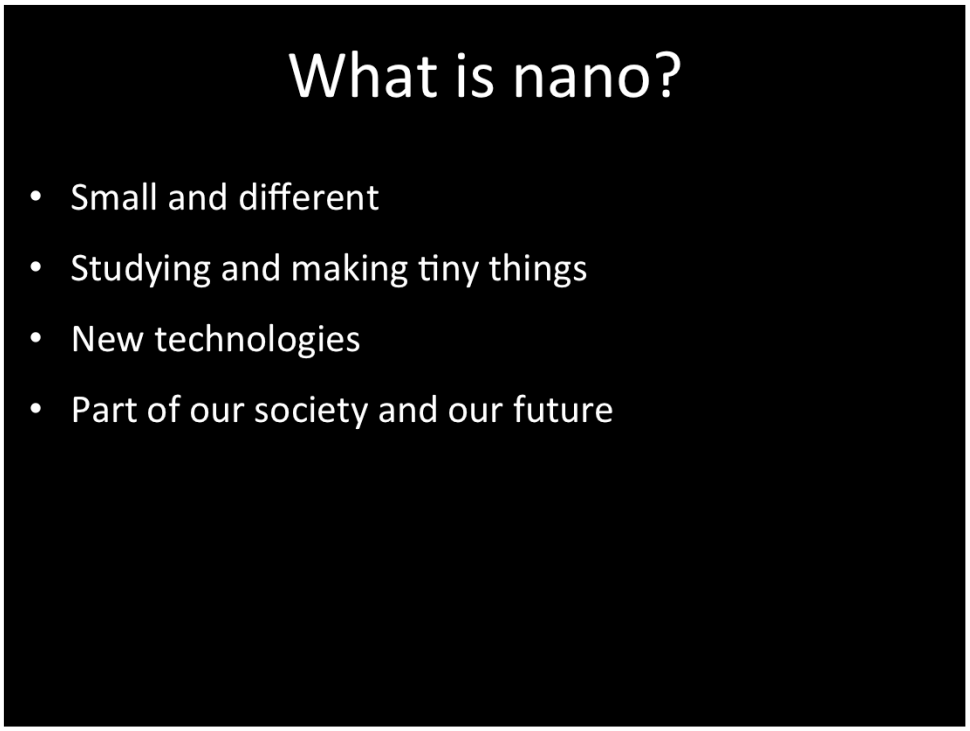
Today we are going to talk about nanoscale science, engineering and technology. Have you ever heard about *nano?* That's OK, you're not alone. It's new. (Or: You have? What have you heard?)

Nano is a prefix, like mega -or micro-. You've probably heard of megabytes or microscopes. Nano basically means small.



In this program, we'll learn about four concepts related to nano:

