This PDF of classroom resources accompanies The Amazing Nano Brothers Juggling Show Educator Guide.
# Classroom Activities & Extensions

The following fun activities can serve as pre- or post-show classroom enrichment and can be modified to meet your students’ needs. They have been tested and shown to be engaging and effective. The included activities are summarized below, and the activity guides and resources can be found on the following pages. These activities were excerpted from The National Informal STEM Education Network’s (NISE Network) Programs and Activities Catalog (http://www.nisenet.org/search/product_type/programs-and-activities-10) and the NISE Network DIY Nano book (http://www.nisenet.org/catalog/diy-nano-book). They are designed to be easily edited and adapted for different audiences under a Creative Commons Attribution Non-Commercial Share Alike license.

Contact nano@mos.org with questions.

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<td><strong>Ready, Set, Fizz:</strong> In this activity, students conduct a simple hands-on experiment using large and small pieces of effervescent antacid tablets to discover that small things are more reactive than big things. <strong>Learning goals:</strong> Materials act differently at the nanoscale. A nanometer is a billionth of a meter. Full activity from NISE: <a href="http://www.nisenet.org/sites/default/files/catalog/uploads/9881/diy_nano_print_fizz_03_21.pdf">http://www.nisenet.org/sites/default/files/catalog/uploads/9881/diy_nano_print_fizz_03_21.pdf</a></td>
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<td><strong>Mystery Shapes:</strong> In this hands-on activity, students learn how a scanning probe microscope works by using their sense of touch to identify objects that are hidden out of sight in a bag or box. <strong>Learning goals:</strong> Nano is too small to see. Scientists need special microscopes to “see” things at the nanoscale. A nanometer is a billionth of a meter. Full activity from NISE: <a href="http://www.nisenet.org/catalog/programs/exploring_tools_-_mystery_shapes_nanodays_2013">http://www.nisenet.org/catalog/programs/exploring_tools_-_mystery_shapes_nanodays_2013</a></td>
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<td><strong>Tiny Ruler &amp; Cutting it Down to Nano:</strong> In these hands-on activities, students attempt to cut a paper ruler down to the nanoscale. The goal of the activity is to cut the ruler in half as many times as possible. Most people can only make about 7 cuts to the paper, resulting in a piece of paper about 1 millimeter, but a nanometer is one million times smaller than a millimeter! It would take 27 cuts to get down to the nanoscale! <strong>Learning goals:</strong> Nano is too small to see. A nanometer is a billionth of a meter. Scientists need special tools to work at the nanoscale. Full activity from NISE: <a href="http://www.nisenet.org/catalog/exploring-size-tiny-ruler-nanodays-08-09-10">http://www.nisenet.org/catalog/exploring-size-tiny-ruler-nanodays-08-09-10</a> Similar activity from NISE (Cutting it Down to Nano) with worksheet: <a href="http://www.nisenet.org/catalog/cutting-it-down-nano">http://www.nisenet.org/catalog/cutting-it-down-nano</a></td>
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| 3 – 8        | **What Am I? Mystery Cards:** In this hands-on activity, students flip between macro and nanoscale images of familiar objects on cards to learn about concepts in nanoscience and nanotechnology.  
**Learning goals:**  
Things at the nanoscale behave differently than bigger things  
Nanotechnology is making and studying materials at the nanoscale  
A nanometer is a billionth of a meter  
Full activity from NISE: [http://nisenet.org/catalog/what-am-i-mystery-cards](http://nisenet.org/catalog/what-am-i-mystery-cards) | 37 – 46 |
| 5 – 8        | **Powers of Ten:** This card game activity explores the relative sizes of objects. Students compete to organize their hand of cards into lists of objects from largest to smallest. This activity is recommended for upper-elementary and middle school students, but it can be adapted for younger grades by simply sorting images from largest to smallest.  
**Learning goals:**  
The size of an object is important  
A nanometer is a billionth of a meter  
| 6 – 8        | **Nano and Society Posters:** In this interactive discussion activity, students explore the relationship between nanotechnology and society. Posters with text and images are used to spark conversations about how nanotechnology will affect our lives and what the risks and benefits of different technologies might be.  
**Learning goals:**  
Nanoscience and nanotechnology are relevant to our lives  
Nanoscience and nanotechnology are leading to new products and innovations  
As with any new technology, we should be aware of potential risks.  
Try measuring little things!

ladybug

grain of sand

ant
A nanometer is a billionth of a meter.

