DIY NANO

Do-it-yourself science activities that investigate the nanoscale

Filled with fun science experiments and clear step-by-step instructions, the DIY Nano book encourages the whole family to explore science, technology, and engineering on the *nanoscale*. A nanometer is just one billionth of a meter—that's the scale of individual atoms and molecules. We're surrounded by amazing things made possible by tiny, nano-sized structures and nanotechnologies, from the sticky surface of a gecko's foot and the iridescent colors of a butterfly's wing, to the gadgets and cosmetics we use every day.

These hands-on activities, developed by museum educators and university scientists, introduce the fundamentals of nano science. Using basic supplies and inexpensive materials, you can investigate some of the tools and techniques nano researchers use, discover where to find nano in nature, and explore how nanotechnology might transform our lives, now and in the future.

NISE network NANOSCALE INFORMAL SCIENCE EDUCATION

NSF Grant Nos. 0532536 and 0940143

Are you ready for an egg drop?

DIY NANO

Do-it-yourself science activities

DIY NANO

Do-it-yourself science activities that investigate the nanoscale—the scale of atoms and molecules!

How hard is it to pour water out of a tiny teacup?

Have you ever made your own gummy worms?


GET HANDS-ON WITH
SCIENCE!

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.

Published by the NISE Network

Distributed by the Science Museum of Minnesota
April 2016

This book is adapted from the DIY Nano app developed by Lawrence Hall of Science University of California, Berkeley.
Book and cover design by Emily Maletz Graphic Design.
Cover and chapter intro photography by Emily Maletz.
Activity photography and illustrations by Gary Hodges, Emily Maletz, and Sciencenter.
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See pages 134–135 for individual activity credits.

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Do-it-yourself science activities that investigate the nanoscale—the scale of atoms and molecules!

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Acknowledgments

This book reflects the creativity and hard work of many people. Thank you to the NanoDays and programs workgroups of the Nanoscale Informal Science Education Network (NISE Net) for their contributions toward developing these activities in all their many versions and iterations. These and other workgroups of the project have included many wonderful developers, designers, educators, evaluators, and researchers through the years. Thank you to all of you for your hard work and for sharing your expertise. A special thank you to the members of the DIY Nano app development team for their vision of Do-It-Yourself nano activities. Thanks, also, to all the many others who have supported and contributed to these activities and to this book project, including the content and design editors, the reviewers, and the network leadership group.

This book is dedicated to all the curious and enthusiastic people across the country, who have celebrated the exploration of nanoscale science, technology, and engineering with us for over ten years!


PURE
pure almond extract
pure vanilla extract

Get hands-on with science!

The activities in this book are designed to encourage kids and adults to learn together about complex scientific content—in ways that are fun and easy to understand. Activities and materials were carefully chosen to be as easy to put together as possible. You'll be able to gather materials from local craft stores, grocery stores, and likely your own kitchen!

All of these activities are modified from programs developed by the Nanoscale Informal Science Education Network (NISE Net). Funded by the National Science Foundation, 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.

These activities were developed by a team that includes members from museums and universities across the country. They have been tested by museum visitors and families, and have been reviewed for scientific accuracy by researchers.

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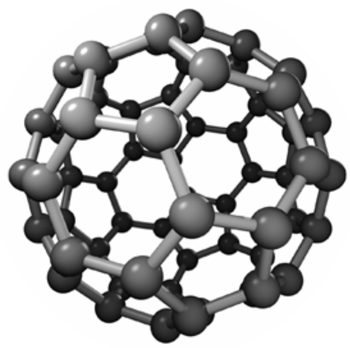
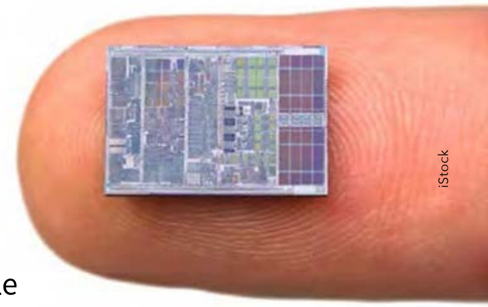
What Is Nano?

Nanoscale science, engineering, and technology (or "nano" for short) is an interdisciplinary field of research and development. 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 nanotechnologies may transform our lives—similar to the way the automobile and personal computer changed the way we live and work.



Martin McCarthy



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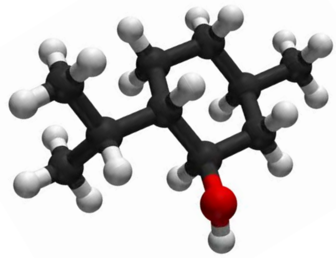
Size and Properties

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

Tools and Techniques

Nanoscientists and engineers study and make tiny things 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.



Wikipedia

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Nano and Nature

Some of the beautiful and surprising things we observe in nature are due to special nano properties. The iridescent color of insect wings, the self-cleaning properties 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.

Nano and Our Lives

Nano isn’t just in the lab—we can already find it in our homes, stores, and hospitals. Soon, we’ll see more and more nano in everyday products, such as computers, food, cosmetics, and clothing. Nano might also be part of solutions to big problems, such as clean energy, pure water, and cancer treatments. It’s important for everyone to be informed about nanotechnologies, because they’ll be an important part of our future. 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.

Emily Maletz

Our website, whatisnano.org, has even more information, videos, and linked resources about this exciting field of research.

The free DIY Nano app for iPhone or iPad is a companion to this book. It includes the activity content and additional videos and resources. The app is available on the App Store.

Emily Maletz

Did You Know?

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.

CHAPTER 1

SIZE AND PROPERTIES

Are you ready for an egg drop?

Egg Drop

Can Ooze protect an egg?

Is it a gooey liquid or a strong solid? Mix cornstarch and water to make Ooze and then test the material in an egg drop. Ages 5+

45+ min

Time

Preparation: 20 minutes
Activity: 15 minutes or longer
Cleanup: 10 minutes

Materials

Ooze:

- 2 measures cornstarch
- 1 measure water
- 2-3 drops food coloring *(optional)*

Medium bowl

2 large plastic bags

Small plastic bag

2 eggs *(uncooked!)*

Note: *If the Ooze sits for more than a few hours, you may need to add more water. Additionally, you may want to have more eggs on hand to repeat the experiment a few times.*

Safety: *Supervision required. Although nontoxic, do not eat or drink the Ooze.*

Step 1

Grown-ups, prepare the Ooze in a medium plastic bowl. If you're using food coloring, add that to the water first. Then slowly add water to the cornstarch. When making the Ooze, you may need to adjust the amount of water. The Ooze solution should harden when pressure is applied, but otherwise will flow like a liquid.

Step 2

Kids, play with the Ooze! What do you notice about this funny material? Try tapping or squeezing the Ooze. Is it a solid or a liquid? If you get messy with the Ooze, you should dunk your hands into a tub of water before washing in a sink. **Empty all Ooze directly into the trashcan or compost, NOT the sink. Ooze can clog a sink if too much is put down the drain.** If saved for more than a few days Ooze can begin to smell, so throw it out promptly.

Step 3

Time to experiment! Put one of your eggs into a large plastic bag. Zip it up. Pour about half your Ooze into the other large plastic bag. Place the other egg into the small plastic bag. Add the small plastic bag (with the egg) to the large bag that holds the Ooze. Zip it up.

Step 4

Hold both large bags about 8 inches over a table. Line the eggs up so they are the same height off the table. Drop both bags at the same time. What happens? Do both eggs break?

What's going on?

Ooze is one of many materials called *non-Newtonian fluids*. Most fluids move faster when they are pushed harder, but Ooze (and other non-Newtonian fluids) moves slower when more force or pressure is applied. When you slowly stir the Ooze it behaves like a liquid. The same force applied quickly makes it act more like a solid.

How is this nano?

The way a material behaves on the macroscale is affected by its structure on the nanoscale. (A nanometer is a billionth of a meter.)

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.

iStock

STFs make a winter hat more like a helmet

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

Researchers have developed new fabrics made with shear-thickening fluids (STFs) that contain suspended nano-sized particles. This new material displays non-Newtonian behavior, similar to Ooze. The fabrics are used in a variety of technologies, from flexible body armor to protective (and fashionable) winter hats.

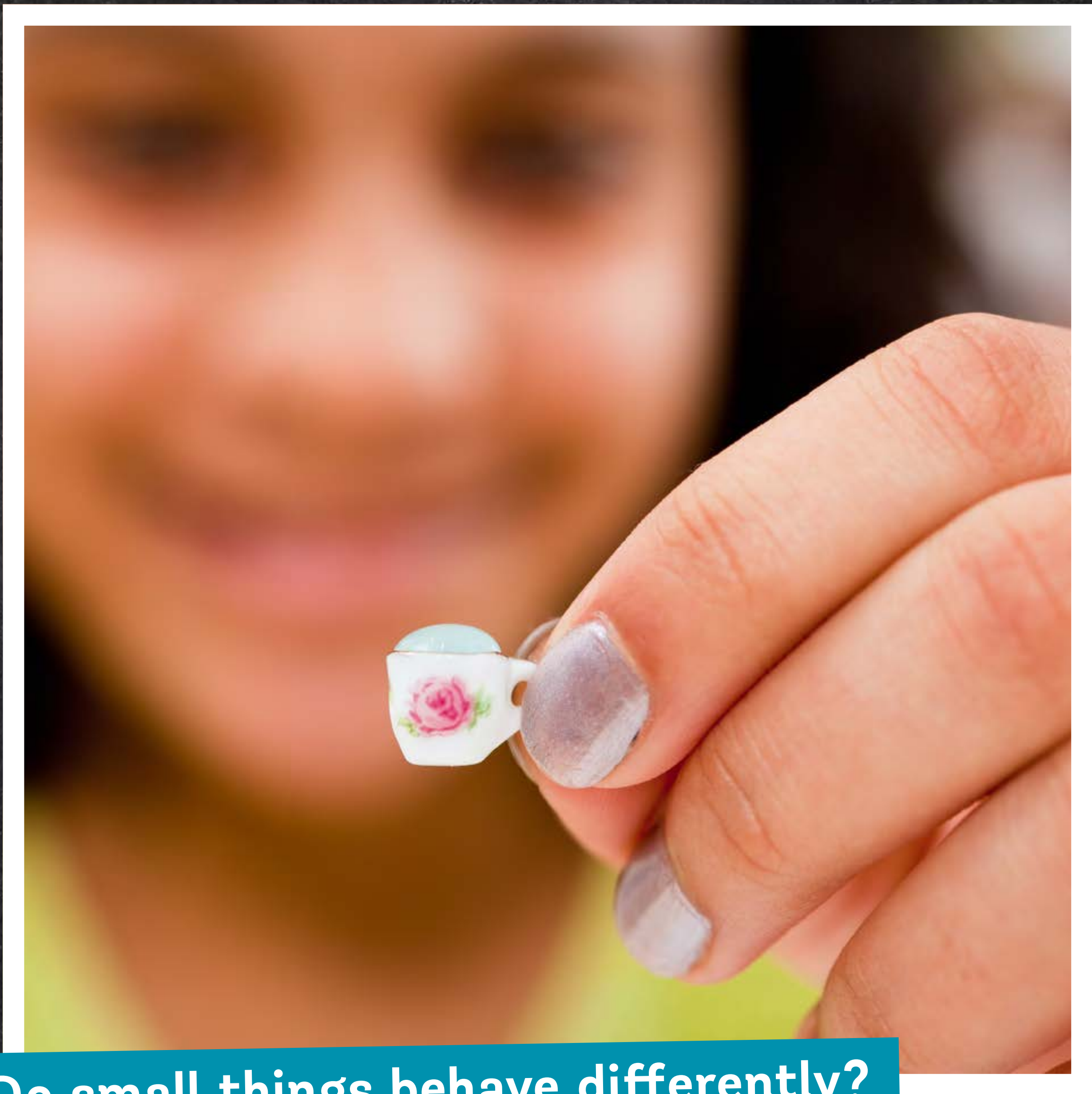
Nanotechnology is helping to make strong new materials

When you quickly apply a lot of pressure to Ooze, like tapping or squeezing, it firms up like a solid. When no pressure is applied, it flows like a liquid.

When it hits the ground, a quick direct force is applied to the Ooze. The cornstarch clumps together and hardens like a solid, absorbing the impact and protecting the egg. Then the Ooze quickly goes back to acting like a liquid.

Researchers are using shear-thickening fluids (STFs) that behave a lot like Ooze 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.

Gravity Fail



Do small things behave differently?

What's the power of tiny things? Try pouring water out of a regular cup and a miniature cup. It's harder than it sounds! Ages 3+

Time
15 min
Preparation: 5 minutes
Activity: 5 minutes
Cleanup: 5 minutes

Materials

Regular-sized cup or glass

Miniature cup or glass *(with an opening smaller than ½ inch)*

Container of water, large enough to dip the cups

Note: *Miniature cups can be found at dollhouse suppliers. One source is dollhousesandmore.com (#CB2719). An extra-small thimble or toothpaste cap might also work.*

Step 1

Fill the regular cup by dipping it in the water. Try to pour the water back into the container. What happens?

Step 2

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

What's going on?

It's easy to pour water out of a full-sized cup, but not out of a miniature cup. The size of the cup determines which force is more important, surface tension (the natural tendency of water molecules to stick together) or gravity.

With a regular-sized cup, gravity is much stronger than surface tension, so the water falls out when you tip the cup. But in a miniature cup, there's a lot less water, so surface tension is strong enough to hold it in the cup.

How is this nano?

Different physical forces dominate when things get very, very small. For example, gravity is very obvious at human size, but it's hardly noticeable to nano-sized things like water molecules. Other forces, like surface tension, are much more important.

A force called *van der Waals,* similar to surface tension, lets geckos walk on walls!

New materials

Researchers take advantage of the ways that nano-sized things behave differently to make new products and applications.

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

Autumn Kellar, Lewis & Clark College

Millions of tiny, nano-sized hairs on a gecko's foot use strong molecular forces called van der Waals to climb up walls and walk across ceilings.

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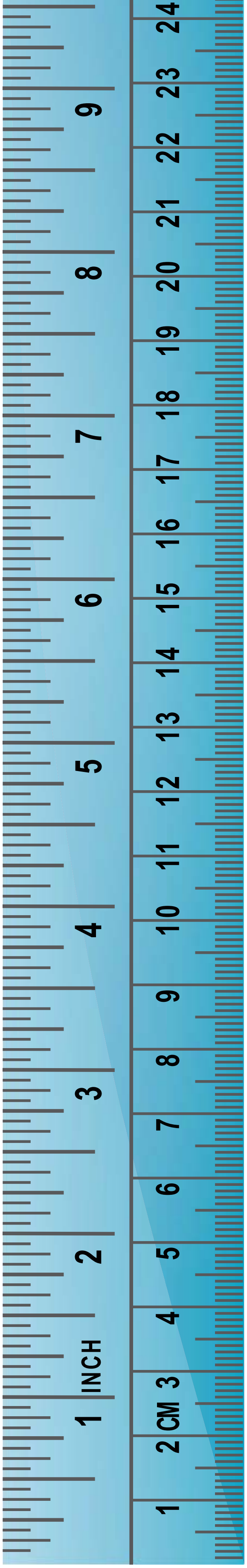


How Big Is Your Hand?

Try measuring in nanometers!

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

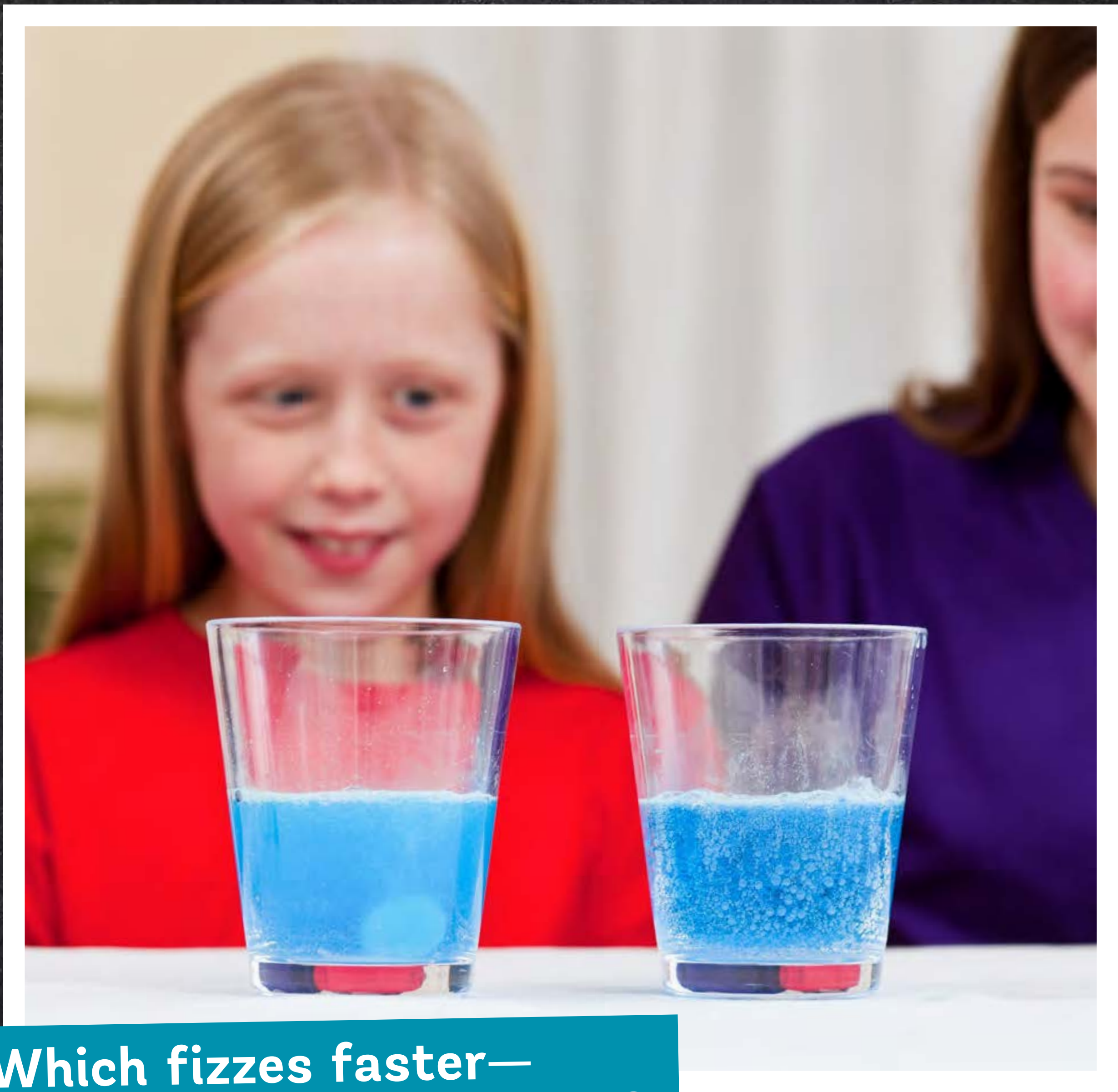
30 million nanometers

20 million nanometers

10 million nanometers

0 nanometers

Ready, Set, Fizz



Which fizzes faster—big pieces or little pieces?

Why does the exact same material behave in different and surprising ways? Explore the chemical reaction between water and effervescent antacid tablets to see how much size really matters. Ages 3+

15 min

Time

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

Materials

4 cups or glasses *(ones that you can see through are best)*

Effervescent antacid tablets

Water

Food coloring

Safety: *Supervision required. Do not eat or drink these materials. The antacid tablets contain medication.*

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. 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!

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

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.