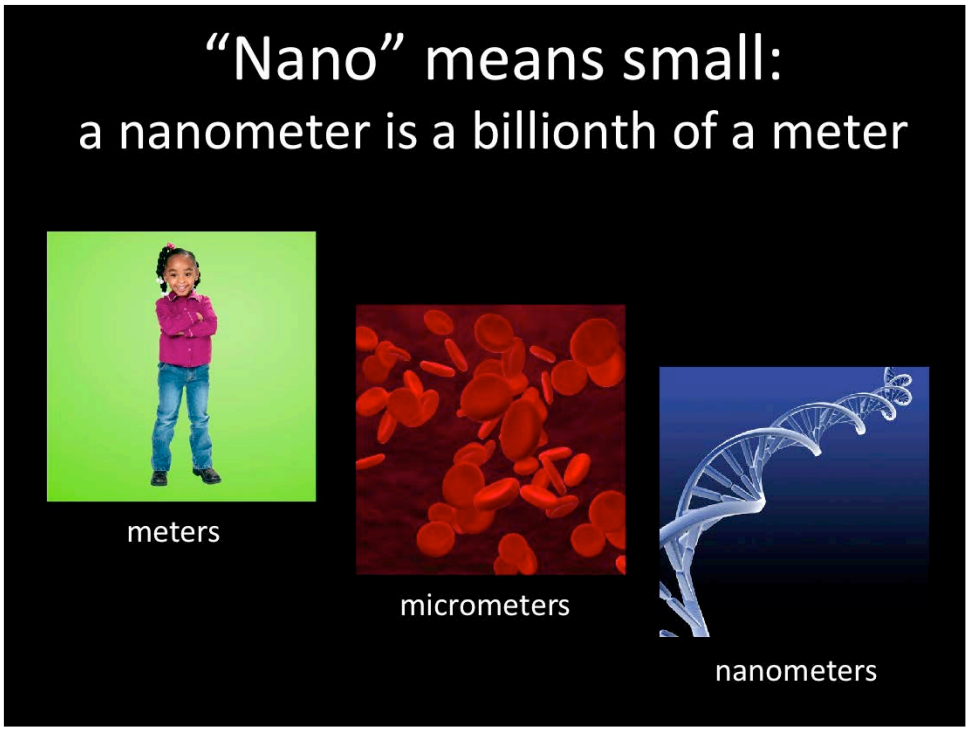
1. Nano is small and different: Nanoscale things are very small, and often behave differently than larger things do.

2. Nano is studying and making tiny things: Scientists and engineers have formed the interdisciplinary field of nanotechnology by investigating properties and manipulating matter at the nanoscale.

3. Nano is new technologies: Nanoscale science, engineering, and technology lead to new knowledge and innovations that weren't possible before.

4. Nano is part of our society and our future: Nanotechnologies have costs, risks, and benefits that affect our lives in ways we cannot always predict.

Let's get started by talking about what the prefix "nano" means, and some of the ways that nanometer-sized things behave differently or act in surprising ways.

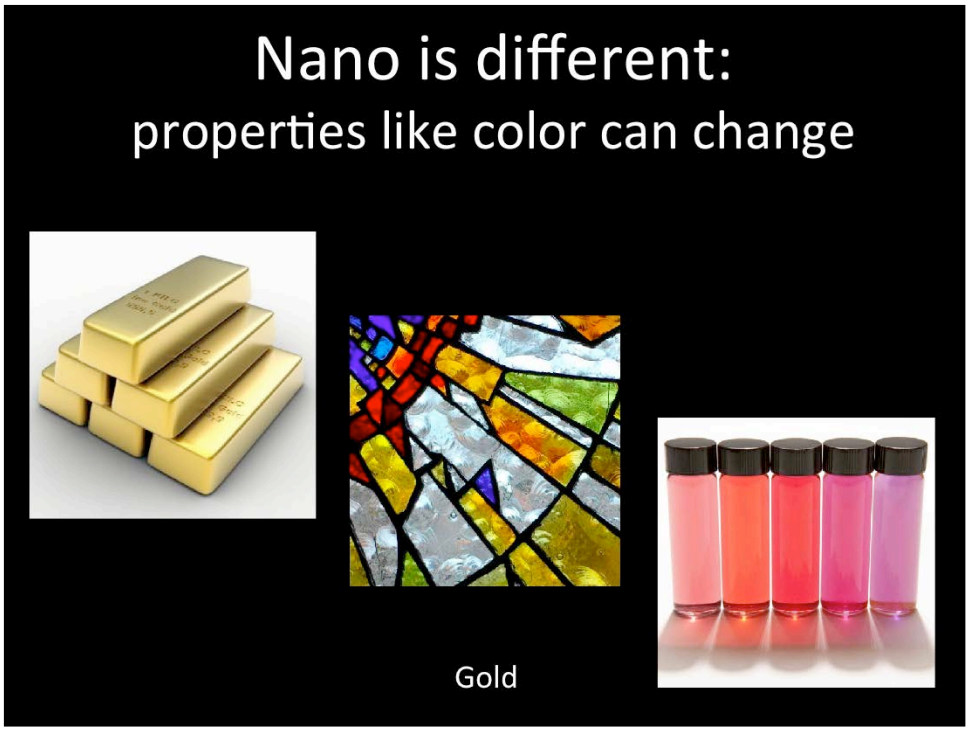


A nanometer is very small. Can you hold up your hands so they are a meter apart? When I hold out my arm, the distance from my nose to the tips of my fingers is about a meter. A 6-year-old child is about one meter tall.