A millimeter is a thousandth of a meter.

A centimeter is a tenth of a meter.

A meter is the basic unit of length.
How Big Is Your Hand?

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

My name is _____________________________________________________________

My hand is ____________________________________________________________ nanometers long!
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!

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.
CUTTING IT DOWN TO NANO

Cut paper strips in half. Tape onto worksheet. Repeat.

150,000,000 nanometers: length of a pencil

0

75,000,000 nanometers: length of a stick of gum

1

37,500,000 nanometers

2

18,750,000 nanometers: diameter of a dime

3

9,375,000 nanometers: width of a sugar cube

4

4,688,000 nanometers

5

2,344,000 nanometers: head of a pin

6

1,172,000 nanometers

7

586,000 nanometers

8

293,000 nanometers: length of a dust mite

9

146,000 nanometers

10

73,000 nanometers: width of a human hair

11

36,600 nanometers

12

18,300 nanometers

13

9,200 nanometers: length of a red blood cell

14

4,600 nanometers

15

2,300 nanometers

16

1,100 nanometers: length of bacteria

17

570 nanometers: width of pits on CD

18

296 nanometers

19

143 nanometers

20

72 nanometers: length of a virus

21

36 nanometers

22

18 nanometers

23

9 nanometers: thickness of cell membrane

24

4.5 nanometers

25

2.2 nanometers: width of the DNA helix

26

1.1 nanometers: length of 10 hydrogen atoms

27
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.)

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.

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

1. Things come in different sizes—and size is important!
2. 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.

Related educational resources

The NISE Network online catalog (www.nisenet.org/catalog) contains additional resources to introduce visitors to the nanoscale and nanometers:

- Public programs include Cutting it Down to Nano and Shrinking Robots!
- Media include How Small is Nano?, Image Scaler Software, Intro to Nano, Multimedia Zoom into a Human Hand, Multimedia Zoom into a Nasturtium Leaf, Scale Ladder, Zoom into a Butterfly Wing, Zoom into a Computer Chip, and Zoom into the Human Bloodstream.
- Exhibits include At the Nanoscale and Three Drops.

Credits and rights

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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Eagle Nebula

+17

Black hole

+11

The Universe

+26

Red Giant star

+10

Milky Way

+20
Blue whale

Football field

School gym

Cruise ship

Train engine

Statue of Liberty
Amoeba

Ant

Paramecium

Microprocessor

Dust mite

Grain of sand

Image courtesy of IBM
Neutron

Radon nucleus

Proton

Helium nucleus
Ready, Set, Fizz!

Which fizzes faster—big pieces or little pieces?

Description

In this activity, kids explore the chemical reaction between water and effervescent antacid tablets.

Suitable for kids of all ages.

Materials

4 cups or glasses  
(onces that you can see through are best)
Effervescent antacid tablets
Water
Food coloring

Time

Preparation: 5 minutes
Activity: 5 minutes
Cleanup: 5 minutes

Safety

Do not eat or drink any of the materials in this activity. The antacid tablets contain medication. Supervise children at all times.
Step 1
Fill two of the cups halfway with water.
Put the same amount of water in each cup.
Add a drop of food coloring to each cup.

Step 2
Remove two antacid tablets from their wrapper.
Drop one into one of the empty cups.
Crush or break the other tablet into many small pieces, and put it in the other empty cup.

Step 3
At the same time, pour the colored water into both of the cups containing the antacid.
Which fizzes up faster, the whole tablet or the tablet you broke into lots of pieces?
What’s going on?

The crushed tablet fizzes faster than the whole 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.

How is this nano?

A material can act differently when it’s nano-sized. A nanometer is a billionth of a meter.

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.

For example, nano-sized particles of aluminum are explosive. Good thing regular-sized aluminum doesn’t explode, or it would be dangerous to drink soda pop!

Surface area

Nanotechnology takes advantage of the way things behave differently at the nanoscale to make new products and applications.

For example, an extra-sticky glue can be made from tiny starch molecules that are only 100 nanometers in size. This eco-friendly adhesive is used to stick graphics onto cardboard packaging.
Learn more
Learn more at:
www.whatisnano.org

Credits
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Activity photographs, Gary Hodges Photography
Images of soda can and hamburger, www.istockphoto.com
Mystery Shapes

Can you see by feeling?