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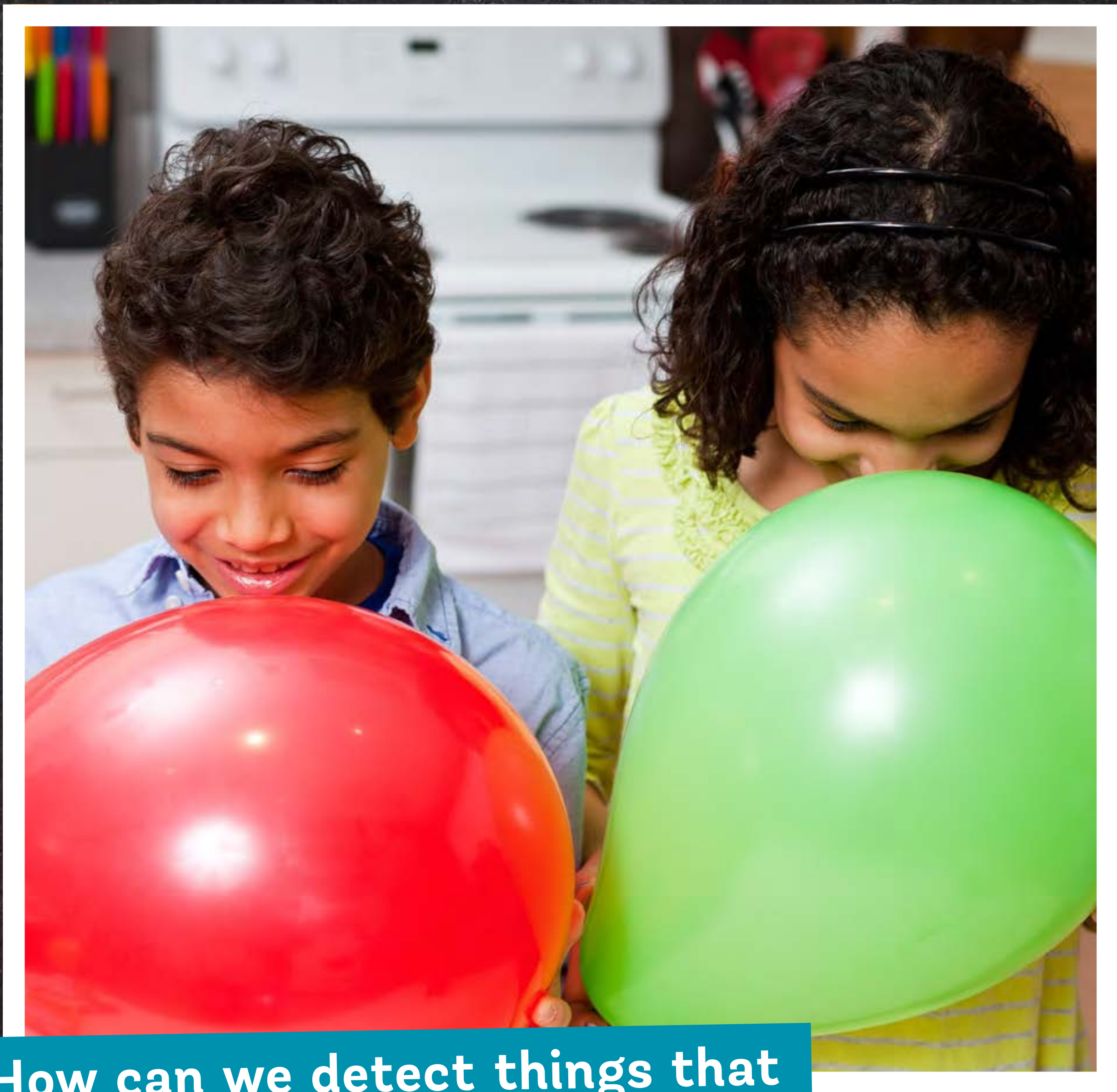
Smelly Balloons



How can we detect things that are too small to see?

Tiny molecules are too small to see, but sometimes we can smell them. Sniff balloons to find the hidden scents, and match the smell to the scent molecule. Ages 3+

15 min

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

Materials

Round balloons in a variety of different colors

Several different scented extracts *(such as vanilla)*

Medicine dropper *(optional)*

Hand pump for inflating balloons *(optional)*

Matching game activity page

Crayons or markers

Safety: *Supervision required. Popped balloons can be a choking hazard. Many balloons are made with latex. This activity is not suitable for individuals with a sensitivity or allergy to latex.*

Step 1

Grown-ups, put about about a half teaspoon of extract in each balloon by pouring carefully or using a medicine dropper. Use a different color balloon for each kind of extract. Blow up the balloons and tie them securely. Give them a shake. A hand pump makes it much easier to inflate the balloons.

Step 2

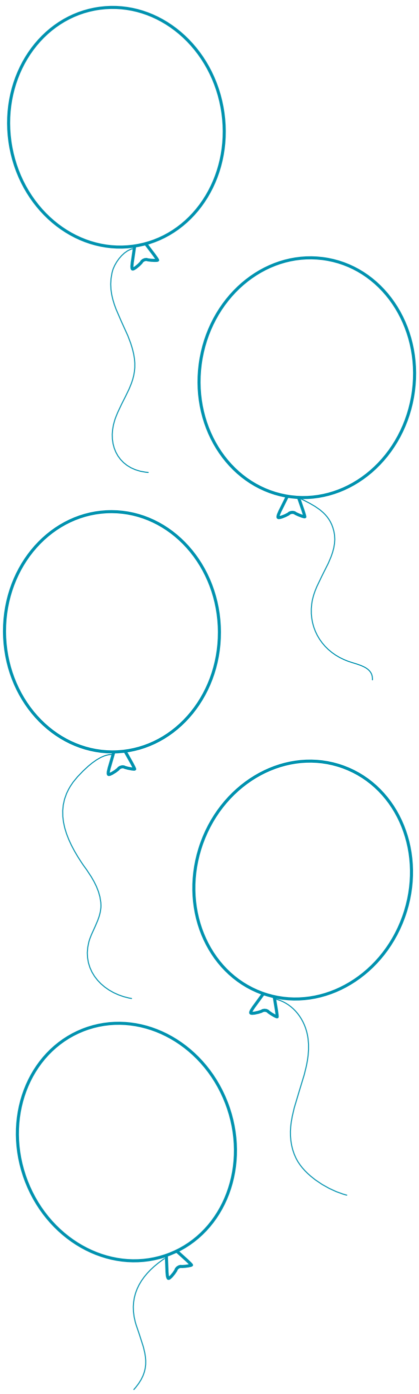
Kids, investigate the balloons! Smell the balloons. Can you figure out which scent is hidden in each balloon?

Step 3

Fill in the activity sheet. Color in the balloons. Next to each one, write the scent that's hidden inside. You can also jumble the order of the balloon colors and scents, and play a matching game!

Match the Scent

Color in the balloons to match yours and write the names of the scents on the right.
Then use your nose to match them up!



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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 shapes 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.

How is this nano?

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

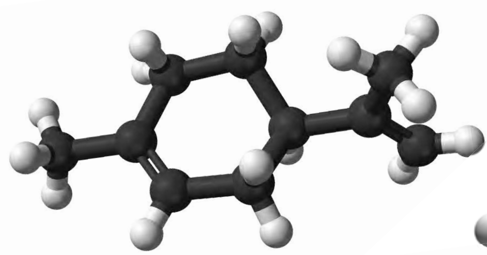
So if you can smell, your nose is your very own nano-detector!

Wikipedia

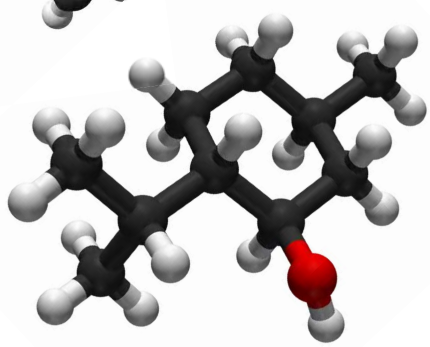
Atoms and molecules

Nanotechnologies include new materials and tiny devices so small they are sometimes built from individual atoms and molecules!

For example, researchers are creating nano-sized sensors that can sniff out very small amounts of chemicals in the air. Some of them work the way your nose does, by detecting the different shapes of molecules.



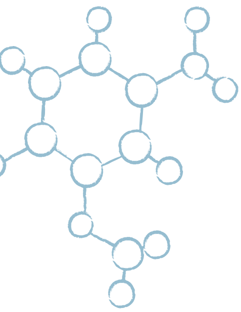
Model of a limonene scent molecule

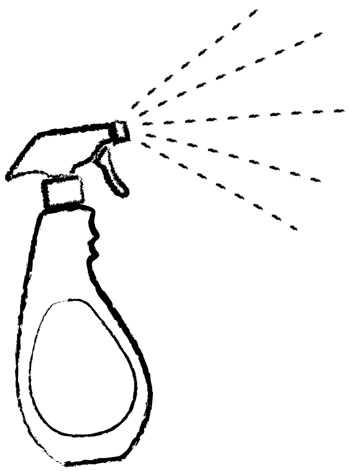


Model of a menthol scent molecule

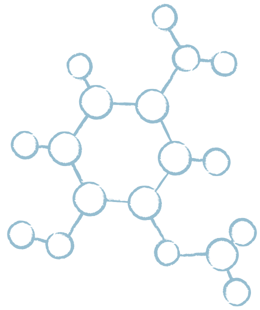
Draw Things That Smell Like…

vanilla

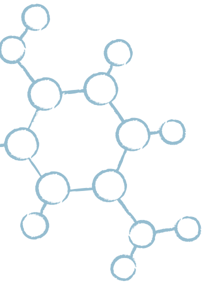


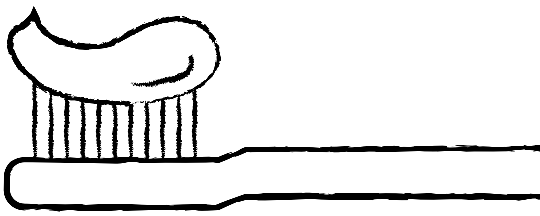


lemon

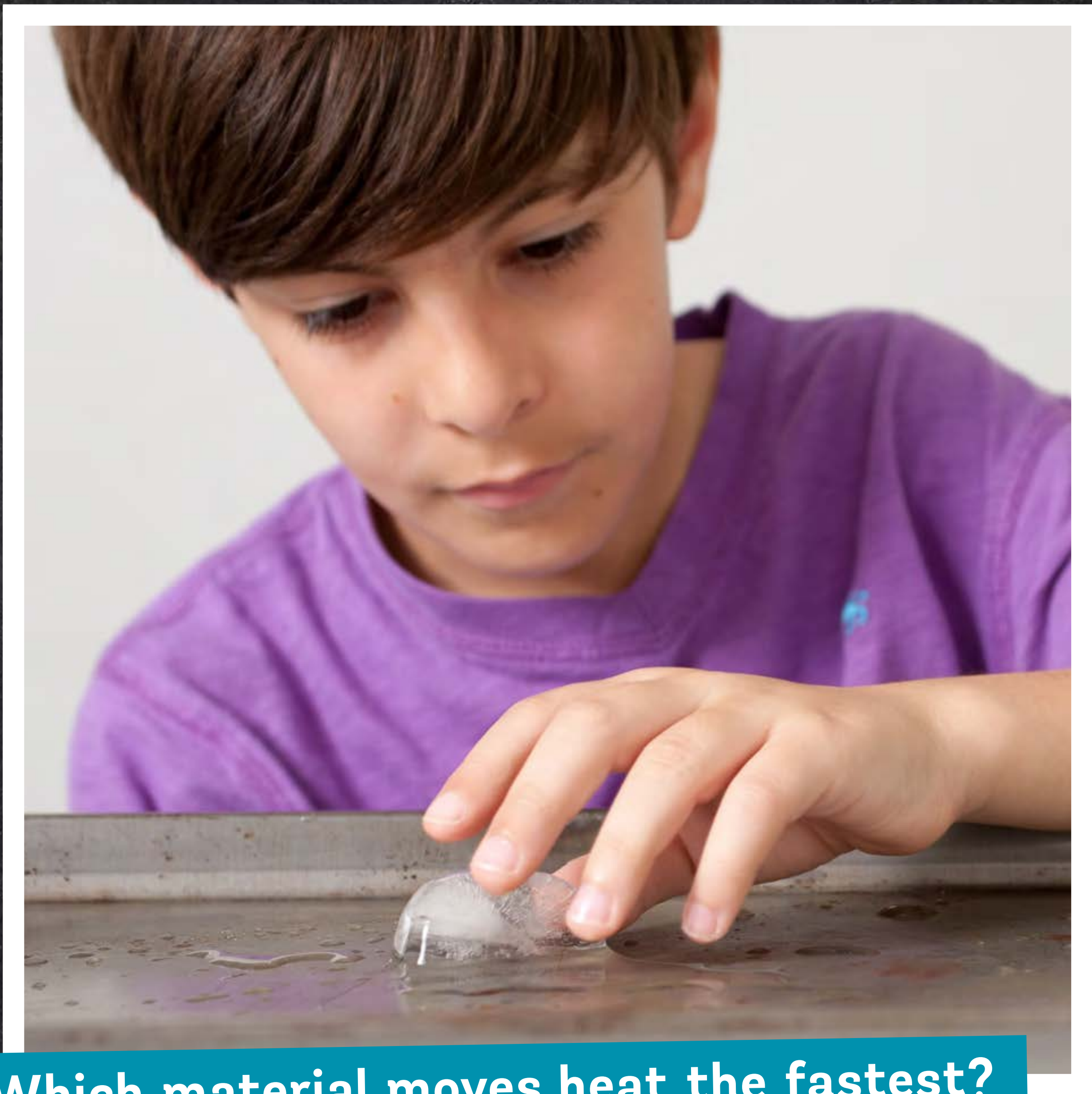


mint





Heat It Up



Which material moves heat the fastest?

Make predictions about how quickly some common household items will transfer heat. Then figure out why some materials feel colder to the touch, even when they're all at room temperature. Ages 4+

20+ min

Time

Preparation: 5 minutes
Activity: 10 minutes or longer
Cleanup: 5 minutes

Materials

Ice cubes

Plastic cutting board

Metal cookie sheet

Sponge or paper towels
(for cleanup)

Optional: *Other house hold items made out of different materials such as a styrofoam plate, a wooden cutting board, a ceramic dish, etc.*

Safety: *Supervision required. Advise children not to consume ice as it may be a choking hazard. Avoid using additional objects that may be a choking hazard.*

Step 1

Grown-ups, get everything ready! A few hours before you do this activity make some ice cubes in the freezer.

Step 2

Kids, look at the different kitchen items. Touch them. Do you think they're the same temperature? Make a prediction about which one will melt an ice cube the quickest.

Step 3

Now, place an ice cube on each kitchen item. Watch closely! Do the ice cubes melt at the same rate? **Optional:** Try melting the ice on other items made of different materials from around the house. Make a prediction: line the items up in the order you think ice will melt, from slowest to fastest. How close were you?

What's going on?

These common kitchen items are made of different materials. They're all room temperature, but even though the metal item feels colder to the touch, it actually makes the ice melt faster!

When you touch something made of metal, the heat from your hand quickly transfers away into the metal. This leaves your hand feeling cold. But when you touch something made of plastic, only a little heat slowly flows away from your hand. So your hand still feels warm. Heat transfers quickly from a metal pan to an ice cube, melting it very quickly. But heat only slowly transfers to the ice cube on the plastic cutting board, making it melt more slowly.

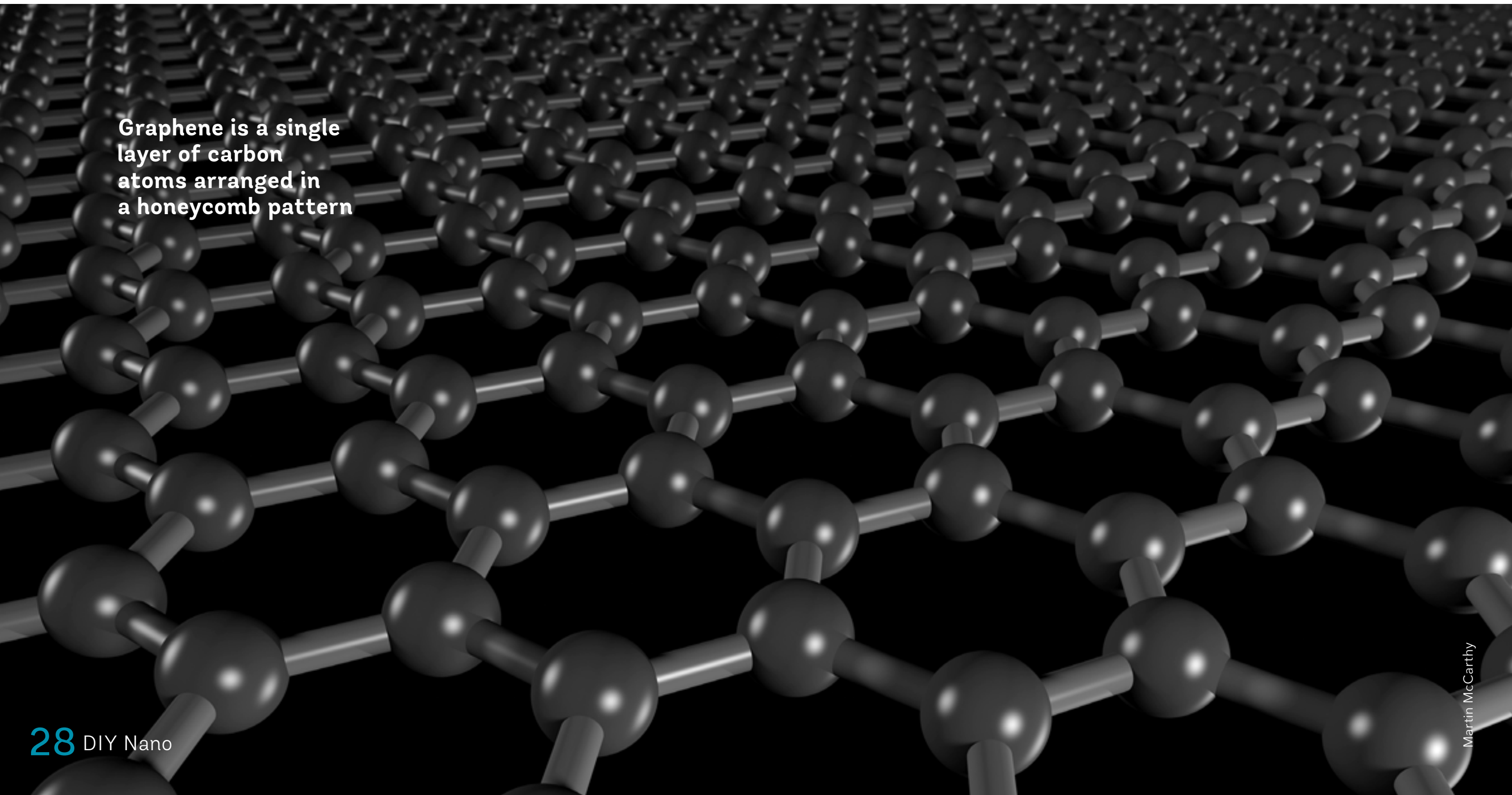
The difference happens because of *thermal conductivity*. Thermal conductivity measures how quickly heat flows through a material. Metal has a higher thermal conductivity and plastic has a lower thermal conductivity.

How is this nano?

When you use electronic devices, like laptops, cell phones, and video game consoles, they generate a lot of heat. Dealing with this heat is very important. When engineers design electronics they must consider which materials will work best to quickly transfer and remove heat. For most materials, thermal conductivity decreases as the material gets thinner. As engineers design smaller, thinner electronic devices, these thinner materials can't transfer heat quickly enough.

Nanoelectronics

Graphene, a single layer of carbon atoms arranged in a honeycomb pattern, is the thinnest existing material and it has the highest known thermal conductivity! Unlike 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 a single layer of carbon atoms arranged in a honeycomb pattern

Martin McCarthy

Emily Maletz

Think About It!