The picture in the middle is of a red blood cell. A red blood cell is about one-millionth of a meter—a micrometer across.

A nanometer is one thousand times smaller than a red blood cell. A red blood cell is 1 micrometer, or 1000 nanometers, across.

The picture on the right is a DNA molecule. DNA is found in your cells. A DNA molecule is 2 nanometers wide.



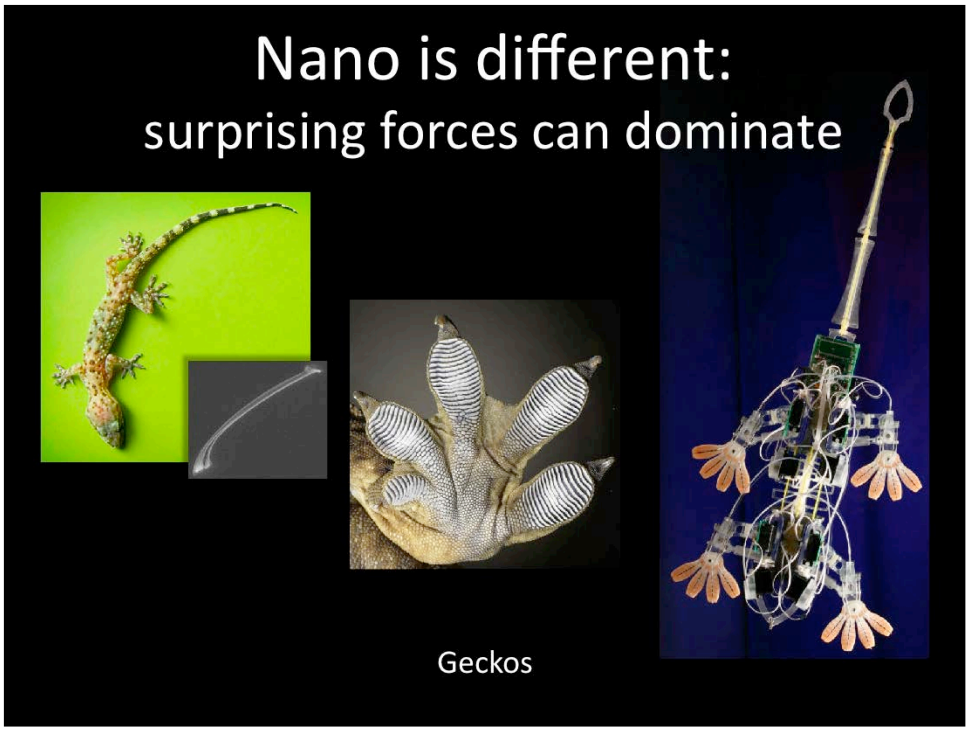
Perform demo: *Exploring Materials—Nano Gold*

Can you describe the material in this vial? (Show the vial with the bulk gold.) This is the size of gold we are used to seeing. It is gold or yellowish in color.

But in this vial I have nano-sized particles of gold. (Show the vial with the nano-sized gold.) What color is it? Red/ orange.

Nanoscale gold can be red, purple or blue depending on the size of the particles and the distance between them. Nanoscale gold has been used in red stained glass since the Middle Ages!

The photo on the right is of nano-sized gold particles. The different colors are because the gold nanoparticles are different sizes. The middle picture is of a stained glass window. The red glass could be colored by nano-sized gold particles.