**Description**

In this activity, kids describe an object they can’t see!

Suitable for kids ages 3 and up.

**Materials**

Pillow case
(or other opaque sack-like bag)

Assorted small objects
(such a letter blocks, rubber balls, small plastic animals or toys)

Paper
(you can use the print out provided)

Pens or pencils

Bandana or eye-mask (optional)

*Note: Online craft stores sell ready-made assortments of different plastic shapes.*

**Time**

**Preparation:** 5 minutes

**Activity:** 10 minutes or longer

**Cleanup:** 5 minutes

**Safety**

Use normal precautions while doing this activity. Avoid objects that may be a choking hazard.
Step 1
Grown-ups, get everything ready!
Pick out a few objects and place them in the pillowcase, but be sure to keep the other objects out of sight.

Step 2
Kids, investigate the hidden objects!
Without looking, put your hands into the pillowcase. What do your feel?
Draw a picture or use detailed words to describe what you feel inside the bag.

Step 3
Compare! Now, take the object out of the bag and compare it to your picture. What information does your drawing include? What’s missing?
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.”

SPMs let us make images of tiny, nano-sized things like atoms that are much too small to see, even with powerful light microscopes.

How is this nano?
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. That’s really, really small.

Scanning Probe Microscopes
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!
I Spy Nano! Find the hidden objects in the picture. They all use nanotechnology!

**Pencil**
Carbon atoms can form graphite (pencil “lead”), which is a very soft material, but they can also form diamond, the hardest natural material known on Earth. Atoms are the building blocks of nature, and they’re even smaller than a nanometer.

**Diamond ring**
Carbon atoms can form diamond, the hardest natural material known on Earth, but they can also form graphite, a very soft material. Atoms are the building blocks of nature, and they’re even smaller than a nanometer.

**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 only two nanometers across.

**Butterfly**
The brilliant color of the Blue Morpho butterfly is actually created by tiny, colorless nanostructures! Light waves bounce off the tiny structures, reflecting blue light to your eyes.

**Smartphone**
Computer chips have tiny, nano-sized parts. So when you use a smartphone, computer, gaming console, or any other electronic device with a chip, you’re using nanotechnology!

**Lemon**
The shapes of scent molecules give them their smell. Molecules are made up of atoms. They’re measured in nanometers, so your nose is your very own nano detector!

**Solar cell**
New flexible solar cells contain nano-sized structures and materials, allowing them to be less expensive and more efficient.

**Sunblock**
Many sunblocks contain nano-sized particles of zinc oxide or titanium dioxide, which protect skin from the sun’s rays without leaving a visible white film.

**Ice cream**
Nanotechnology is already on the shelves of your supermarket. Edible nanostructures make ice cream look and taste better.

**Golf club**
Tiny carbon nanotubes make some bicycles, golf clubs, and tennis rackets stronger and lighter.
what am I?

I have tiny transistors that are only 30 nanometers across.
A nanometer is a billionth of a meter.
Computer chips have nano-sized transistors that make them small and fast.
whatisnano.org
Nano view:
what am I?

I have particles of titanium dioxide that are only 50 nanometers across. A nanometer is a billionth of a meter.
Many sunblocks go on clear because they have nano-sized particles of titanium dioxide.

whatisnano.org
Nano view: what am I?

My feet have tiny “hairs” that are only nanometers across.
A nanometer is a billionth of a meter.
Geckos can walk upside down because their feet have millions of nano-sized “hairs.”
whatisnano.org
Nano view:
what am I?

I have bumps covered in tiny, nano-sized whiskers.
A nanometer is a billionth of a meter.

Flip to find out!
Lotus leaves shed water because they have bumps covered in nano-sized whiskers.
whatisnano.org
A nanometer is a billionth of a meter.

I get my blue color from tiny structures only 400 nanometers long.
A nanometer is a billionth of a meter.
Macro view: Blue Morpho butterfly

Flip to look closer!

Blue Morpho butterflies get their color from transparent, nano-sized structures.
whatisnano.org

Macro view: Blue Morpho butterfly

Flip to look closer!

Blue Morpho butterflies get their color from transparent, nano-sized structures.
whatisnano.org
Nano and Society Poster Guide for Grade 6-8 Classroom Use  
(Adapted from the NISE Network)

Big idea:
Nanotechnology is relevant to everyone’s lives, and has important societal and ethical implications.