Have you ever 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.

Did You Know?

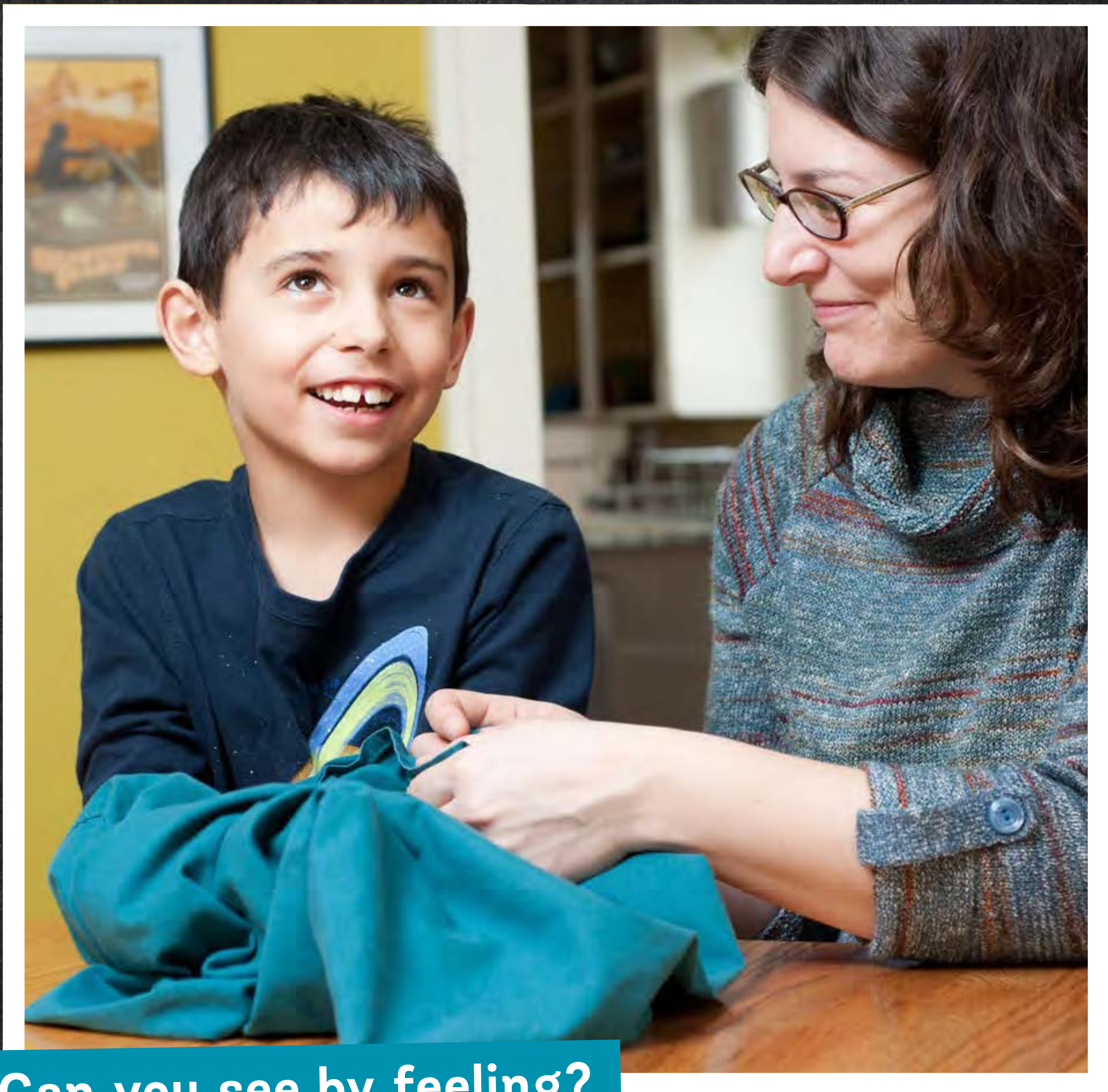
Scientists use special tools and equipment to work on the nanoscale. The invention of scanning probe microscopes was a great breakthrough in the field of nanotechnology. SPMs allow researchers to detect and make images of individual atoms and other things that are too small to see!

CHAPTER 2

TOOLS AND TECHNIQUES

Have you ever made your own gummy worms?

Mystery Shapes



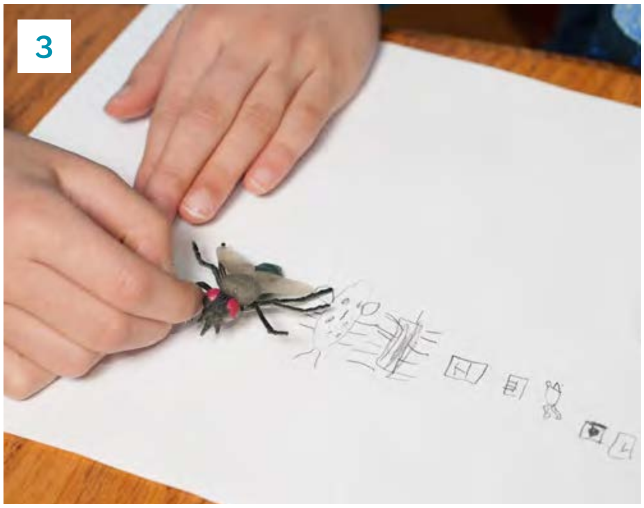
Can you see by feeling?

How can you learn about something you can't see? Use your sense of touch to "see" an object and then make a drawing. How similar does it look? Ages 3+

20+ min

Time

Preparation: 5 minutes
Activity: 10 minutes or longer
Cleanup: 5 minutes



Materials

Pillow case *(or other opaque sack-like bag)*

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

Paper *(draw right in the book, or use scrap paper)*

Pens or pencils

Bandana or eye mask *(optional)*

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

Safety: *Avoid using objects that may be a choking or puncture 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 you 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 bag 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!

Charles Harrington Photography, Cornell NanoScale Science & Technology Facility Cleanroom

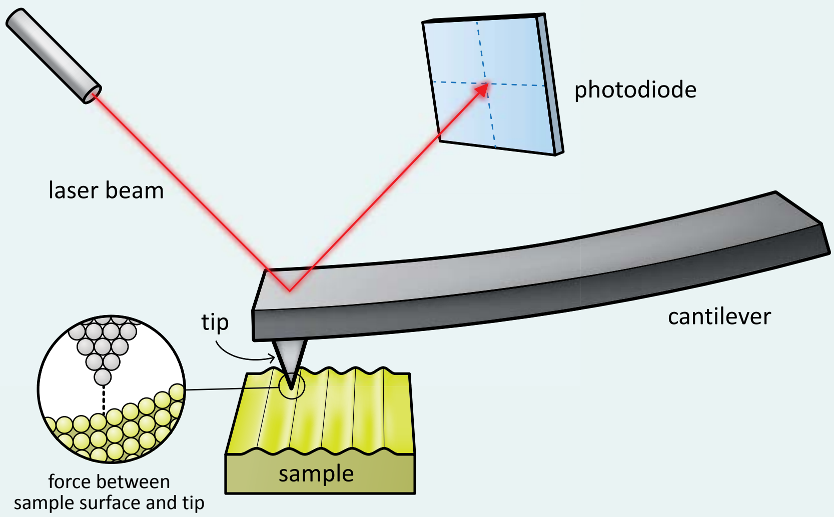
Researcher using an SPM

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.

This is the tip of an SPM magnified 1000x

SecretDisc

Emily Maletz



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.

What do you feel in the bag? 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.

Draw a Circuit

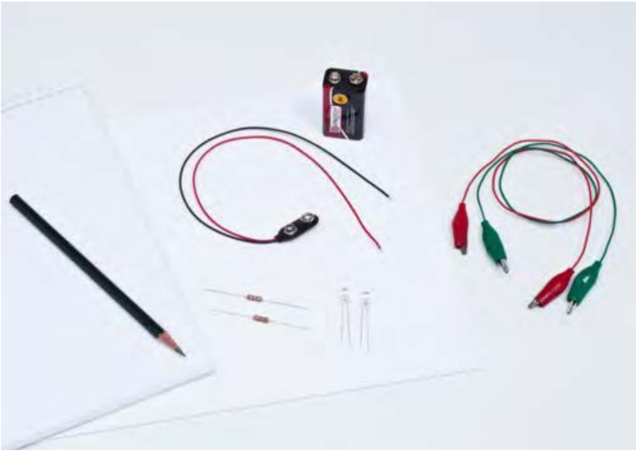
Can a pencil conduct electricity?

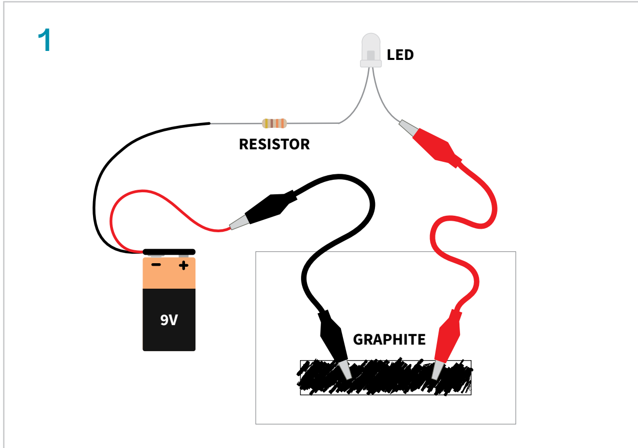
How is a pencil like an electrical wire? Complete an electrical circuit using graphite (pencil "lead") to make a light bulb shine. Ages 5+

35 min

Time

Preparation: 15 minutes
Activity: 15 minutes
Cleanup: 5 minutes





Materials

Soft drawing pencil *(6B is best)*

Paper

5mm LED bulb

9-volt battery

9-volt snap connectors

330-ohm resistor

Two insulated wire leads

Notes: *Battery and bulb circuit materials can be purchased from radioshack.com (LED bulb #276-021, 9v battery #55039849, battery connectors #270-324, resistor #271-1113, insulated leads #278-1156).*

Safety: *Supervision required. Small objects can be a choking hazard.*

Step 1

Grown-ups, make the battery and bulb circuit! Follow the diagram.

Step 2

Kids, lay down some graphite! (Graphite is the real name for pencil "lead.") Use the drawing pencil to color a thick, dark box on the piece of paper. Make it several inches long and around half an inch thick. Make the box thick and heavy—try not to let any patches of paper show through.

Step 3

Touch the two insulated wire leads to the graphite box. Watch the bulb—what happens? Now try moving the leads closer together and further apart. Do you notice a difference?

What's going on?

The bulb lights up! The graphite on the card conducts electricity, completing the electrical circuit.

Graphite is commonly called "pencil lead," but it's actually not lead at all. Graphite is a mineral made of many layers of carbon stacked on top of each other.

How is this nano?

Graphene is a single layer of carbon atoms arranged in a honeycomb pattern. It's the thinnest material in the world!

In 2010, Andre Geim and Konstantin Novoselov won a Nobel Prize in Physics for creating a material called graphene out of graphite. Their celebrated method was simple. They used ordinary transparent tape to peel apart layers of graphite until it was very thin. They measured their results and found out that they'd made graphene.

Graphene

In the field of nanotechnology, scientists and engineers make new, nano-sized materials and devices. (A nanometer is a billionth of a meter.) Graphene is an example of a nano-sized material.

Ji Hye Hong

Flexible graphene circuit

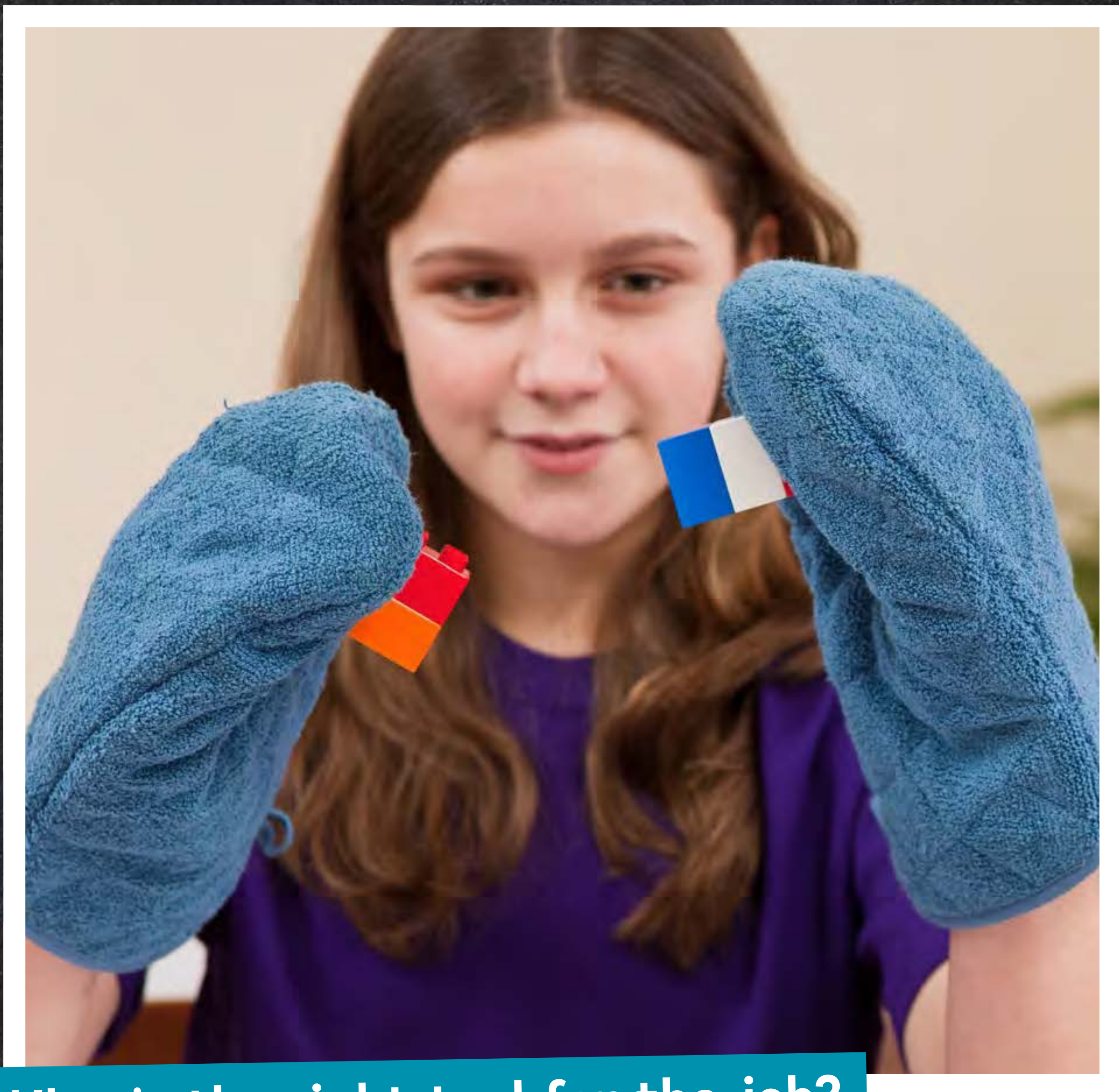
Graphene has a lot of potential in nanotechnology because of its useful properties. It's flexible, super strong, nearly transparent, and conducts electricity. One day, graphene could be used to make see-through, bendable electronic displays, and tiny, fast computer chips.

Draw Graphene!

Continue the graphene structure by adding more carbon atoms arranged in a honeycomb pattern.

iStock

Mitten Challenge



What's the right tool for the job?

Try putting together toy bricks—wearing oven mitts! The right tool for the job can make a big difference, and your hands are just the right size for this task. Ages 3+

15 min

Time

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

Materials

Lego® or Duplo® type building blocks

Oven mitts

Note: *Larger Duplo-sized building blocks are better for young kids, while smaller Lego-sized ones are better for older kids.*

Safety: *Supervision required. Small building bricks can be a choking hazard for young children.*

Step 1

Put on a pair of oven mitts. Try to build something out of the bricks.

Step 2

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 while wearing them.

How is this nano?

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 our world.

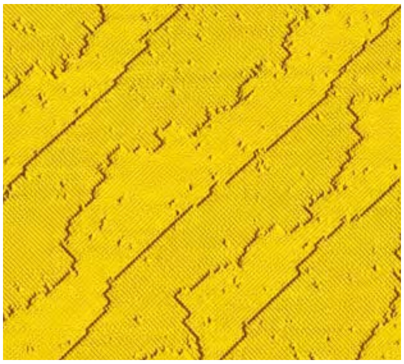
Moving atoms around with regular tools is kind of like trying to build something out of toy bricks with oven mitts on your hands! Like everyone else, scientists and engineers need the right size tools for the job.

Tools

Scientists and engineers use special tools and equipment to study and make nano-sized things. For example, a special tool called a *scanning probe microscope* (SPM) lets scientists "feel" things that are too small to see with regular microscopes. Using this tool, researchers can detect and make images of individual atoms and molecules.

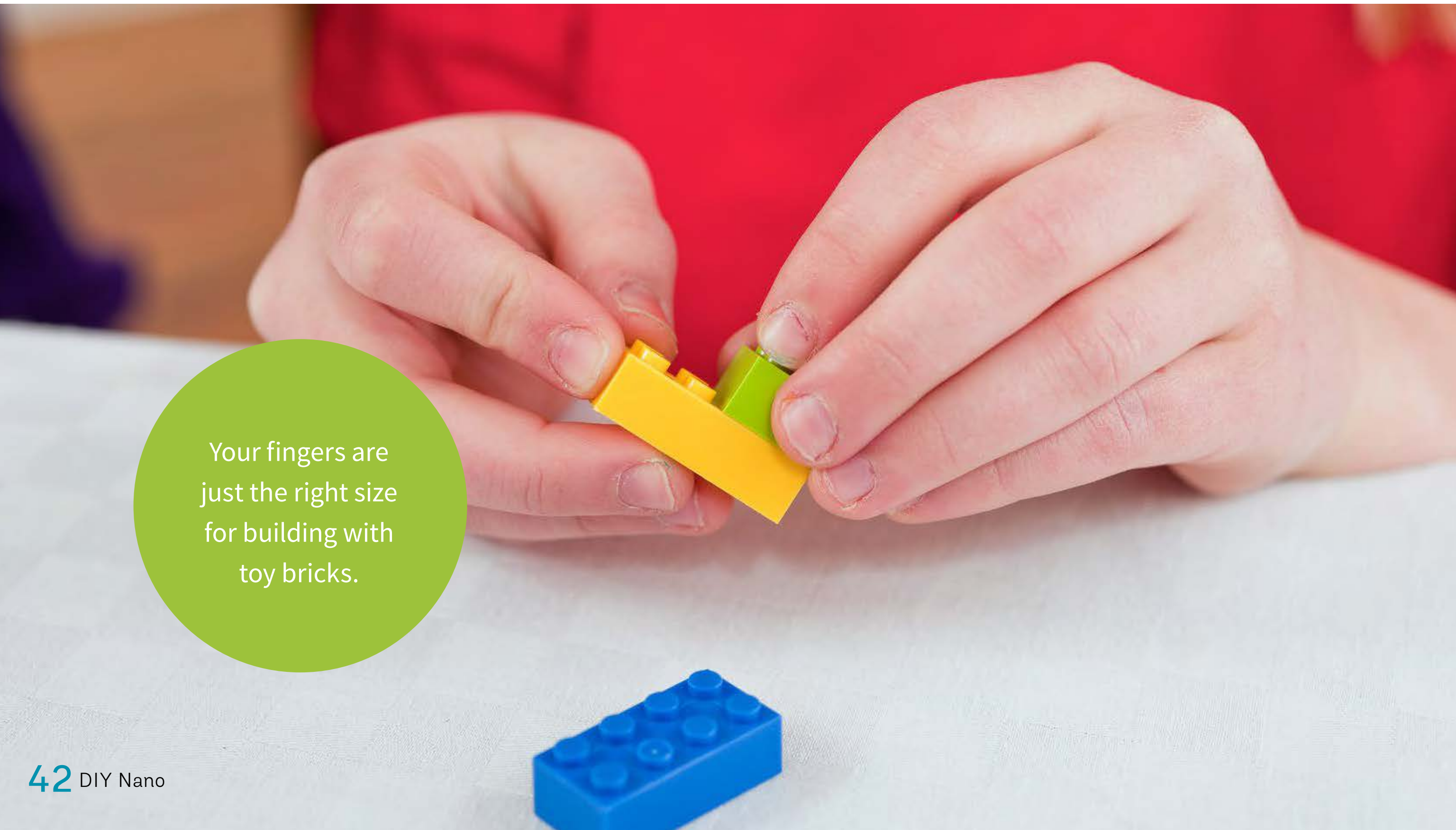
Charles Harrington Photography, Cornell NanoScale Science & Technology Facility Cleanroom

Researchers in a lab



Brian Swartzentruber, courtesy Max Lagally

SPM image of silicon atoms



Nanoscientists use special tools and equipment to study and make tiny things.