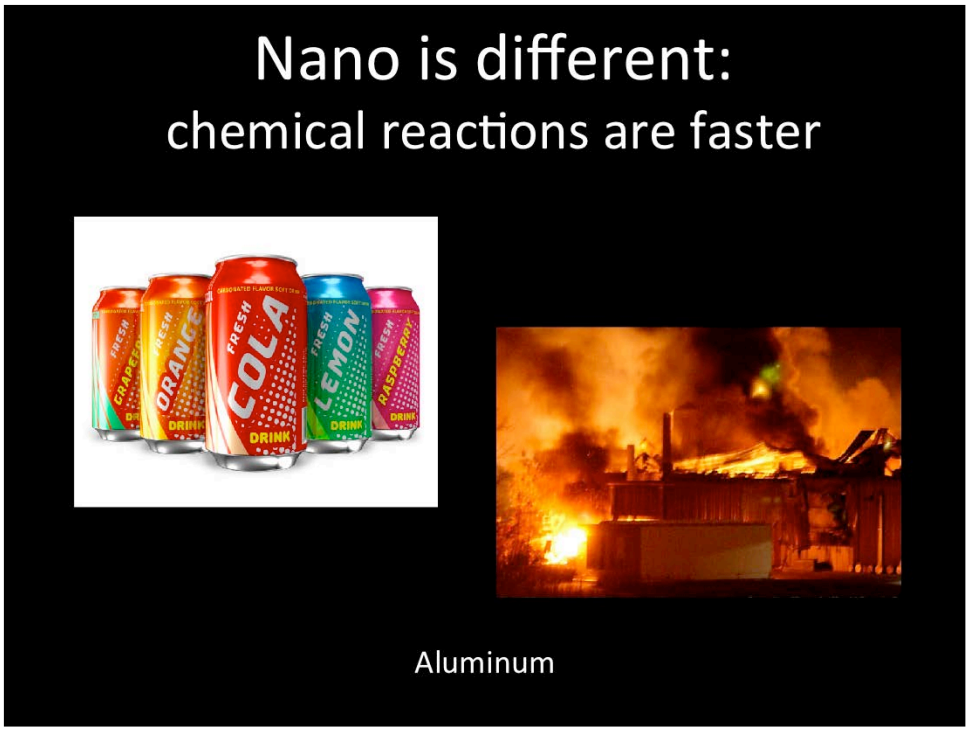
There are other things that change when material is nano-sized. Different forces dominate at the nanoscale, making things behave in unexpected ways.

For example, geckos can climb up walls and across ceilings, but there's no glue on the bottom of their feet! Instead, millions of tiny, nano-sized "hairs" form bonds with the wall. These tiny structures, called *setae*, are only about 200 nanometers wide. Molecules in the setae are attracted to molecules in the wall, and they form a temporary bond. While each bond is weak, there are enough setae that the intermolecular forces overcome the force of gravity. To move, the gecko tilts it foot, breaking the bonds.

Perform demo: *Exploring Forces—Static Beads*

Do you see a difference in how the balls behave in the two tubes? The small balls seem to float; they are more affected by static electricity than by gravity. The larger balls are more affected by gravity.

When things are very, very small gravity can be a less important force.