Learning goals:
Explore the following ideas:

1. Nanoscience and nanotechnology lead to new applications.

2. Like any technology, nanotechnology has risks and benefits.

3. Because nanotechnology has new applications, including innovative applications for known materials, we need to evaluate and reevaluate risks and benefits carefully.

National Science Education Standards:
Personal and Social Perspectives
- K--4: Science and technology in local challenges
- 5--8: Risks and benefits
- 5--8: Science and technology in society

Program Delivery (Adapted for classroom use)

Encourage students to discuss the questions raised on the posters, encouraging them to think about how nanotechnology might affect society. The posters use provocative questions and images, because they were designed to challenge people to think about emerging technologies in a different way.

Suggested classroom activities:
- Students read about one or two of the posters on their own or in groups and then share their thoughts about the poster questions in whole class discussion.
- Students read about the posters and write a brief essay (alone or in pairs) on one or two of the poster topics.
Will nanotechnology solve our energy crisis?

Nanotechnology is improving how we harness the sun's energy.

Nanotechnologies could deliver world-altering changes in the ways we create, transmit, store, and use energy. Scientists are working to develop super-efficient batteries, low-resistance transmission lines, and cheaper solar cells. However, the likelihood and time frame of these developments is unknown.

The next generation of solar cells is thin film solar cells—flexible sheets of solar panels—that are easier to produce and install, use less material, and are cheaper to manufacture. These sheets can be incorporated into a briefcase that charges your laptop, woven into wearable fabrics that charge your cell phone and iPod, or incorporated into windows that can supply power to high-rise buildings.

Nanotechnology-enabled energy production and distribution has the potential to solve a number of pressing energy issues. Reworking our enormous, highly integrated energy infrastructure will not be an easy task. How can these new technologies fit into domestic energy policies to best benefit society?
Can nanotechnology solve our energy crisis?

Well, we don’t know. But imagine for a moment what it would be like if we had windows that supply power to buildings, affordable paint-on solar energy technologies or super-efficient batteries to power our cars. Rising energy costs, dwindling natural resources, pollution, and climate change concerns have drawn increasing attention to the relationship between human activity and the earth’s environment. Alternative and renewable energy sources and efforts towards conservation are in the public eye and in the priorities of public service officials and industry leaders as never before.

Policymakers face difficult choices when deciding how to allocate funding for energy and the environment. How should nanotechnology research fit into domestic energy policies in the future? Should the bulk of research funding be dedicated to the implementation of existing technologies, or should more effort be dedicated to designing new technologies that could be of greater long-term impact? These are important questions and we as a society must decide to pursue this technology if we wish to see it developed.

What factors do we need to consider?

Nanoparticles could allow us to build ultra-efficient transmission lines for electricity, produce far more effective and inexpensive solar cells, make cheaper and more efficient biofuels from a wide variety of sources, and improve the safety and efficiency of existing nuclear reactors. Other developments made possible by nanotechnology might one day do far more to lessen the human impact upon the environment than current alternative and renewable energy options. Reaping these advantages, however, will not be easy. For instance:

1. The scope and timetable of nanotechnology’s contribution to alternative and renewable energies is uncertain. Immediate action to address increasing energy costs and global climate change may be necessary, but the ultimate benefit, risk, and short-term effects of nanotechnology remain unknown.

2. Governments and corporations will have to decide how nanotechnology will be used to generate and distribute energy. One model focuses on making existing power plants more efficient or developing new types of power plants. This model is basically our current model where power is generated by large corporations and governments and then distributed to people who need it. Another model is to decentralize the generation of power through small solar cells. This could allow individuals to produce their own power and then use it as they see fit. Some argue that if people generate their own energy they will use less of it, but it may be that only wealthy people have the ability to generate their own power. We should consider how these technological decisions will affect people of all walks of life. We can certainly work on both approaches, but there will be interest groups trying to push policy in specific directions.
Will nanotechnology improve living conditions around the world?

Nanofilters can produce safe drinking water.

In many parts of the world, people don't have access to safe drinking water. New nanofiber water filters can remove bacteria, viruses, heavy metals and organic materials from water. They're relatively inexpensive and easy to use, so nanofilters could be widely employed in developing countries.