Gary Hodges

Gummy Shapes

How can things build themselves?

Use chemistry to "self-assemble" slimy squiggles and blobs! What happens when you use a lot of goo? What about just a little? How much of a gooey mess can you make? Ages 3+

30+ min

Time

Preparation: 5 minutes
Activity: 15 minutes or longer
Cleanup: 10 minutes

Materials

Sodium alginate worm kit

Mesh strainer

Bowl that holds the strainer

Plate

Spoon

Note: *Sodium alginate worm kits are inexpensive and available from educational science stores, such as stevespanglerscience.com (#WORM-700) and teachersource.com (#CK-600). It's extra fun to make worms in two different colors!*

Safety: *Supervision required. Although nontoxic, do not eat or drink these materials.*

Step 1

Grown-ups, get everything ready! Follow the kit instructions to prepare the worm ingredients. Place the strainer in the bowl with the salt water. Not all kits indicate their ingredients. The gooey stuff is sodium alginate. The salt water is a calcium chloride solution (often made from mixing crystals with water).

Step 2

Kids, time to get gooey! Squeeze the bottle of goo into the bowl of salty water. Drip it gently to make little droplets. You can also squeeze harder to make long worms. **Make sure you squeeze the goo into the strainer.**

Step 3

Lift the strainer out of the bowl. Dump the contents onto the plate. Feel the goo. Is it still liquid? Try squeezing it. What happens?

The colorful droplets you make are similar to nanocapsules—tiny particles with an outside shell and a hollow interior that can be filled.

Gary Hodges

What's going on?

When the liquid goo comes 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 goo, where it touches the salt water, creating a shell around the liquid interior.

How is this nano?

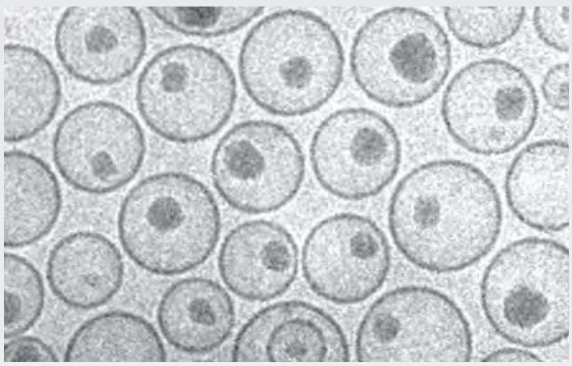
The polymer droplets you made are similar to *nanocapsules*, tiny particles with an outside shell and hollow interior that can be filled. Nanocapsules are very, very small—a nanometer is a billionth of a meter.

To create tiny, nano-sized technologies, scientists can use a process called *self-assembly*, in which tiny things actually assemble themselves!

Nanomedicine

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

For example, nanocapsules can be designed to deliver medicine to diseased parts of the body, bypassing healthy parts. They can use much less medicine, so they can have fewer and less harmful side effects.

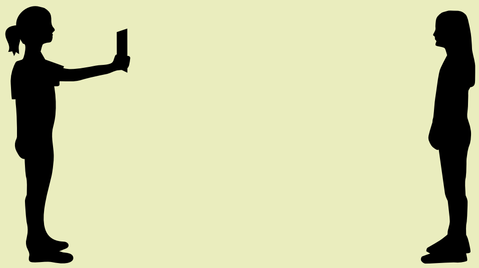


Katarina Edwards, Uppsala University

Nanocapsules containing cancer medication

Dress Up Like a Nanoscientist!

Gary Hodges



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 away from you.

Think About It!

If you grow up to be a scientist what will you invent?

Gary Hodges

Did You Know?

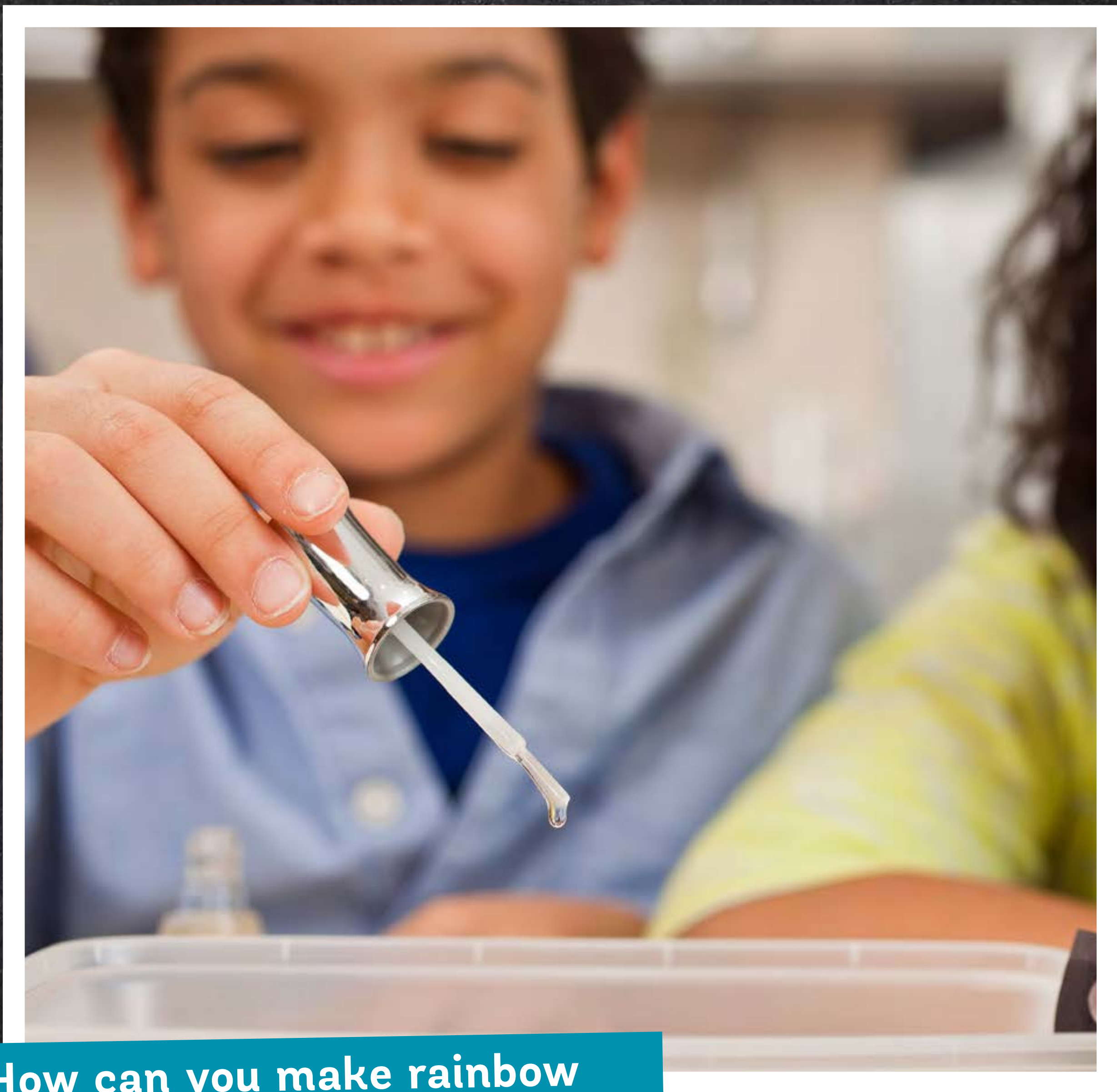
The brilliant blue color on a Blue Morpho butterfly 's wings come from tiny nanoscale structures reflecting light back to your eyes.

CHAPTER 3

NANO AND NATURE

Extract tiny strands of DNA in your own kitchen!

Rainbow Film



How can you make rainbow colors out of clear nail polish?

A drop of clear nail polish is barely visible on water. But you can capture it on black paper to see the beautiful iridescent pattern. Ages 3+

15 min

Time

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

Note: It takes about 30 minutes for the paper strips to dry.

Materials

Shallow pan filled with water

Strips of black paper *(Bristol is best, but construction paper works)*

Clear nail polish

Pencil

Place to let paper dry

Safety: *Supervision required. Do not eat or drink these materials. Be sure to do this activity in a well-ventilated area.*

Step 1

Use the pencil to write your name on a strip of black paper. Holding onto one end, slide the paper into the pan. Make sure it's completely underwater (except for the end you're holding).

Step 2

Use the nail polish to drip one drop of polish onto the surface of the water. (With young children, an adult can hold the paper and the child can drip the polish.) Watch what happens—the polish instantly spreads out into a thin film!

Step 3

Lift the paper up and 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 thin film, which creates iridescent colors on the paper. The film is only a few hundred nanometers thick. (A nanometer is a billionth of a meter.)

The film is slightly thicker in some places and thinner in others. The film reflects light differently depending on how thick it is, so you see different colors.

How is this nano?

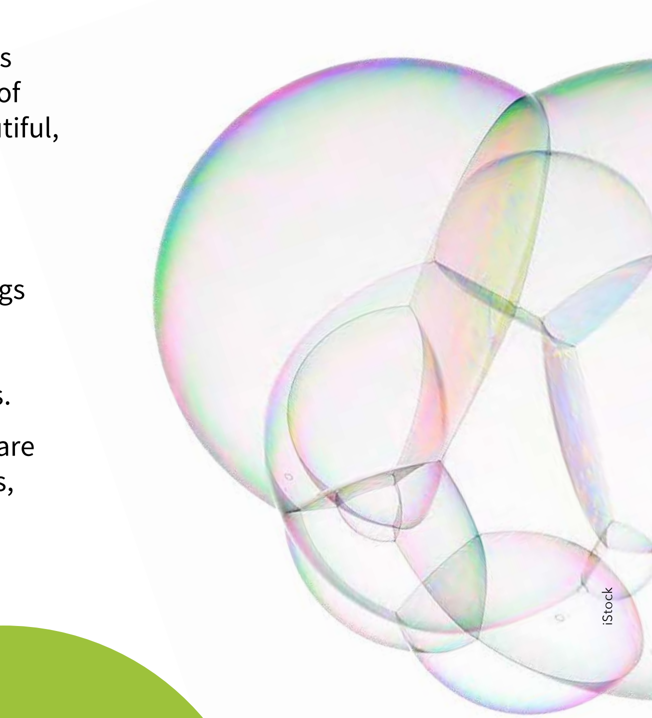
Thin films can reflect light in special ways, because they're only a few hundred nanometers thick. That's in the same size range as the wavelength of visible light.

Soap bubbles and oil slicks are some other examples of thin films that create beautiful, iridescent colors.

Thin films

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

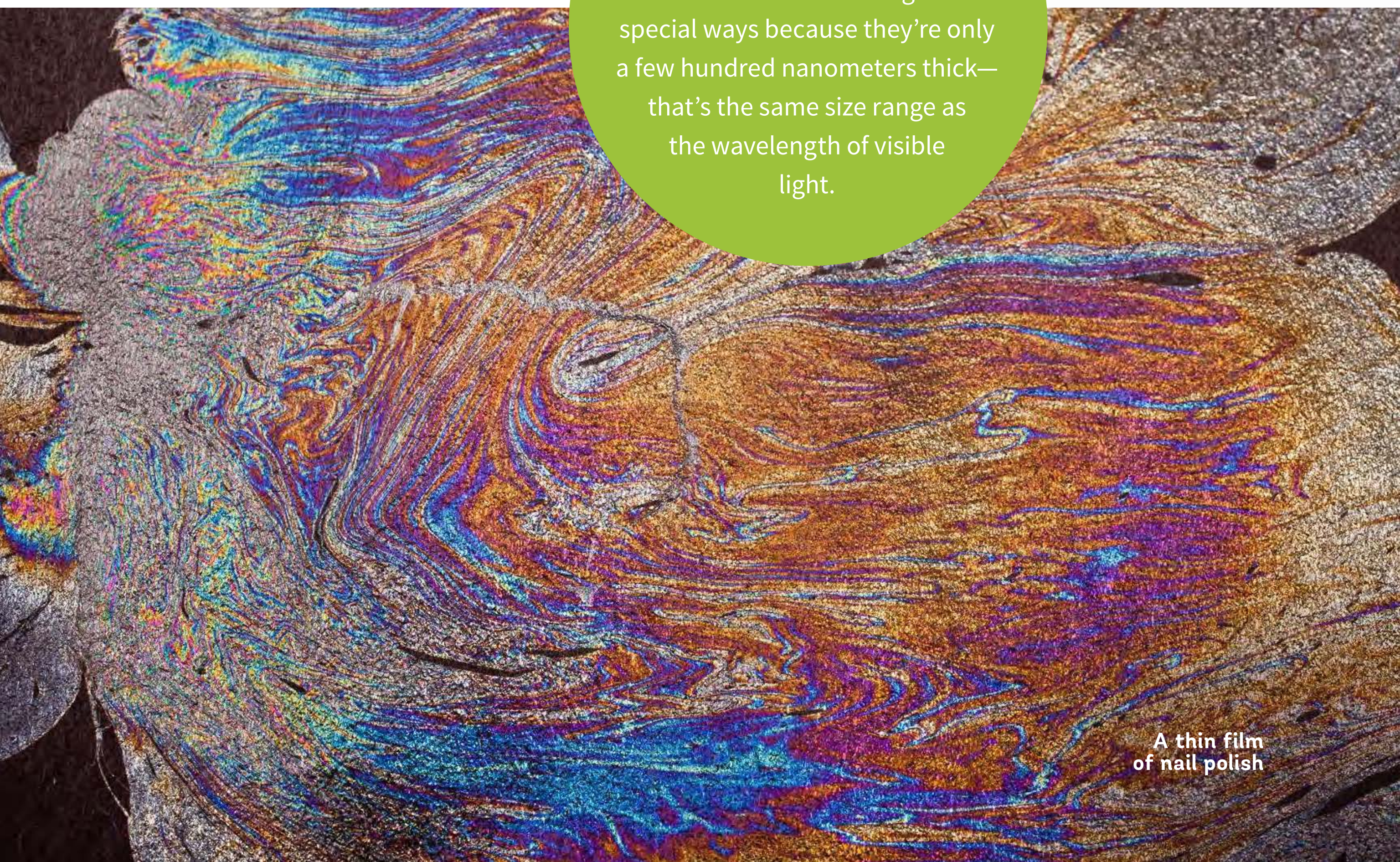
For example, researchers are creating thin film batteries, solar cells, and electronic displays.



iStock

Did You Know?

Thin films can reflect light in special ways because they're only a few hundred nanometers thick—that's the same size range as the wavelength of visible light.



A thin film of nail polish

Konarka

In the future, we expect thin films will be less expensive to make than conventional materials.

See DNA

How is DNA used to make tiny things?

You don't need a lab or fancy equipment to find DNA—the genetic instructions for all living things. Learn how to extract DNA from wheat germ in your own kitchen! Ages 5+

40+ min

Time

Advance preparation: 5 minutes
(beginning several hours ahead of time)
Preparation: 15 minutes
Activity: 15 minutes
Cleanup: 5 minutes

Materials

Isopropyl alcohol *(rubbing alcohol)*

Hot water

Raw wheat germ

Detergent *(dishwashing liquid or shampoo)*

Meat tenderizer *(optional)*

Small cup or bowl for mixing ingredients

Regular spoon

Small, transparent glass for observing DNA *(a shot glass works well)*

Bamboo skewers *(optional)*

Eyedropper *(optional)*

Notes: *Raw wheat germ is available in grocery stores. If you can find 90% isopropyl alcohol (rather than 70%), it works better.*

Safety: *Supervision required. Although nontoxic, do not eat or drink these materials.*

Step 1

Grown-ups, put the alcohol in the refrigerator to cool several hours before starting the activity.

Step 2

Grown-ups, prepare the wheat germ mixture 20 minutes before starting the activity. Put ½ cup hot water in your mixing container. Add 1 spoon wheat germ, ½ spoon detergent, and ½ spoon meat tenderizer (optional). Stir well. Let mixture settle for 15 min.

Step 3

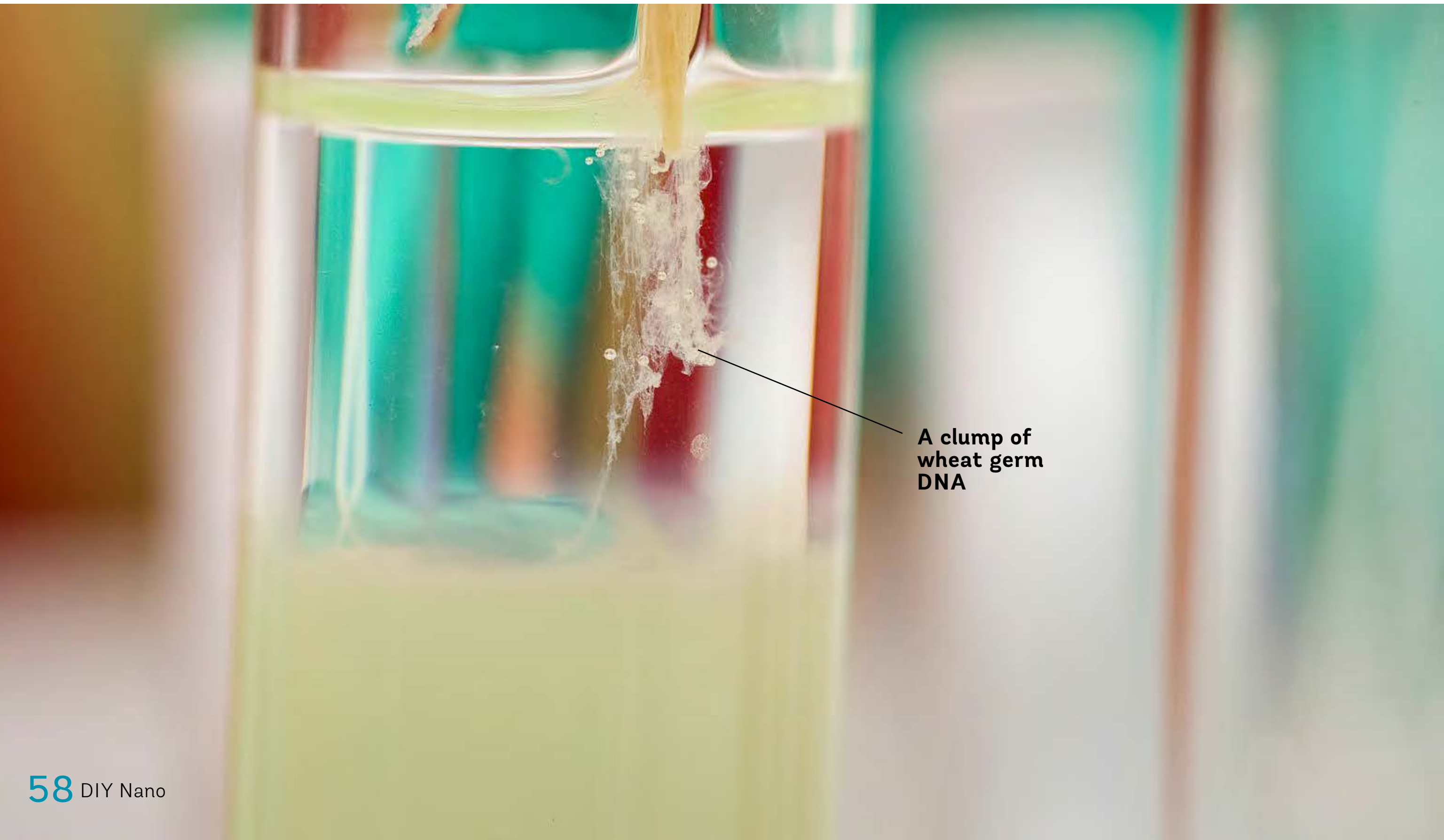
Kids, let’s extract DNA! Use a spoon (or an eydropper) to put about half an inch of wheat germ liquid in the bottom of your glass. Try to get just the liquid from the top of the glass, and none of the gunk at the bottom.