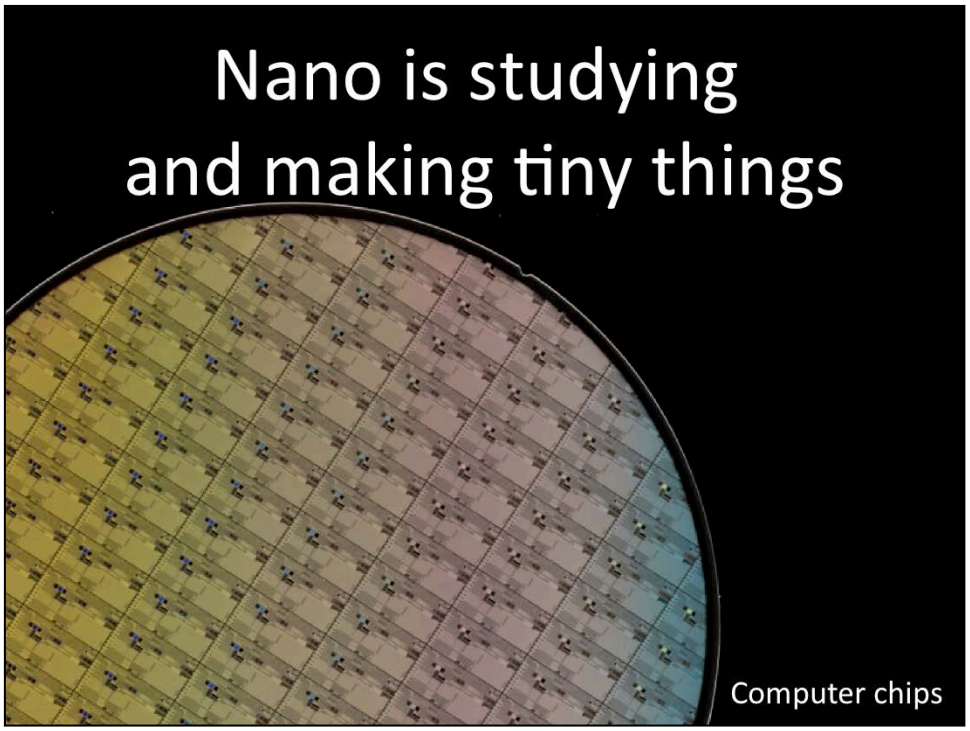
There are other ways that small things act differently from big things.

Recommended Demo: Exploring Properties—Surface Area

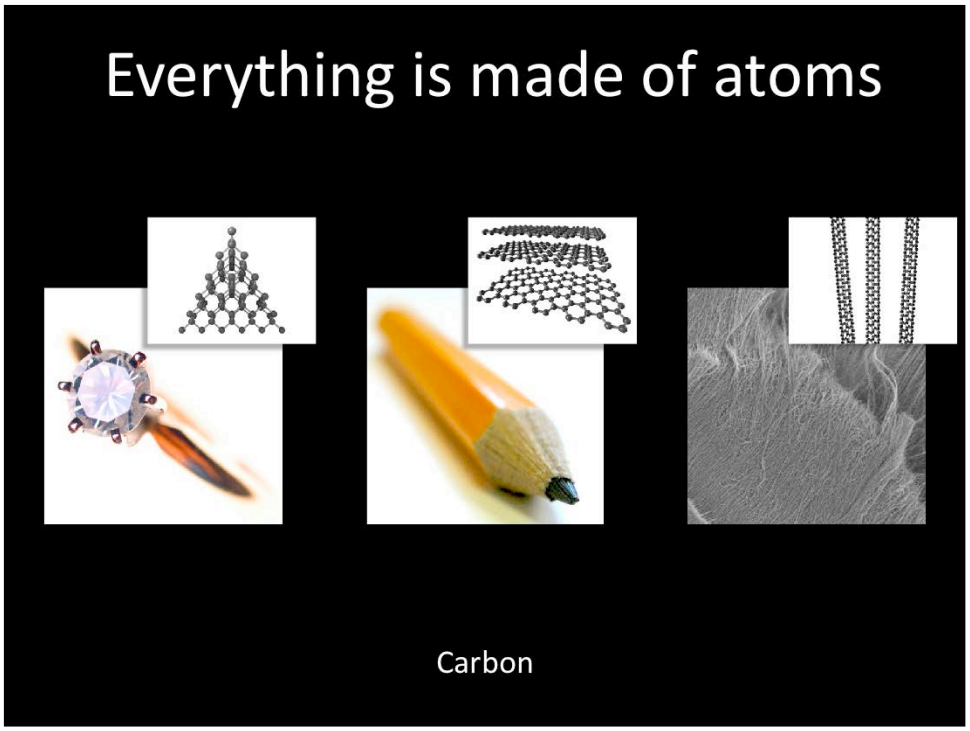
Here we have two tubes and two cups of water. And I have two tablets, one that I'm going to put in the tube, and the other, which I crushed into powder. (Visibly pour the powder into the cylinder.)