Providing pure drinking water would help prevent disease in many parts of the world, but it wouldn't resolve many basic inequalities.

Emerging technologies can help us address specific problems, but there's no “magic bullet” to improve life for all human beings. How can we develop and share promising nanotechnologies in ways that are equitable and responsible?
Risks vs. Benefits

- **Can nanotechnology benefit me?**

  Well, we don’t know. But imagine for a moment what it would be like if we had windows that cleaned themselves, affordable paint-on solar energy technologies, or drugs that targeted only the tumor and not the patient’s healthy cells. Currently, the majority of nanotechnology products available are targeted to wealthy consumers in such things as stain-resistant dress pants, smoother cosmetics, and golf clubs and tennis rackets that are stronger and lighter. But nanotechnology can also be used to address many problems in developing countries. In addition to being used for fighting disease, nanotechnology has been employed to purify water, improve food preservation and develop new materials used for shelter.

- **Could nanotechnology be dangerous?**

  Yes. We already know that some nanotechnologies are dangerous and many others that we currently know less about could also be dangerous. But just because something is dangerous doesn’t mean we shouldn’t use it. We use a lot of dangerous things today in our everyday lives. Gasoline, for instance, is extremely toxic and flammable, but because its use is so prevalent and necessary, we take steps to use it safely. There are strict regulations about how gasoline can be produced, transported and sold. Of course, there is always a chance for accidents, but regulations help a great deal to make our use of gasoline safe. A similar approach should apply to nanotechnology. We should use it when it is most beneficial for our needs, but develop regulations to prevent nanotechnology from being mishandled or applied in dangerous ways.

  The dangers posed by nanotechnology might be bigger than other technologies because they are impossible to see and difficult to detect, and the ultimate dangers might not be seen for a long time. Scientists, engineers, social scientists, lawyers and other specialists are already working to determine what the effects of some of the applications will be and their work is helping us to understand nanotechnology better. However, we can never know the full effect or dangers of a new technology until it is being regularly utilized. Nanotechnology is no exception.
Would you use a dangerous technology?

Gasoline is toxic and flammable.

Gasoline can be dangerous, but because it’s useful, we have regulations for producing, transporting and using it safely. It’s part of our daily lives, so we rarely consider all the systems we have in place to make gasoline safe. But when emerging energy technologies hit the market, we’ll need to create new regulations to ensure safety.

New applications of nanotechnology might provide clean, efficient sources of energy. If so, they’ll have a profound effect on our society. After all, our reliance on gasoline-powered transportation affects our daily lives, the design of our communities and our natural environment.

As new technologies—including nanotechnologies—are developed, we’ll reap new benefits but also face new risks. And our lives, relationships and ways of looking at the world will change in ways we can’t always predict. How can we think ahead and plan for these changes?
Risks vs. Benefits

■ Can nanotechnology benefit me?
Well, we don’t know. But imagine for a moment what it would be like if we had windows that cleaned themselves, affordable paint-on solar energy technologies, or drugs that targeted only the tumor and not the patient’s healthy cells. Currently, the majority of nanotechnology products available are targeted to wealthy consumers in such things as stain-resistant dress pants, smoother cosmetics, and golf clubs and tennis rackets that are stronger and lighter. But nanotechnology can also be used to address many problems in developing countries. In addition to being used for fighting disease, nanotechnology has been employed to purify water, improve food preservation and develop new materials used for shelter.

■ Could nanotechnology be dangerous?
Yes. We already know that some nanotechnologies are dangerous and many others that we currently know less about could also be dangerous. But just because something is dangerous doesn’t mean we shouldn’t use it. We use a lot of dangerous things today in our everyday lives. Gasoline, for instance, is extremely toxic and flammable, but because its use is so prevalent and necessary, we take steps to use it safely. There are strict regulations about how gasoline can be produced, transported and sold. Of course, there is always a chance for accidents, but regulations help a great deal to make our use of gasoline safe. A similar approach should apply to nanotechnology. We should use it when it is most beneficial for our needs, but develop regulations to prevent nanotechnology from being mishandled or applied in dangerous ways.

The dangers posed by nanotechnology might be bigger than other technologies because they are impossible to see and difficult to detect, and the ultimate dangers might not be seen for a long time. Scientists, engineers, social scientists, lawyers and other specialists are already working to determine what the effects of some of the applications will be and their work is helping us to understand nanotechnology better. However, we can never know the full effect or dangers of a new technology until it is being regularly utilized. Nanotechnology is no exception.
What’s hidden in your sunblock?