Step 4

Carefully pour about the same amount of alcohol into the glass, making a separate layer on top of the wheat germ liquid. To add the alcohol gently, you can tilt the glass slightly and pour the alcohol down the side. Younger children may need help with this step.

Step 5

Gently rock or swirl the glass. Look inside. Can you see anything forming in the layer of alcohol? Don't be too rough while you rock the cup—you don't want the two layers to mix.



What's going on?

That white, slimy stuff you see is DNA! By adding 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*.

How is this nano?

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

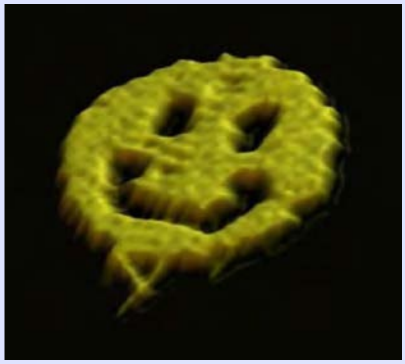
Self-assembly occurs in nature—snowflakes, soap bubbles, and DNA are just three examples of things that build themselves.

DNA nanotechnology

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

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.)

A researcher at Cal Tech got DNA to fold itself up into a nano-sized smiley face!

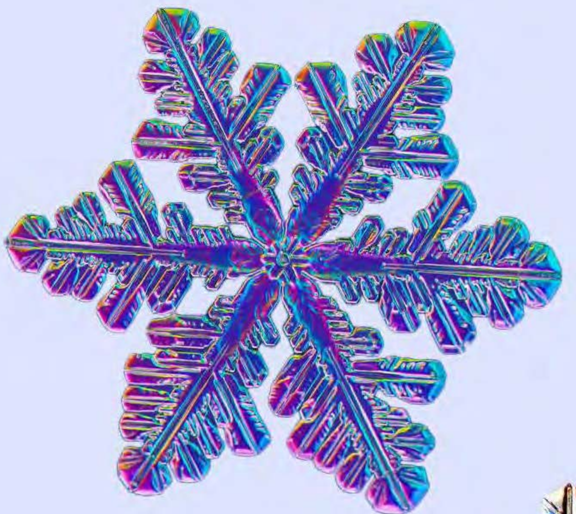


Paul Rothemund, California Institute of Technology

Smiley face made out of DNA

Did You Know?

When weather conditions are right, tiny hexagonal ice crystals grow in clouds and fall to the ground as intricate snowflakes. This process is known as self-assembly because snowflakes assemble themselves from water molecules. Some researchers predict that in the future, new nanotechnologies and materials will build themselves the way snowflakes do!



Kenneth Libbrecht, snowcrystals.com

Morphing Butterfly

Is a Blue Morpho butterfly really blue?

Nano can even be found in nature! Explore how nano-sized structures create brilliant color on a Blue Morpho butterfly's iridescent wings. Ages 7+ Younger kids can observe, but the butterfly wings might be too fragile to handle.

25 min

Time

Preparation: 5 minutes
Activity: 15 minutes
Cleanup: 5 minutes

Materials

Blue Morpho butterfly specimen

Brightly lit window or light box

Isopropyl alcohol *(rubbing alcohol)*

Eyedropper

Note: *Blue Morpho butterfly specimens are available on the Internet. The exact species doesn't matter—just look for a brilliant, iridescent blue.*

Safety: *Supervision required. Be careful with the isopropyl alcohol—do not drink it or get it in your eyes.*

Step 1

Look at the front and back of the butterfly. Handle the butterfly carefully—it's fragile!

Step 2

Hold the butterfly up to a bright window, so light passes through it. When you're looking at the brown side, does it change color? What about when you're looking at the blue side?

Step 3

Set the butterfly down on a table. Use the eyedropper to drip one small drop of alcohol onto the blue side of the wing. What happens? Wait a little while—does anything change?

What's going on?

When you hold the butterfly up to the light, the blue side of the wings looks brown! That's because the blue color is created by the interference of light bouncing off tiny, colorless nano-sized structures, while the brown color is created by pigment.

When bright light passes through the butterfly, the reflective effect is lost on the blue side, and you see the brown pigment from the back side of the wings.

When you put the alcohol on the butterfly's wing, it fills up the spaces between the tiny nanostructures, so they reflect green light, not blue. When the alcohol evaporates, the wings look blue again.

How is this nano?

The Blue Morpho's wing reflects light in special ways because it has tiny structures that are only a few hundred nanometers thick. That's in the same size range as the wavelength of visible light.

Soap bubbles, peacock feathers, and oil slicks are some other examples of nanostructures that create beautiful, iridescent colors.

Nanotechnology

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

Researchers have created low-energy electronic displays inspired by the wings of Blue Morpho butterflies.

Tiny nanostructures on the butterfly's wing

A drop of alcohol makes the Blue Morpho's wing green

Wing nanostructures: Shinya Yoshioka, Osaka University

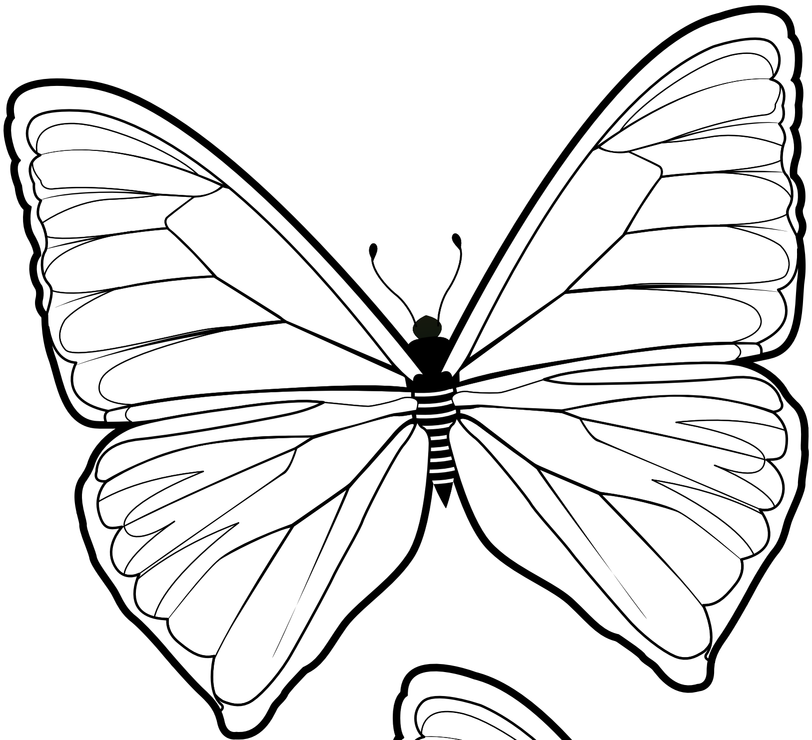
iStock

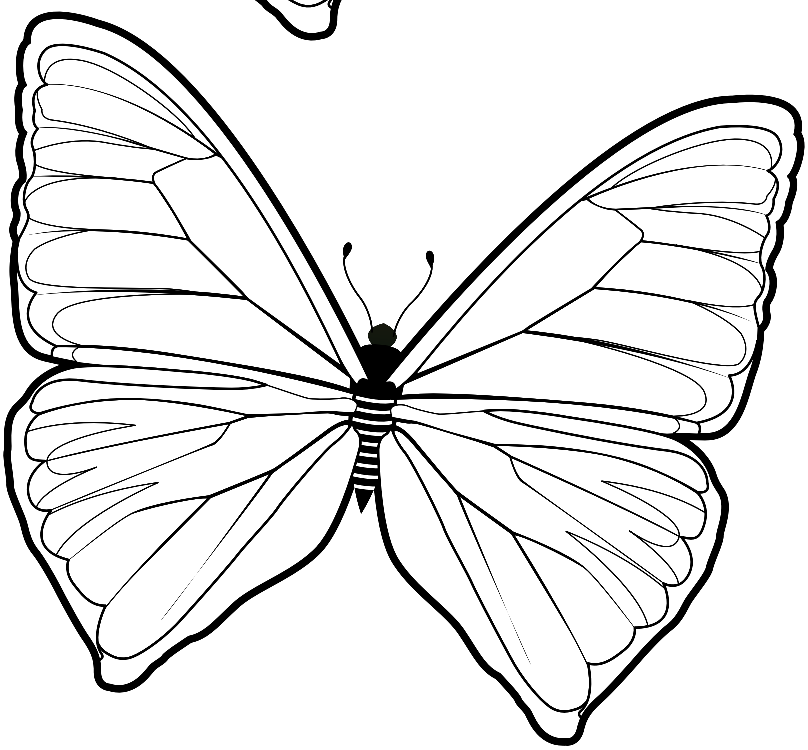
Did You Know?

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

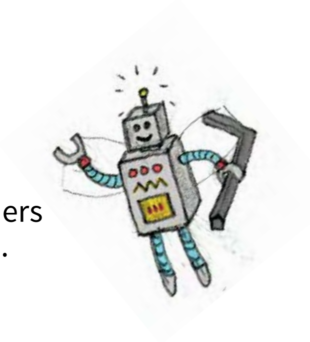
Color These Butterflies Blue!

Real Blue Morpho butterfly wings are a bright, iridescent blue.
Surprisingly, their brilliant color is actually created by tiny, colorless nanostructures!
Light waves bounce off the tiny structures, reflecting blue light to your eyes.





Draw Your Own Robot!



Nano is all around us—in nature and in technology. Some researchers are inspired by nature to create new materials and technologies. Invent a robot inspired by nano in nature.

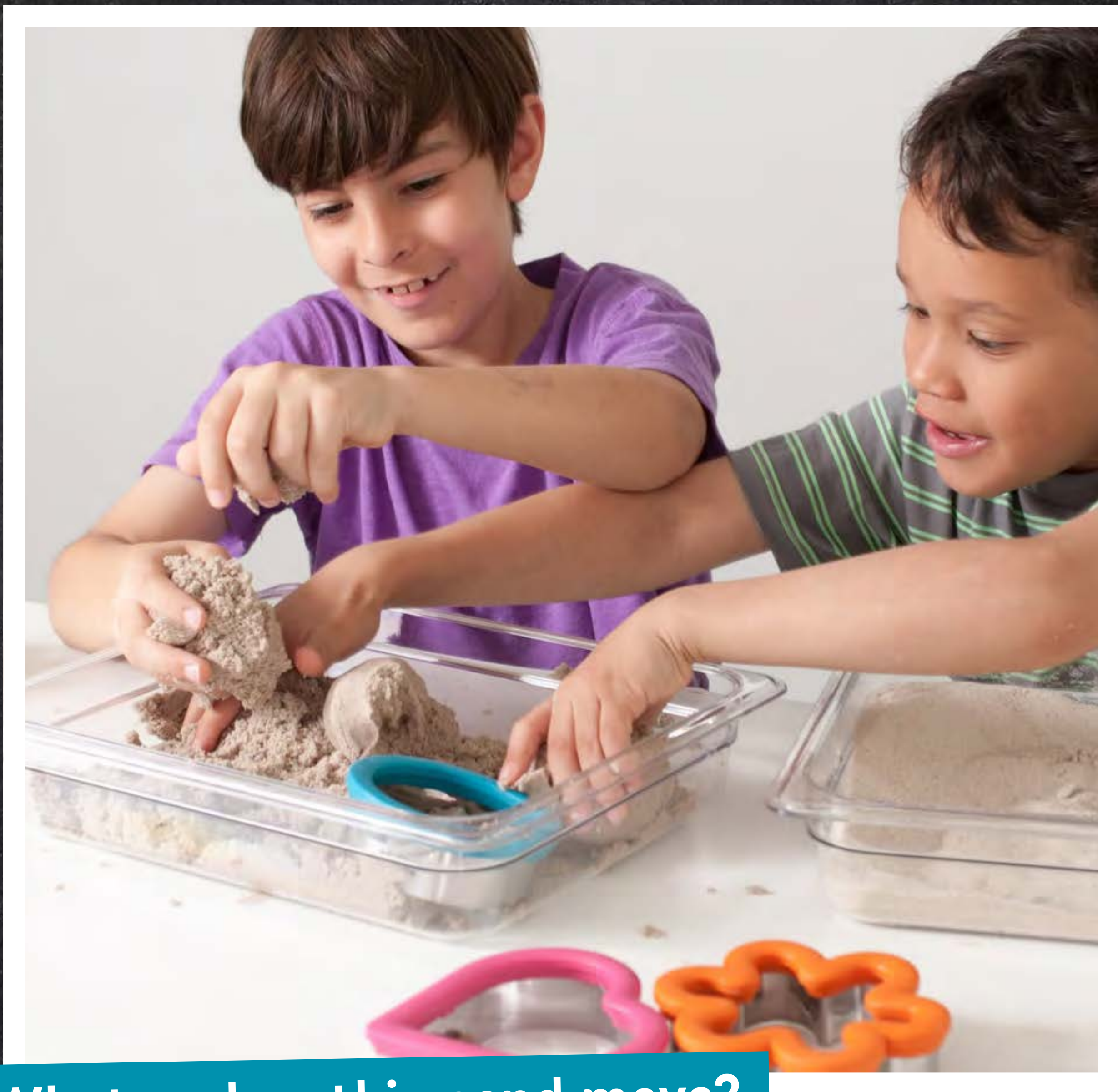
My robot's name is ______________________________

Its job is ______________________________

It could change my life by ______________________________

____

Sticky Sand



What makes this sand move?

Play around with Kinetic Sand™ and learn about ways scientists are inspired by nature to create new materials. Can you build a sand castle? A mermaid? An alligator? Ages 3+

Time

Preparation: 5 minutes
Activity: 10+ minutes
Cleanup: 5 minutes

Materials

Kinetic Sand™

Play sand *(regular beach or sandbox sand)*

Cookie cutter shapes *(assorted)*

2 trays or containers to hold the sand

Kinetic Sand is available in many toy stores or you can order it online from wabafun.com.

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.*

Safety: *Avoid including objects that may be a choking hazard. Avoid getting sand in eyes.*

Step 1

Grown-ups, get everything ready! Place each kind of sand in its own tray or container. These sands can get messy, so plan to do this activity outside or someplace where clean-up will be easy.

Step 2

Kids, play with both kinds of sand! Poke it. Pick it up. Let it fall slowly from your fingers. What happens?

Step 3

Use the cookie cutter shapes to make small sculptures. Do your sculptures hold their shapes? What happens if you leave them alone for a little while? What differences do you notice between the two kinds of sand?

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 Kinetic Sand looks and feels just like regular sand, but a whole container 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 the 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.

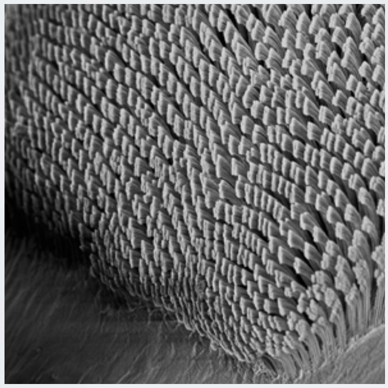
PDMS isn't only used in Kinetic Sand—it's used in many commercial products, including water repellants, lubricating oils, and even anti-gas drops for babies!

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.

New nanotechnologies are inspired by nature

Scientists at the University of Massachusetts Amherst have used PDMS, as well as other soft polymers, to make a material known as Geckskin™.



University of Massachusetts Amherst

Gecko toes have tiny, nano-sized hairs that allow them to walk on walls and cling to ceilings.

The amazing, sticky properties of Geckskin were inspired by real geckos in nature. Geckos can walk on walls and cling to ceilings because of tiny nano-sized hairs on their feet.

University of Massachusetts Amherst

The sticky feet of geckos have inspired new products

I Spy Nano!

Find the hidden objects in the picture.
They all use nanotechnology!

Pencil

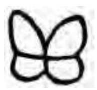
Carbon atoms can form graphite (pencil "lead"), which is a very soft material, but they can also form diamond, the hardest natural material known on Earth. Atoms are the building blocks of nature, and they're even smaller than a nanometer.

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.

Maggie Swanson

Did You Know?

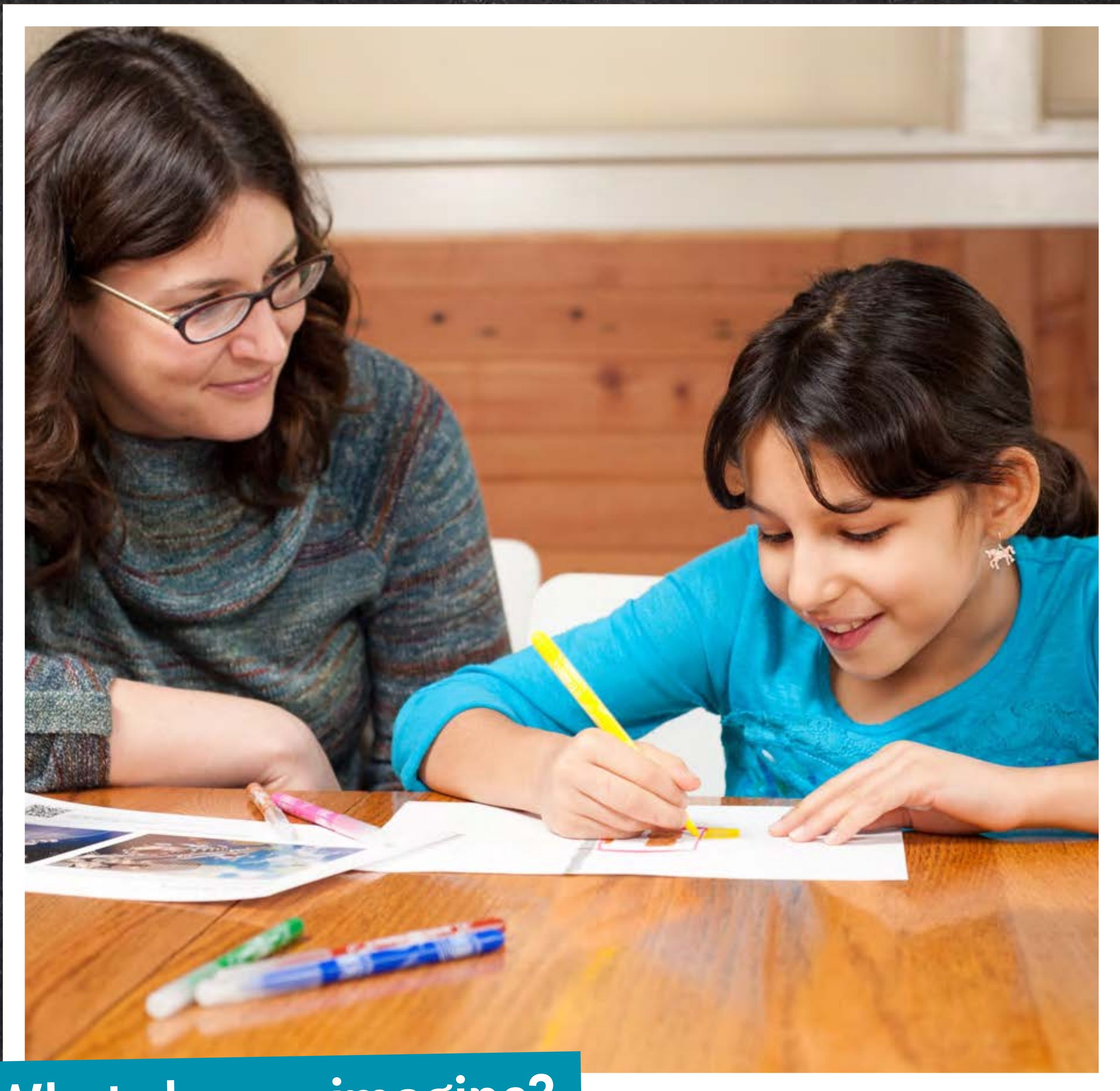
Since the Middle Ages, nano-sized gold and other metals have been used to color stained glass.

