale science and technology among public audiences, especially underserved and underrepresented audiences. Based on input from NISE Network partners, we have adapted our most popular programs for Spanish-speaking audiences. Spanish translated activities and programs are available in the NanoDays kits and through the online catalog, at nisenet.org.

Identify Audience

Non-English speaking populations in the United States are not homogeneous. For example, U.S. Hispanic and Latino audiences represent many different countries of origin, comprise both U.S.-born and immigrant residents, and include communities with varied levels of assimilation, socio-economic status, and education.

- Before you begin, develop an understanding of the makeup of the non-native speaking population(s) within your community.
- Be focused and clear about which audience(s) you're engaging or hope to engage.
- Prototype and test out different offerings so you can figure out what works and what doesn't (get feedback!)

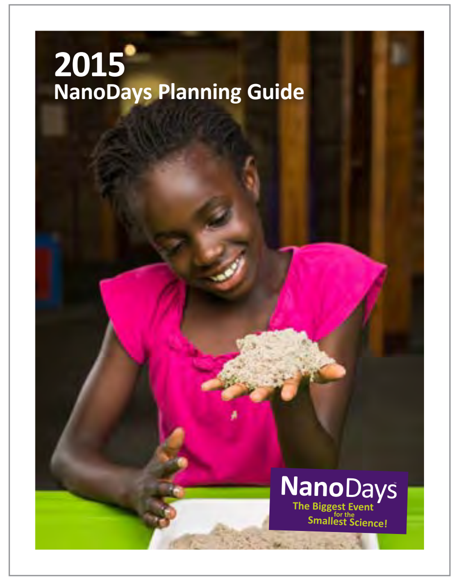
Marketing

Do your homework. Read-up on and talk to other institutions about ways to engage and communicate with different audiences. Establish an institutional culture around reaching out to include community members in your programming and events.[i]

- Build relationships, establish trust, and make active use of community partners.
- Encourage 'word-of-mouth' marketing. People are more likely to become involved when an individual from their own community invites them or has provided endorsement of the institution.
- Establish personalized (bilingual) communication with parents and family members and build opportunities for communication in multiple ways (examples include, mailings, online newsletters, and announcements via social networking sites).
- Make advertising and promotional materials available in Spanish.
- Partner with Spanish-language radio shows, television, or Spanish-language newspapers.

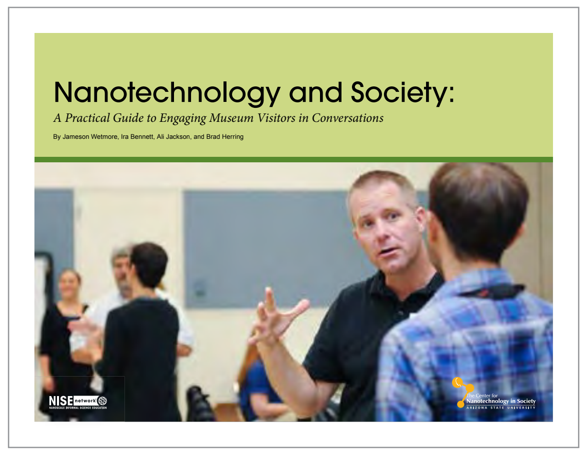
Strategies for Engaging Bilingual Audiences
3 pages

Universal Design Guidlines Guide
26 pages

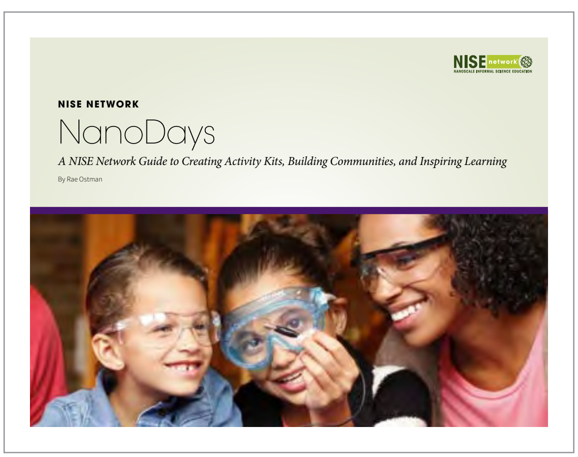


NanoDays Planning Guide
48 pages

TBI Guide
62 pages



Nano & Society Guide
28 pages

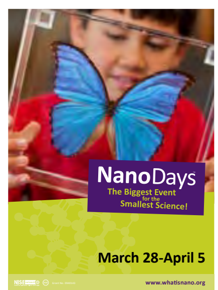


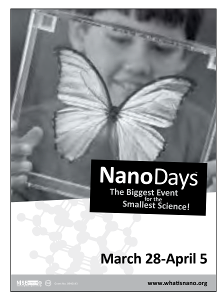
NanoDays Guide
36 pages

Programs Guide
51 pages

Marketing Materials

Logos, ads, posters, press photos, and other marketing materials are included in the NanoDays Marketing Materials Appendix





NanoDays Press Photos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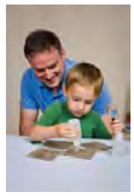
Credit: Gary Hodges, Sciencenter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Credit: Gary Hodges, Sciencenter


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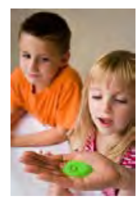
Credit: Gary Hodges, Sciencenter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Credit: Gary Hodges, Sciencenter


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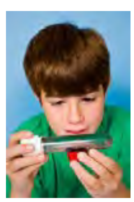
Credit: Gary Hodges, Sciencenter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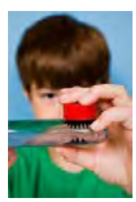
Credit: Gary Hodges, Sciencenter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Credit: Gary Hodges, Sciencenter


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Credit: Gary Hodges, Sciencenter


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Credit: Gary Hodges, Sciencenter


NISE_Net_press_photo_0042.jpg
Credit: Gary Hodges, Sciencenter


NISE_Net_press_photo_0043.jpg
Credit: Gary Hodges, Sciencenter

Activity Index