Many sunblocks contain nanoparticles.

If your sunblock rubs in clear, it might contain nanoparticles. Nanosized particles of zinc oxide or titanium dioxide are too small to reflect light, so they don’t leave a white film on skin. The label will tell you the ingredients in your sunblock, but it doesn’t have to say what size the particles are.

Although studies suggest that the sunblocks are safe for humans, some people worry that the tiny nanoparticles may impact the environment when they wash off our skin.

Nanotechnologies are difficult to regulate because they’re hard to detect and to define, and we don’t really know how safe or dangerous they are. Do you think manufacturers should be required to let you know if their products contain nanotechnology? Would you use a sunblock with nanoparticles in it on your skin?
Under what conditions should nanotechnology applications in medicine and personal care products be made available to the public?

This is an extremely important question. But it is not a question that science alone can answer. It is a question you should ask yourself and discuss with your friends and even your political representatives. Science can help us to understand what risks might be involved, but research alone doesn’t reveal every problem and, ultimately, choosing to accept risks is a value judgment. So we should address this question on a personal level as well as part of a broader community.

On a personal level, many people are willing to take more risks with medicine than with personal care products. For instance, iron oxide nanoparticles are considered a promising contrasting agent used in Magnetic Resonance Imaging (MRI) to detect the presence of tumors. Currently there are no approved nanotechnology-enabled contrast agents for humans, but recent research has discovered that these particles exhibit toxic effects on nerve cells in mice. If a nanotechnology-enhanced shampoo were to involve such dangers, few people would be willing to use it. But because cancer is such a deadly disease and the treatments we have for it already are so dangerous, those who suffer from cancer may be willing to expose themselves to potentially dangerous nanoparticles in seeking a cure.

Individual personal decisions about nanotechnology are incredibly important, but they are not enough. Every time we use a product enhanced by nanotechnology, our actions could affect other people. For instance, the nanoparticles used in cosmetics affect us directly by being absorbed by the skin, but ultimately the containers are disposed of and product residue could potentially end up elsewhere in the environment. Some people have decided that while it would be nice to have nanosilver socks that keep their feet from smelling bad, they won’t purchase them because they don’t know enough about the potential environmental consequences of nanosilver. So we have to make conscious and collective choices about how we want nanotechnology to be used.

It should also be noted that a great number of personal care products are enhanced through nanotechnology. Many cosmetics and sunscreens use nanoparticles of titanium dioxide to help block the sun’s rays or to provide a smoother look when applied. Initially, a number of these companies proudly labeled their products as nanotechnology-enabled. As public concerns about nanotechnology rose, a number of these companies removed the label—but not the nanoparticles—to help limit public concern. There is currently a debate over whether companies that include nanoparticles in their products should be required to label them as such to help the public make an informed choice. Do you think these products should be labeled? If so, how much extra are you willing to pay to ensure that such labels exist?
Are you being tracked?

New surveillance tags are so small, you might never know.

Radio Frequency Identification (RFID) is used for logging livestock, library books—and you. If you have a U.S. passport issued after 2006, it contains an RFID tag. You might also have a transponder in your car to pay road tolls. The human hands in this x-ray have RFID devices embedded in them, similar to identification chips used for pets.

Many people find that the convenience of tracking tags outweighs their concern for privacy. But in the future, tiny nanosized surveillance devices would be impossible to detect without special equipment. Some existing tags are already as small as dust! How do you feel about tracking now? Would you feel differently if the size of the sensors changed?

Currently, the ability to read these tags at a distance is limited to a few feet. Nanotechnology could help make smaller, more powerful tags and sensors. As these tags and sensors get smaller and the technology to read them improves, it may be more difficult to protect individual privacy. Would you use a tiny tag to watch a rebellious teen? What about an elderly parent with Alzheimer’s?
Privacy

- **Our right to privacy**

  There are certain things that we justifiably don’t want others to know about us. The right to privacy is an important cornerstone of our society and not necessarily because we want to be able to get away with doing illegal things. Rather, we would like some control over how others perceive us and believe that some level of privacy will help us to do that. Some people feel that new technologies will make privacy even more difficult to secure.