CHAPTER 4

NANO AND OUR LIVES

Make your own stained glass art!

Space Elevator



What do you imagine?

Imagine what the world might look like if we could build an elevator to space. It's fun to imagine the future and it's important, too! Ages 5+

Time

Preparation: 5 minutes
Activity: 10+ minutes
Cleanup: 5 minutes

Materials

Paper

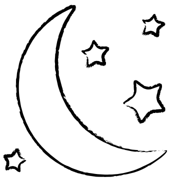
Markers

Step 1
Grown-ups, get everything ready! Take a few moments to look at the space elevators images and to read the suggested question prompts.

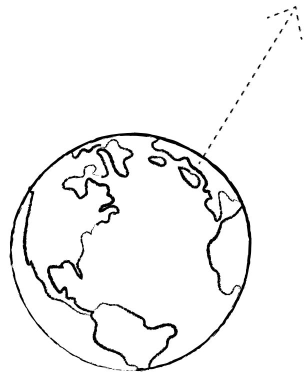
Step 2
Kids, start imagining! What if it were possible to take an elevator into space? Imagine what our world would be like. Draw a picture of the future world you're imagining. What would we need in space? What kinds of plans would we have to make?

Step 3
Think about it! What might the world look like if we could build an elevator to space?

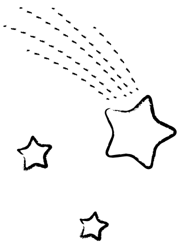
Imagine an Elevator to Space



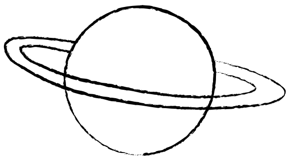
What might the world look like if we could build an elevator to space?



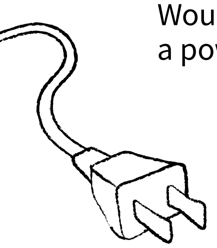
Where would you go in space?



Where would your space elevator start?

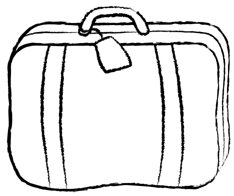


Would you need a power source?



How would the space elevator work?

What would you need to bring with you?



Who would get to use the space elevator?

Mondolithic

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.

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 people in the past 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.

If these scientists are successful, someday it might be easy to bring people and materials into space. 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.

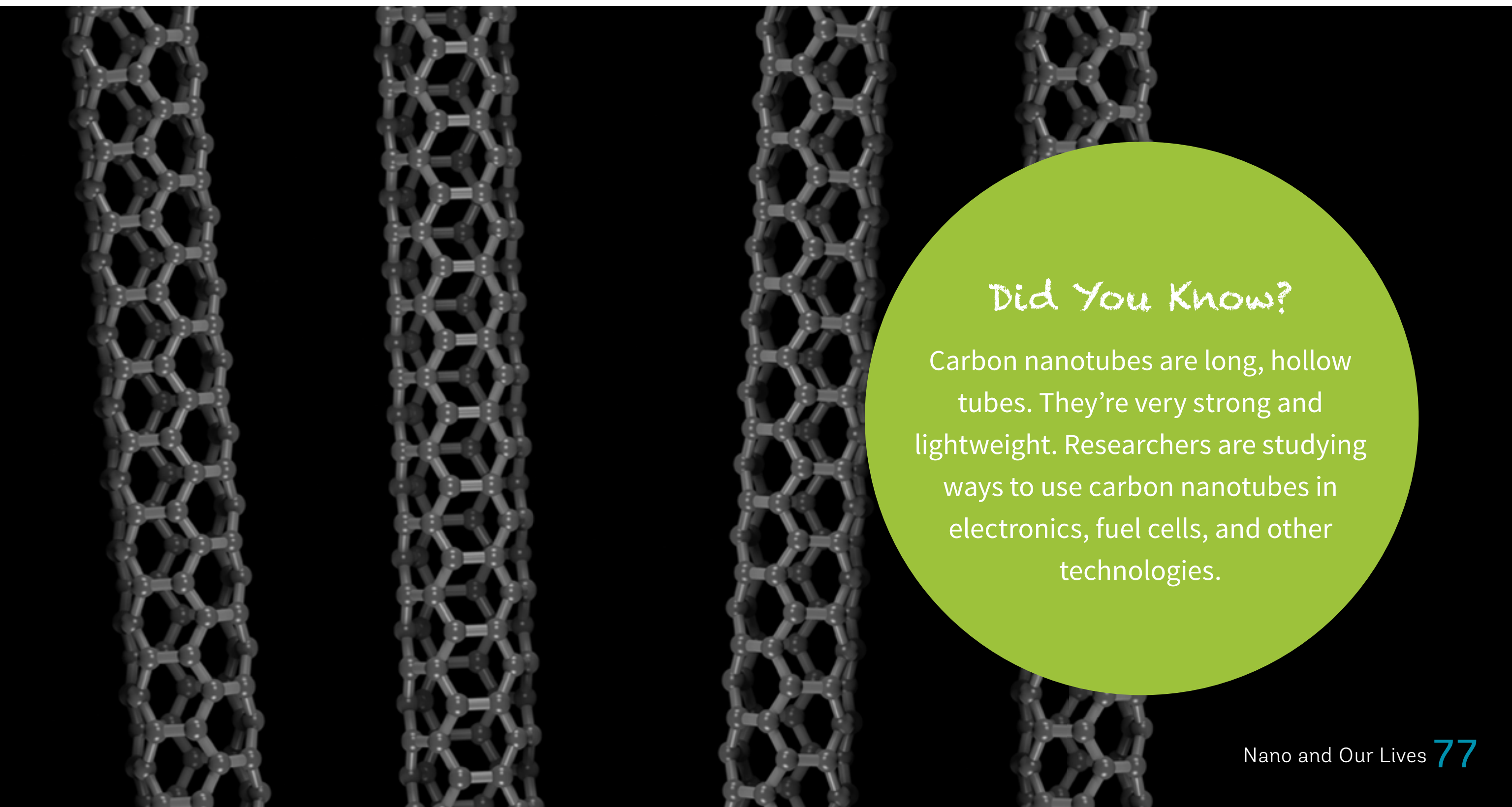
Researchers think about the future world they would like to live in when they create new technologies. And when people decide to use new technologies, those technologies can change their lives in ways that are big and small.

An elevator to space

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!

Pat Rawling / NASA

Artist illustration of a space elevator



Did You Know?

Carbon nanotubes are long, hollow tubes. They're very strong and lightweight. Researchers are studying ways to use carbon nanotubes in electronics, fuel cells, and other technologies.

Mystery Sand

Can sand keep itself dry?

Play around with this surprising sand. Try dropping water onto it, or sprinkle it into a cup full of water. What happens? What keeps it from getting wet? Ages 3+

35+ min

Time

Preparation: 5 minutes
Activity: 15+ minutes
Cleanup: 15 minutes


1


2


3

Materials

"Magic" *(hydrophobic)* sand

Ordinary colored sand

Two containers for sand *(tubs with flat bottoms are best)*

Water

Spoon

Eyedropper *(optional)*

Note: *Hydrophobic sand is inexpensive and available at toy stores and on the Internet—look for "magic sand" or "aqua sand." Ordinary colored sand is available at craft stores and pet shops.*

Safety: *Avoid getting sand in eyes.*

Step 1

Grown-ups, get everything ready! Put the "magic" sand in one container and the ordinary sand in the other container. Set out a small container of water, the spoon, and the eyedropper (optional).

Step 2

Kids, investigate the sand! Check out the two kinds of sand. Can you see or feel a big difference? Sprinkle a little water on both kinds of sand using a spoon or eyedropper. Now can you see a big difference?

Step 3

Once you figure out which sand is special, there are lots of other fun things to try! Use your finger to make a "path" in the sand. Put a drop of water on the path, and tilt the tray to make it follow the path. Pour sand into the water and then scoop it out with the spoon. Is it wet? Sprinkle a "raft" of sand on the surface of the water, and poke it gently with your finger. Can you use the sand to keep your finger dry?

Magic 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.

Sciencenter

What's going on?

The special sand has been chemically treated to repel water. This *hydrophobic* ("water fearing") sand is coated with a silicon compound. The layer is only one nanometer thick, so the coated sand looks and feels like regular sand, but it behaves very differently.

Ordinary sand—the kind you find at the beach or a playground—gets wet. That's because sand and water molecules are attracted to each other.

How is this nano?

The layer of silicon compound coating the hydrophobic sand is only one nanometer thick.

A nanometer is a billionth of a meter. That's really, really small.

Nano-coatings

Nanotechnology takes advantage of the way things behave differently at the nanoscale to make new products and applications. Sometimes a nano-coating is all it takes to make ordinary sand extraordinary!

Emily Maletz

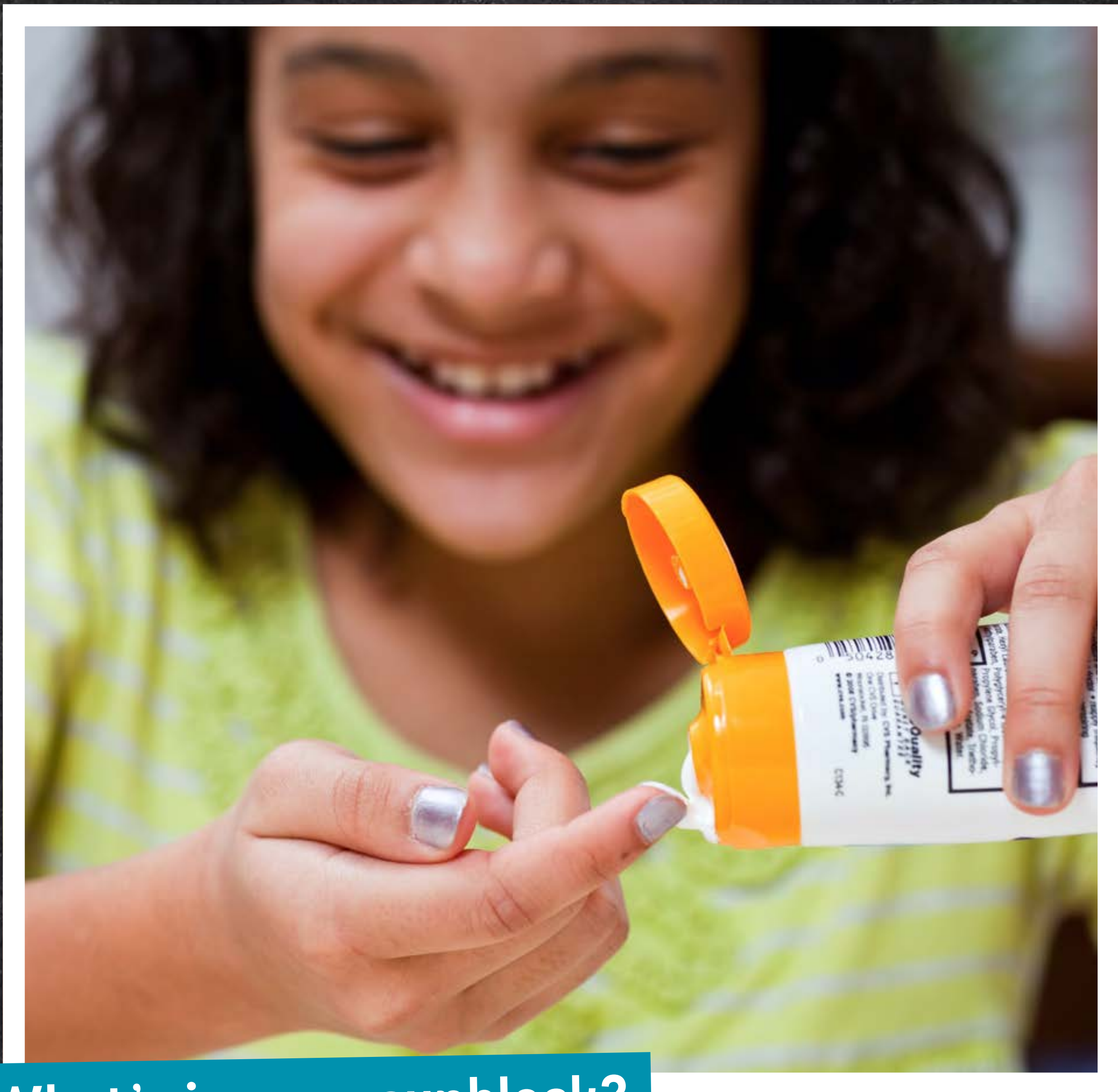
A nanometer is a billionth of a meter. Your fingernails grow a nanometer every second!

iStock

Did You Know?

Hydrophobic or "magic" sand was originally invented to help clean up oil spills. It repels water but attracts oil.

Invisible Sunblock



What's in your sunblock?

Do you remember those lifeguards with the white noses? Find out why some mineral sunblock rubs in clear and why some stays white. Ages 5+

15 min

Time

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

Materials

Black construction paper

Cotton swabs

Zinc oxide diaper cream

Nano zinc sunblock

Note: *You can find a nano zinc sunblock by looking for a formula with zinc oxide that says it goes on clear.*

Safety: *If you have sensitivities or allergies to lotions, ointments, or sunblocks, don't apply these products to your skin.*

Step 1

Use a cotton swab to put a very small dab of diaper ointment on the black paper. Try rubbing it in.

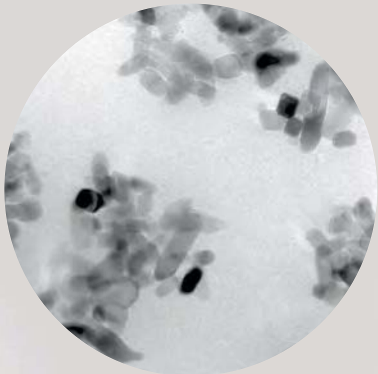
Step 2

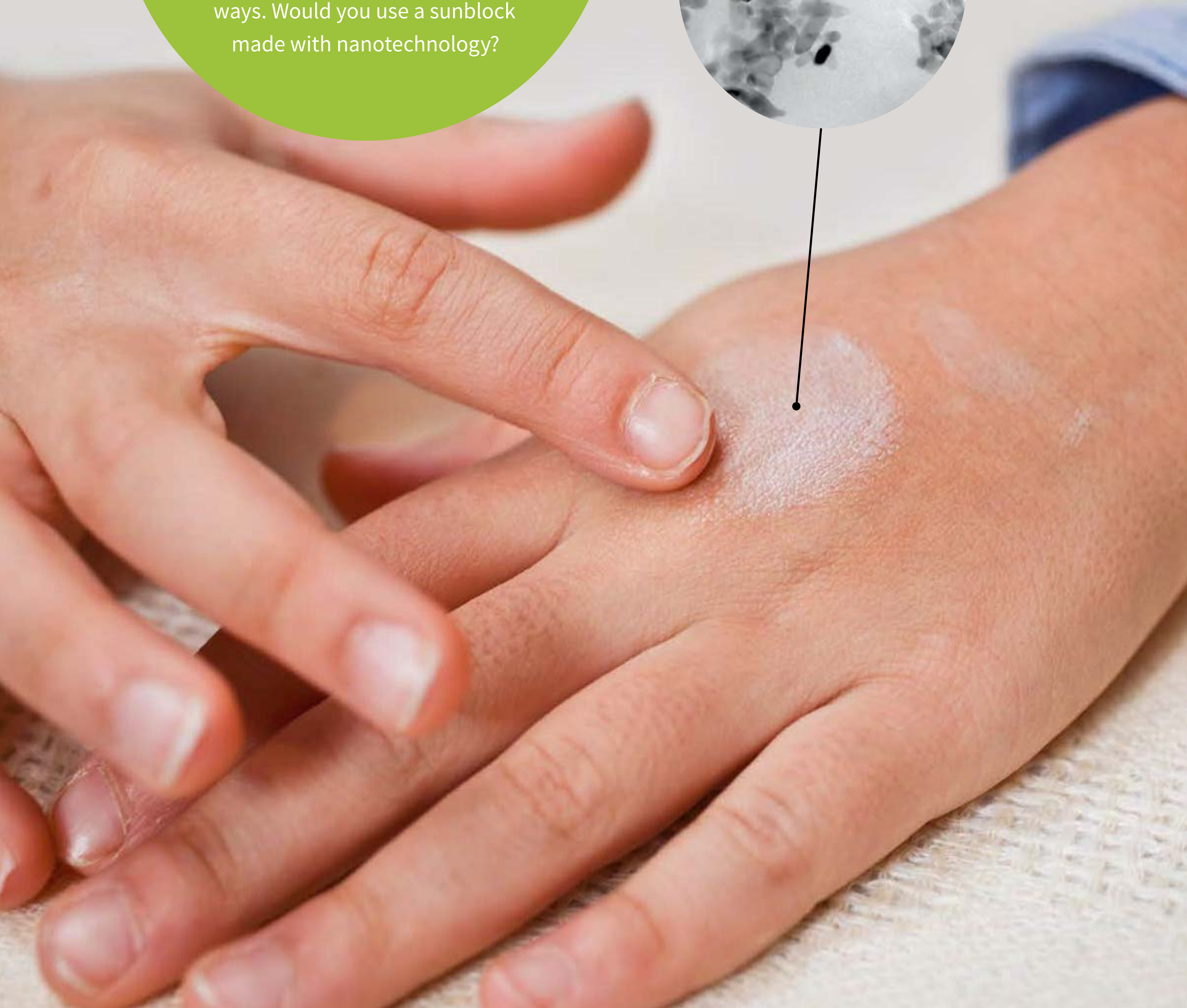
Now use a different swab to rub in a dab of the sunblock. Try to use the same amount of sunblock as ointment. Is it easier to rub in than the ointment?

Think About it

Sunblocks are some of the most common products containing nanotechnology. We think these sunblocks are safe for people, but some research suggests that nanomaterials sometimes affect plants and animals in unexpected ways. Would you use a sunblock made with nanotechnology?

Nanoparticles in sunblock





Nanoparticles: Nanocomposix

Emily Maletz

What's going on?

The sunblock rubs in better than the ointment because it contains tiny, nano-sized 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 do reflect light, so they create a white film.

How is this nano?

Sunblock containing nanoparticles is one of the most common examples of nanotechnology. Many other health and beauty products also contain nano-sized particles, including cosmetics and toothpaste.

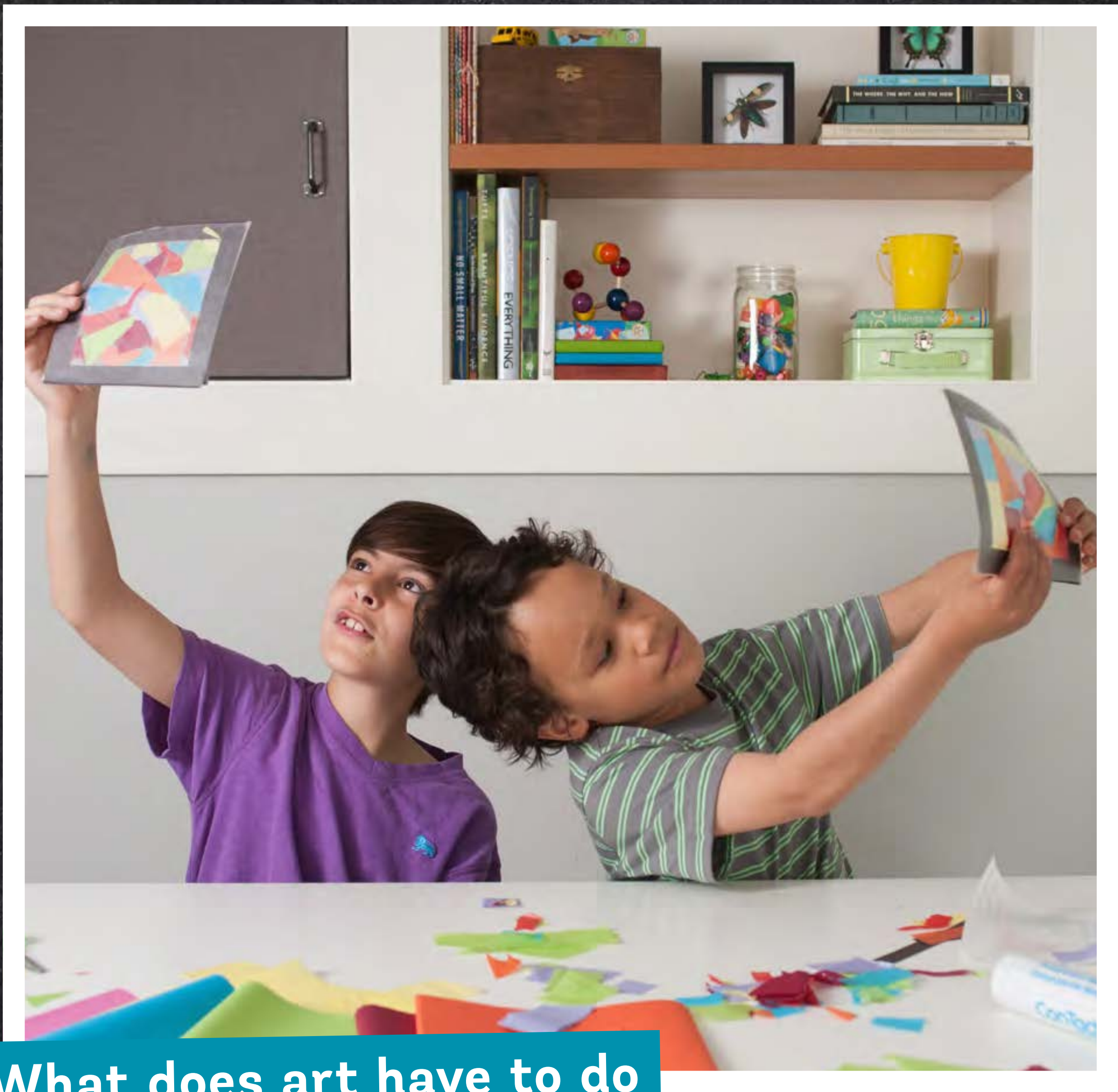
Labels don't have to say what size their ingredients are, so you could use a product containing nanoparticles without knowing it. Does that surprise you?

Nanoparticles

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

The nanoparticles in sunblock are invisible to the human eye because they're smaller than the wavelength of visible light.

Stained Glass Art



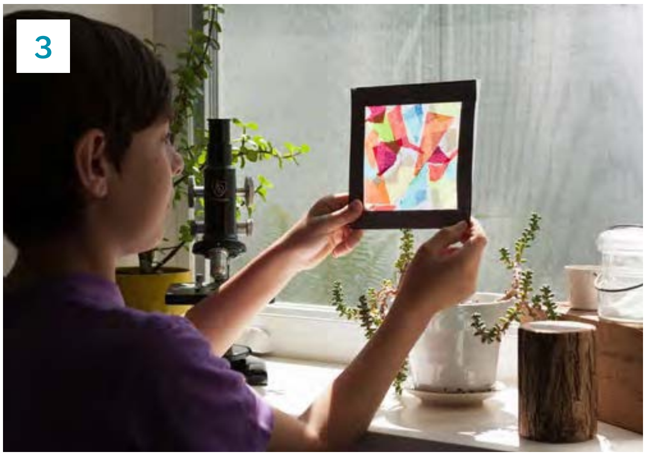
What does art have to do with nanotechnology?

Sunlight filtered through colored glass is beautiful. Use tissue paper to make art inspired by stained glass windows. Ages 5+

20+ min

Time

Preparation: 5 minutes
Activity: 10+ minutes
Cleanup: 5 minutes



Materials

Tissue paper *(assorted colors)*

Black construction paper

Clear contact paper

Scissors

Safety: *Take care using scissors with small children.*

Step 1

Pre-cut pieces of tissue paper, strips of black construction paper, and squares of contact paper. Grown-ups, you can do this ahead of time or let the kids use scissors to cut up their own pieces.

Step 2

Make art! Place the pieces of colored tissue paper on the adhesive side of a piece of contact paper (you'll have to peel off the backing). Use the black construction paper strips to create a border and place them between the pieces of tissue paper to look like the leading in real stained glass. Trim your artwork. You can even cut out a special shape!

Step 3

Now hold your design up to a light or window. What do you notice?

What's going on?

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.

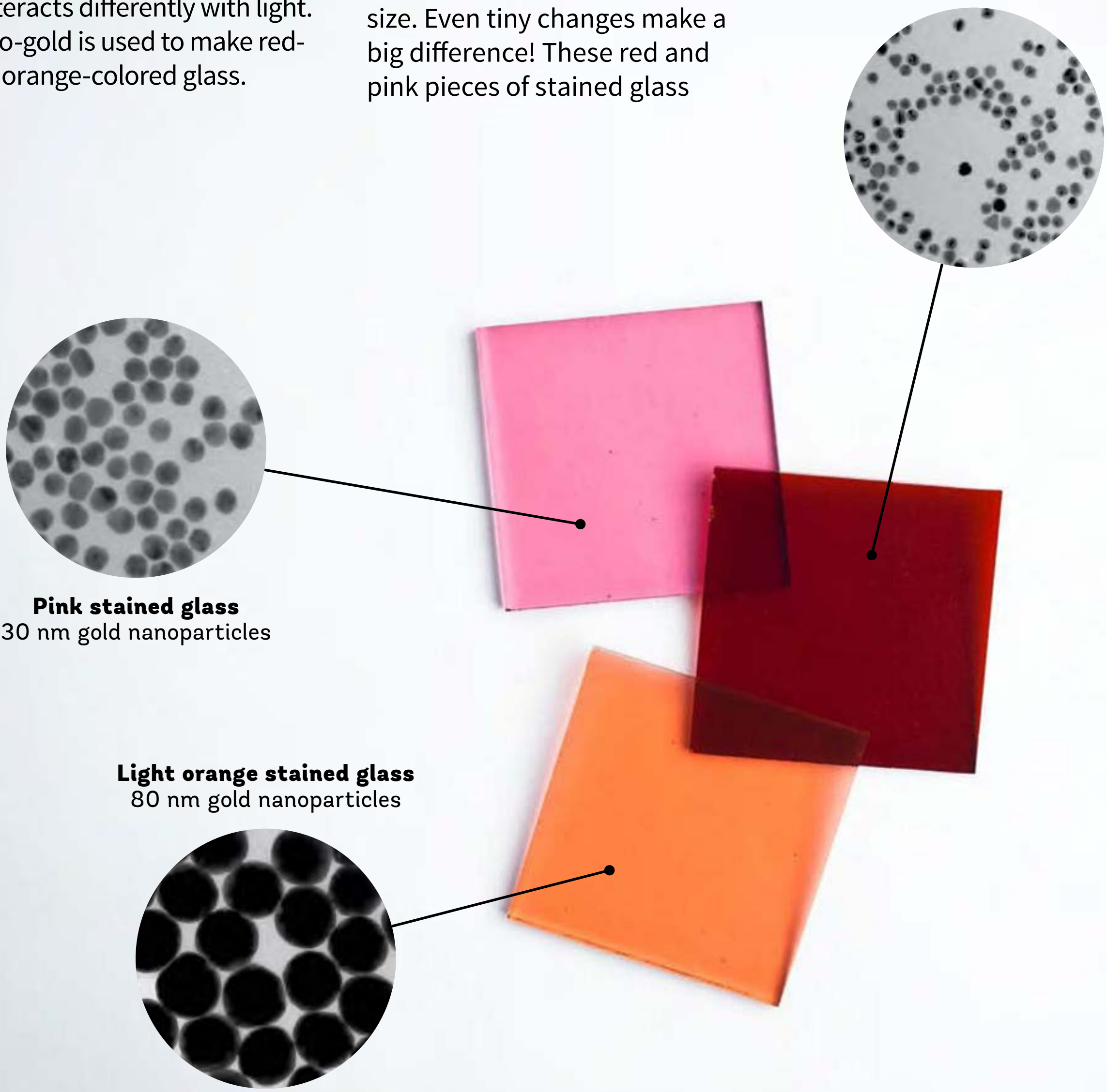
Since the Middle Ages, nano-sized gold and other metals have been used to color stained glass. Large pieces of gold usually look golden and shiny, but when gold gets very, very small its color changes because it interacts differently with light. Nano-gold is used to make red- and orange-colored glass.

Different nano-sized materials produce different colors. For example, green- and yellow-colored staining can come from nano-sized particles of silver.

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 nano-sized.

Many nano materials behave differently as they change size. Even tiny changes make a big difference! These red and pink pieces of stained glass contain gold nanoparticles in the range of 10–30 nanometers across, while the more orange-colored glass contains gold nanoparticles that are just a bit bigger—around 80 nanometers across.



Red stained glass
10 nm gold nanoparticles

Pink stained glass
30 nm gold nanoparticles

Light orange stained glass
80 nm gold nanoparticles

Glass: Emily Maletz, Nanoparticles: Nanocomposix

Emily Maletz

The red coloring in some stained glass comes from tiny particles of nano-gold.

Where Can You Find Nano?

Nano is all around us—sometimes hidden in surprising places. Twenty-three things in this room use nanotechnology or nanostructures to gain special properties. Can you find them all?

5 blue butterflies

orange

5 peacock feathers

8 electronic devices

nanosilver toy bear

nanosilver socks

molecular model

thin-film solar panel

Emily Maletz

Did You Know?

Tiny, nano-sized hairs on a gecko's toes let it climb up walls and walk across ceilings.

Puzzle Blocks

and

Activity Sheets

Nano Puzzle Blocks 94
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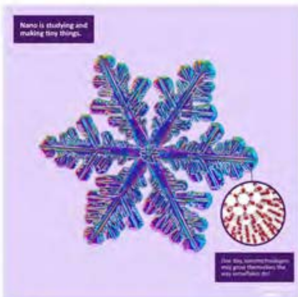
Draw Things That Smell Like 118
AFM Sheet 121
Graphene Drawing Sheet 123
Nanoscientist Card 125
Butterfly Coloring Sheet 127
Robot Coloring Sheet 129
I Spy Nano! 132

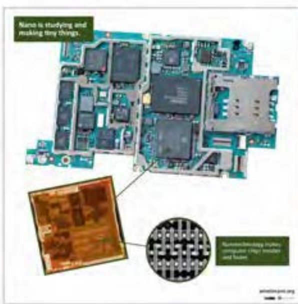
Make a Set of Nano Puzzle Blocks

Step 1 Use the block artwork in this book, or photocopy it onto cardstock or other heavy paper. Printable block designs can also be downloaded from **whatisnano.org**.

Step 2 Cut out each block along the black lines. Fold along the red lines to make a cube. Tuck the tabs inside and tape the block closed.

Step 3 Build the puzzle! Can you make each picture?





Block artwork images:
Stained glass: iStock, Gold nanoparticles: nanoComposix/NISE Network. Snowflake: Kenneth Libbrecht/snowcrystals.com, Ice structure: Martin McCarthy/NISE Network. Butterfly: iStock, Butterfly scales: Rashmi Nanjundaswamy/Lawrence Hall of Science/NISE Network.
Gecko: iStock, Gecko foot "hair": A. Kellar, Lewis & Clark College. Motherboard: Emily Maletz/NISE Network, Processor and SEM chip detail: chipworks.com. Boy and buckyball: Gary Hodges/NISE Network, DNA: iStock.

Block designs can be downloaded from **whatisnano.org**

Block designs can
be downloaded from
whatisnano.org

TAPE OR GLUE THIS FLAP

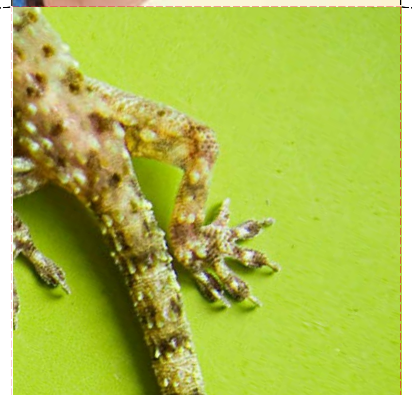
whatisnano.org

NISE network
NANOSCALE INFORMAL SCIENCE EDUCATION
nisenet.org

CUT along black lines

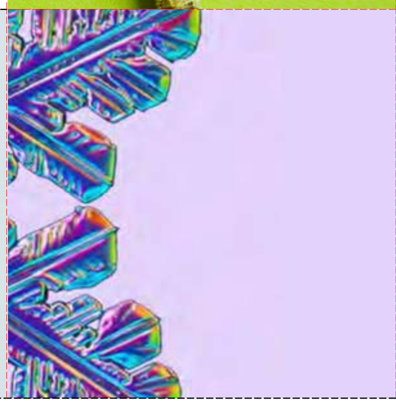
FOLD along red lines

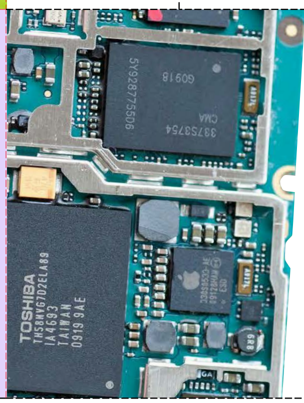
BLOCK 2



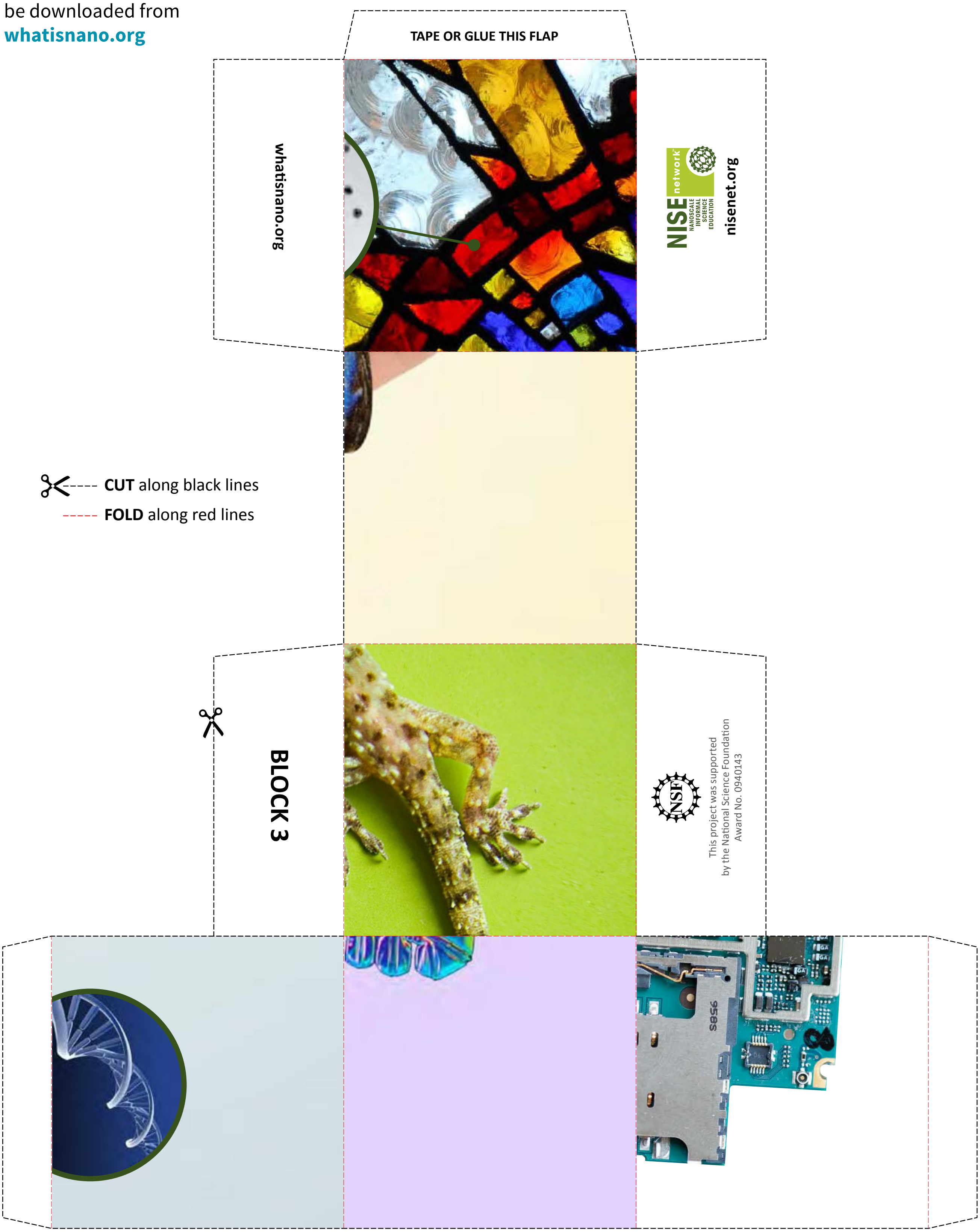
NSF

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





Block designs can be downloaded from **whatisnano.org**



Block designs can be downloaded from **whatisnano.org**

Block designs can be downloaded from **whatisnano.org**

CUT along black lines

FOLD along red lines

Block designs can be downloaded from **whatisnano.org**

CUT along black lines

FOLD along red lines

Block designs can be downloaded from **whatisnano.org**

CUT along black lines

FOLD along red lines

Block designs can
be downloaded from
whatisnano.org

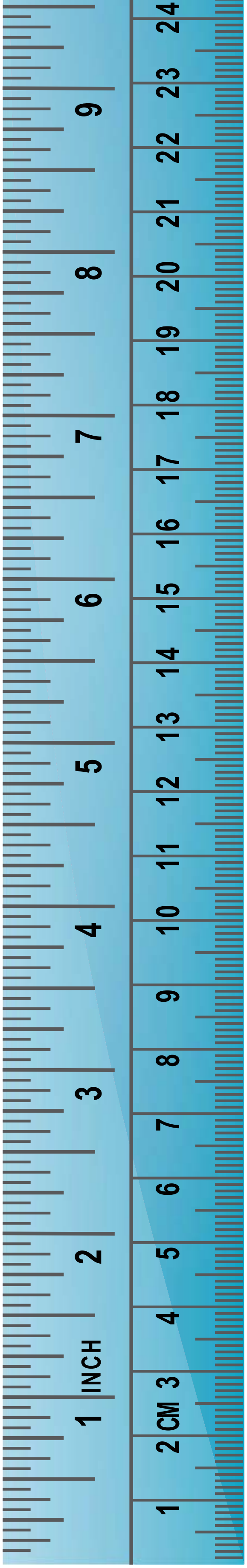
CUT along black lines

FOLD along red lines

Block designs can be downloaded from **whatisnano.org**

✂---- **CUT** along black lines

----- **FOLD** along red lines



How Big Is Your Hand?