  Traditionally, we’ve been able to make mistakes and move on. But the development of technologies like camera phones now make it increasingly difficult to keep embarrassing photos, for instance, from showing up on the Internet. Most people believe that the small errors in judgment they make in their personal life shouldn’t prevent them from getting a job. However, applications like Facebook sometimes make it difficult for us to maintain privacy and keep our social life separate from our work life.

- **How can nanotechnology affect someone’s privacy?**

  Nanotechnology may compromise our privacy in two important ways: First, it will aid in producing sensors that are practically undetectable. And second, it may help to link different sensors so that vast amounts of information can be collected and assembled in one place.

  Video surveillance technology has become a part of our everyday lives. When we walk into some stores, for instance, we can sometimes see that a camera is monitoring us and we may even see a television with our picture. Using nanotechnology, it may soon be possible to make sensors so small that they would be invisible to the naked eye and almost impossible to detect without special equipment. On the flip side, nanotechnology-enabled sensors could be used to detect chemicals in the air and prevent a terrorist attack in a crowded area such as a stadium. Or, they could be used to detect any trace of alcohol on a driver trying to start a car.

  Where does the need for privacy outweigh the need for security? What amount of privacy would you exchange for convenience? The ways that nanotechnology can be used to secretly collect and share data prompts a lot of social, ethical and political questions. We as citizens will have to make these choices, so we should carefully consider what values are most important to us and find appropriate ways to support them.

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The NISE Network  
www.whatisnano.org  
nano & me: Nanotechnology in our lives  
http://www.nanoandme.org/social-and-ethical  
Nano and Society FAQ  
http://cns.asu.edu/nanoquestions  
The Responsible Nano Forum  
www.responsiblenanoforum.org
Any technology has risks and benefits. When one person or group benefits, others may be put at risk. Who should make decisions about whether to use certain nanotechnologies? Does it make sense to use nanosilver catheters to prevent infections in hospitals? What about using a nanosilver washing machine at home?
Regulatory Issues

Who watches out for potential risks posed by nanotechnology?

There is no one regulatory agency that oversees nanotechnology, but the U.S. government’s Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA) are currently developing ways to monitor the effects of nanotechnology. Because nanotechnology is so difficult to identify, and is still an emerging science, we don’t really know yet how safe or dangerous it is—for people or things. So far, the government hasn’t regulated anything specifically because it was enhanced by nanotechnology, but it has weighed in on its use in some products.

Samsung’s “SilverCare” washing machine, for instance, claimed that its product used silver ions to “kill” 99.9% of bacteria in clothes. This claim caught the attention of the EPA, which argued that because Samsung advertised that its washing machine “killed” bacteria, the product should be regulated under the Federal Insecticide Fungicide and Rodenticide Act (or FIFRA). The EPA required Samsung to substantiate the safety precautions the company had taken with SilverCare. Instead, Samsung decided simply to change its advertising to claim that the washer “eliminates” bacteria, which the EPA has chosen not to regulate.

Who else could help regulate nanotechnology?

Another major group that could regulate nanotechnology is you—the public. Recently, a company called Pure Plushy sold a teddy bear that was embedded with silver nanoparticles to prevent dust mites, bacteria and mold from growing on it. By eliminating these organisms, the bear—known as Benny the Bear—could be enjoyed by children with severe asthma and allergies. Benny became famous when Andrew Maynard of the Woodrow Wilson International Center asked publicly whether it was safe for a child to chew on a bear that had nanosilver embedded in it, which the company assured that it was.

Scientists know that nanosilver can be very dangerous for fish and other aquatic life, but there haven’t been any studies showing that nanosilver can be bad for people. In fact, people have been using colloidal silver as an antibiotic treatment for many illnesses and infections for centuries. Pure Plushy took this to mean that its product was safe. But as Maynard and others wrote more articles questioning whether enough research had been done to be confident in its safety, Pure Plushy realized that their position on Benny’s safety didn’t matter as much as the public’s perception. Without specific studies to support their claim, Pure Plushy decided to change their marketing to avoid potential lawsuits as well as public backlash against nanotechnology.

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The NISE Network
www.whatisnano.org

Nanotechnology-based consumer products
www.nanotechproject.org/inventories/consumer

Nano and Society FAQ
http://cns.asu.edu/nanoquestions

nano & me: Nanotechnology in our lives
www.nanoandme.org/regulation

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