Try measuring in nanometers!

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

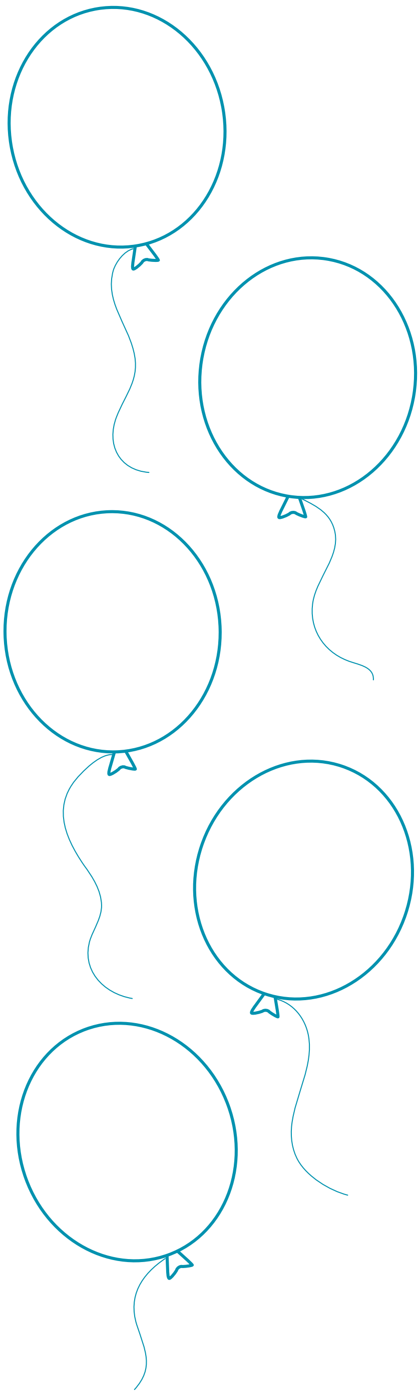
20 million nanometers

10 million nanometers

0 nanometers

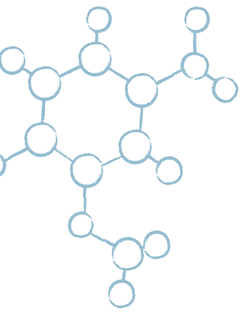
Match the Scent

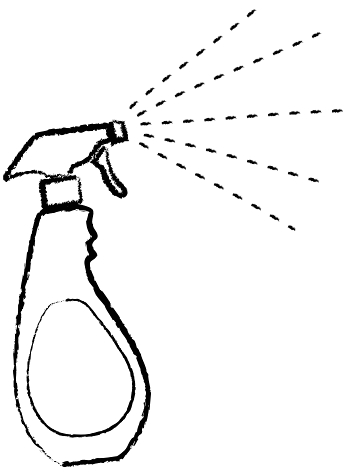
Color in the balloons to match yours and write the names of the scents on the right.
Then use your nose to match them up!



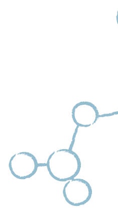
Draw Things That Smell Like…

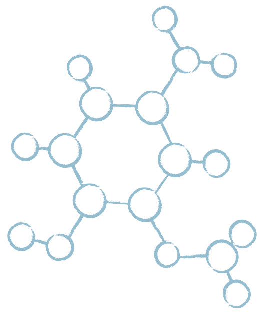
vanilla



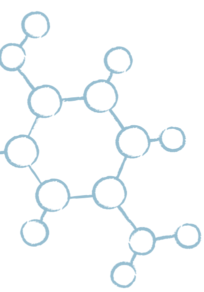


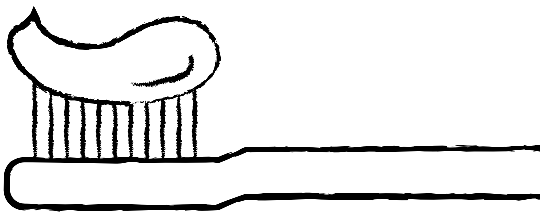
lemon



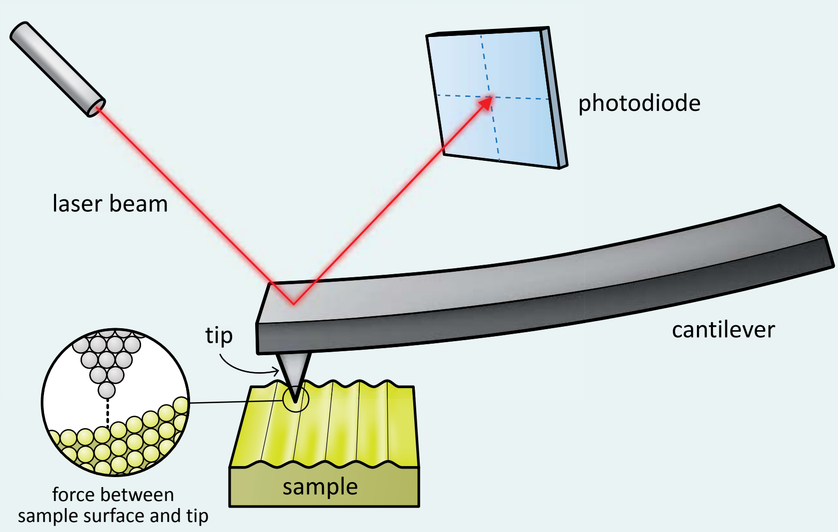


mint





Emily Maletz



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!

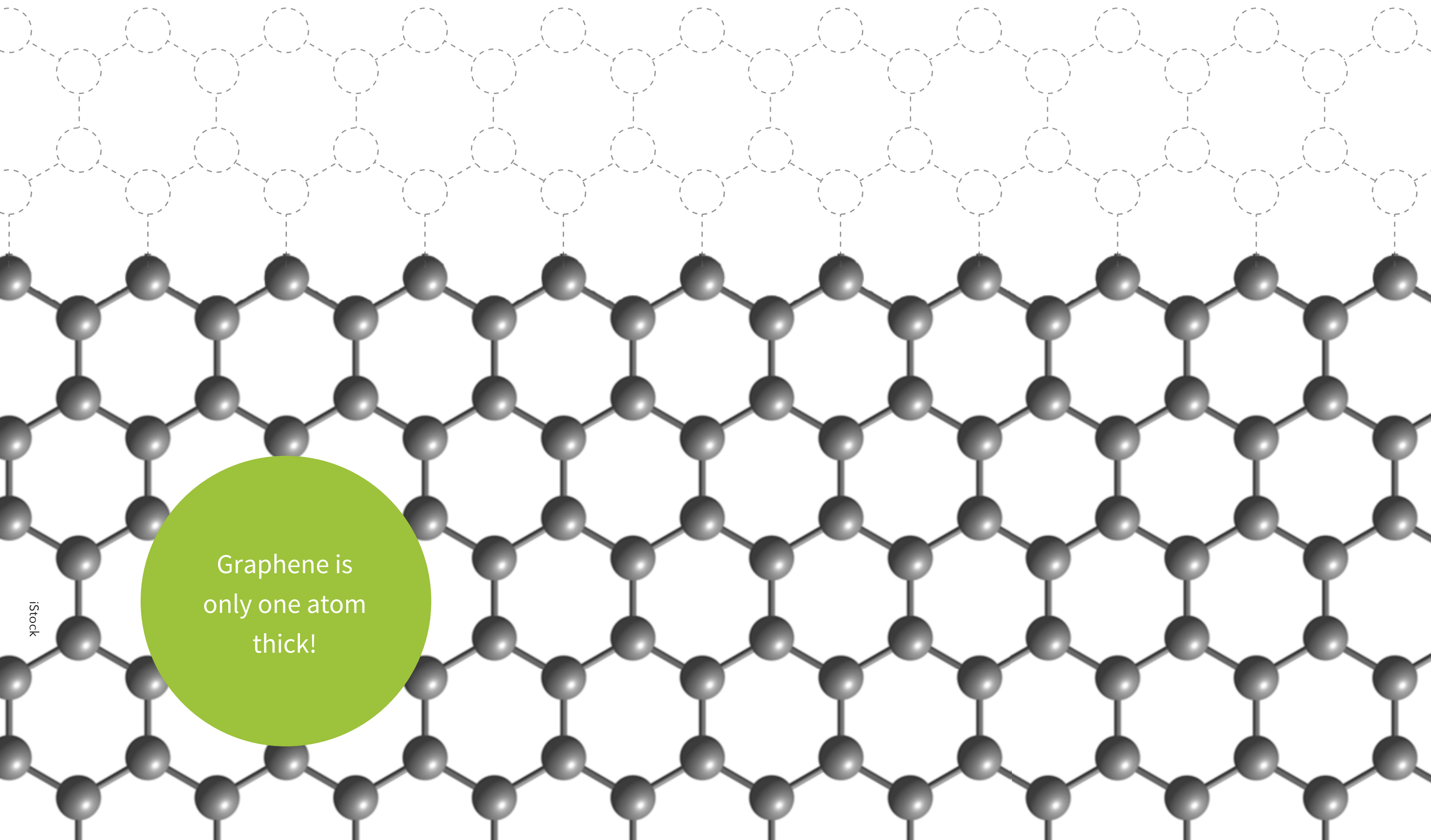
To analyze a sample, the AFM tip is moved back and forth across the surface many times. A computer program combines the data and creates an image.

What do you feel in the bag? 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.

Draw Graphene!

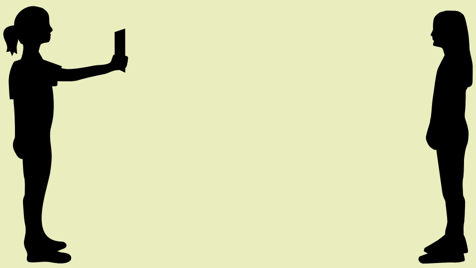
Continue the graphene structure by adding more carbon atoms arranged in a honeycomb pattern.



iStock

Dress Up Like a Nanoscientist!

Gary Hodges



Try this!

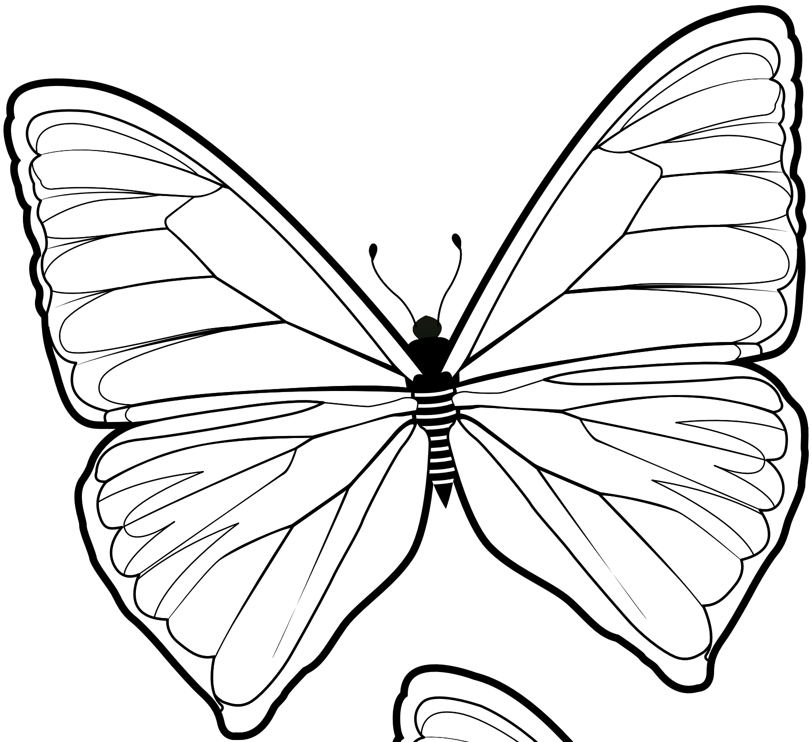
1. Have a friend stand a few feet in front of you. Hold up this card and align your friend's face with the cutout.

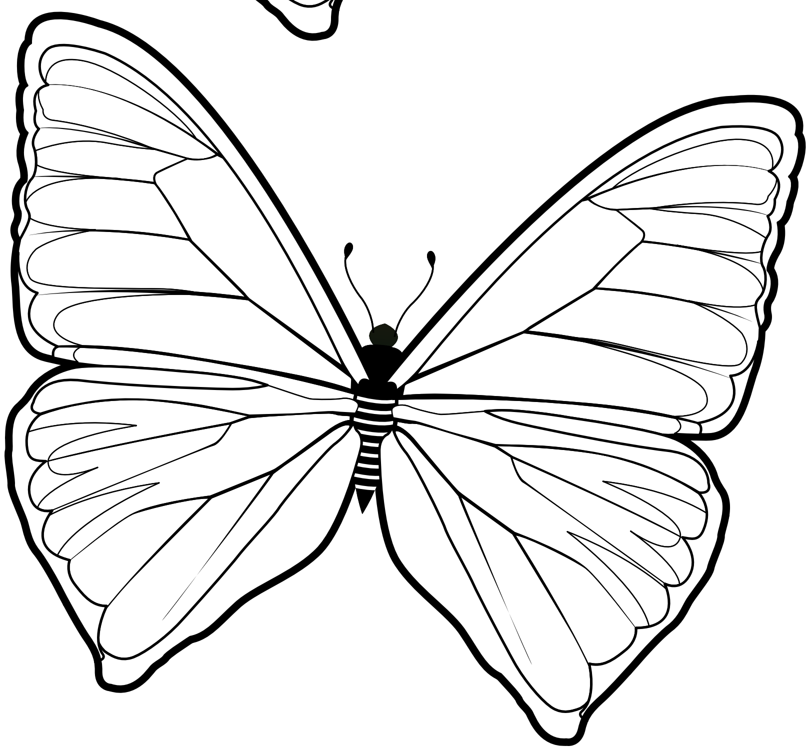
2. Imagine your friend as a future nanoscientist! If you have a camera (or phone with a camera), take a picture!

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

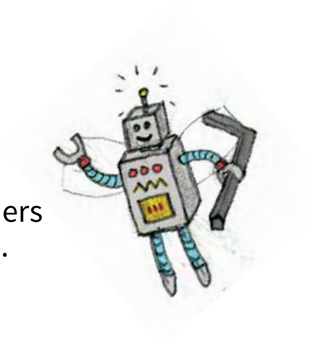
Color These Butterflies Blue!

Real Blue Morpho butterfly wings are a bright, iridescent blue.
Surprisingly, their brilliant color is actually created by tiny, colorless nanostructures!
Light waves bounce off the tiny structures, reflecting blue light to your eyes.





Draw Your Own Robot!



Nano is all around us—in nature and in technology. Some researchers are inspired by nature to create new materials and technologies. Invent a robot inspired by nano in nature.

My robot's name is ____________________

Its job is ____________________

It could change my life by ____________________

____

I Spy Nano!

Find the hidden objects in the picture.
They all use nanotechnology!

Pencil

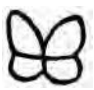
Carbon atoms can form graphite (pencil "lead"), which is a very soft material, but they can also form diamond, the hardest natural material known on Earth. Atoms are the building blocks of nature, and they're even smaller than a nanometer.

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.

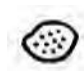


Butterfly

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.

Maggie Swanson

Science Activity Credits

Egg Drop
This activity was adapted from *Liquid Body Armor* developed by the Children's Museum of Houston for the NISE Network. It is a modified version of the NISE Network's educational products Exploring materials—Oobleck and DIY Nano Egg Drop developed by the Sciencenter, Ithaca, NY.

Gravity Fail
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. 89P94. Arlington, VA: NSTA Press. It is a modified version of the NISE Network's educational products Exploring Forces—Gravity and DIY Nano Gravity Fail developed by the Sciencenter, Ithaca, NY.

Ready, Set, Fizz
This activity is a modified version of the NISE Network's educational products Exploring Properties—Surface Area and DIY Nano Ready, Set, Fizz developed by the Sciencenter, Ithaca, NY.

Smelly Balloons
This activity is a modified version of the NISE Network's educational products Exploring Size—Scented Balloons and DIY Nano Smelly Balloons developed by the Sciencenter, Ithaca, NY.

Heat It Up
This activity is a modified version of the NISE Network's educational products Exploring Materials—Heat Transfer and DIY Nano Heat It Up developed by the Sciencenter, Ithaca, NY.

Mystery Shapes
This activity is a modified version of the NISE Network's educational products Exploring Tools—Mystery Shapes and DIY Nano Mystery Shapes developed by the Sciencenter, Ithaca, NY.

Draw a Circuit
This activity is a modified version of the NISE Network's educational products Exploring Materials—Graphene and DIY Nano Draw a Circuit developed by the Sciencenter, Ithaca, NY.

Mitten Challenge
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. It is a modified version of the NISE Network's educational products Exploring Tools—Mitten Challenge and DIY Nano Mitten Challenge developed by the Sciencenter, Ithaca, NY.

Gummy Shapes
This activity was adapted from Sweet Self-Assembly, developed by the Children's Museum of Houston for the NISE Network. It is a modified version of the NISE Network's educational products Exploring Fabrication—Gummy Capsules and DIY Nano Gummy Shapes developed by the Sciencenter, Ithaca, NY.

Rainbow Film
This activity was adapted from Create Some Iridescent Art in the *DragonflyTV Nano Educator's Guide,* published by Twin Cities Public Television, 2009. It is a modified version of the NISE Network's educational products Exploring Materials—Thin Film and DIY Nano Rainbow Films developed by the Sciencenter, Ithaca, NY.

See DNA
This activity is a modified version of the NISE Network's educational products Exploring Tools—DNA and DIY Nano See DNA developed by the Sciencenter, Ithaca, NY.

Morphing Butterfly
This activity is a modified version of the NISE Network's educational products Exploring Structures—Butterfly and DIY Nano Morphing Butterfly developed by the Sciencenter, Ithaca, NY.

Sticky Sand
This activity is a modified version of the NISE Network's educational products Exploring Materials—Kinetic Sand and DIY Nano Sticky Sand developed by the Sciencenter, Ithaca, NY.

Space Elevator
This activity is a modified version of the NISE Network's educational products Exploring Nano & Society—Space Elevator and DIY Nano Space Elevator developed by the Sciencenter, Ithaca, NY in collaboration with the Center for Nanotechnology in Society at Arizona State University.

Mystery Sand
The original version of this activity was adapted from two sources. 1. *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. 2. "Magic Sand," JCE Classroom Activity #23, *Journal of Chemical Education* 77(1): 40A-40B, January 2000. It is a modified version of the NISE Network's educational products Exploring Products—Nano Sand and DIY Nano Mystery Sand developed by the Sciencenter, Ithaca, NY.

Invisible Sunblock
This activity was adapted from "Invisible Sunblock," developed by The Franklin Institute for the NISE Network. It is a modified version of the NISE Network's educational products Exploring Products—Sunblock and DIY Nano Invisible Sunblock developed by the Sciencenter, Ithaca, NY.

Stained Glass Art
The original version of this activity was adapted by the Children's Museum of Houston from NISE Network's Exploring Materials—Nano Gold activity. It is a modified version of the NISE Network's educational products Exploring Products—Stained Glass and DIY Nano Stained Glass Art developed by the Sciencenter, Ithaca, NY.

Nano Puzzle Blocks
This activity is a modified version of the NISE Network's educational products Giant Nano Puzzle Blocks and DIY Nano Puzzle Blocks developed by the Sciencenter, Ithaca, NY.

I Spy Nano!
The original version of this activity sheet was developed by the Science Museum of Minnesota, St. Paul, MN for the *Explore Science—Zoom into Nano!* Kit, as part of the Museum & Community Partnerships project of the NISE Network.