I need two volunteers to pour the water. What do you think is going to happen? Ready? Go! (Have them pour.)

The small bits acted differently than the big tablet, because they were smaller.



Let's talk about how scientists and engineers study and make nano-sized things.

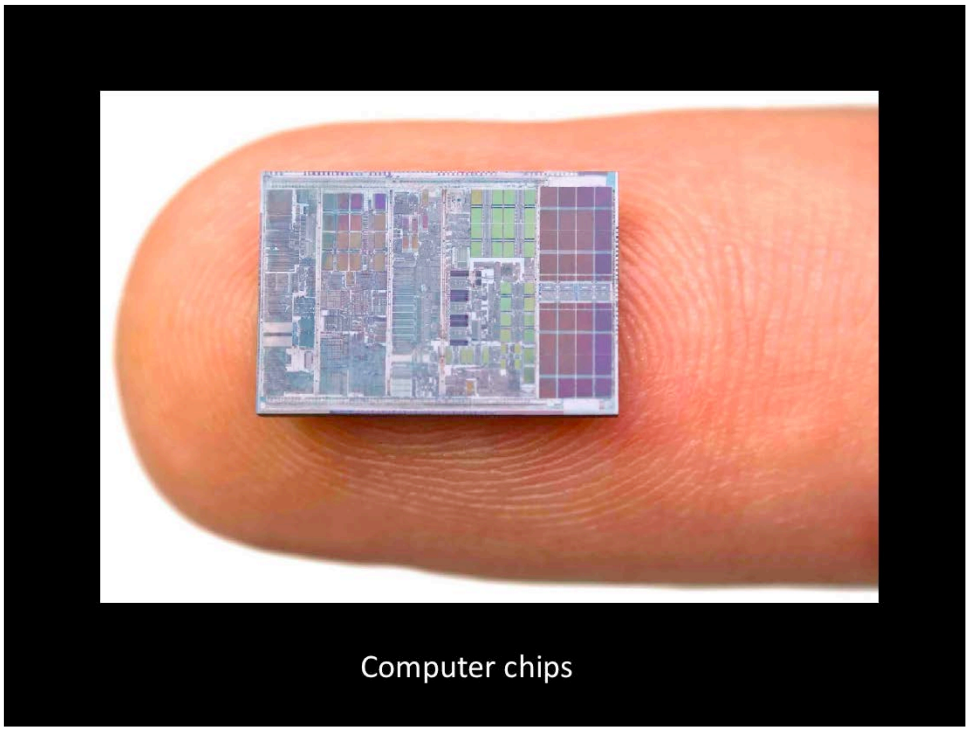


Everything on Earth is made of tiny building blocks called *atoms*. Atoms are tiny particles smaller than a nanometer. The way that these tiny building blocks are arranged helps determine the properties, or behavior, of a material.

These three pictures all have something in common. These things are all made of carbon atoms. Carbon atoms can form diamond, the hardest natural material known on Earth. But they can also form a much softer material, graphite (pencil lead). Both diamonds and graphite are made entirely from carbon atoms.

They have different properties because the carbon atoms are arranged differently. Diamonds are hard and shiny because they have a sturdy molecular structure. Graphite is soft and slippery because its carbon atoms are stacked in sheets.

Carbon can form nanometer-sized structures, including carbon nanotubes and buckyballs. Like larger forms of carbon, these tiny objects have special properties due to the way their carbon atoms are arranged. Researchers are studying how to grow these nanoscale forms of carbon, and use them to build nanotechnologies.



Computer chips

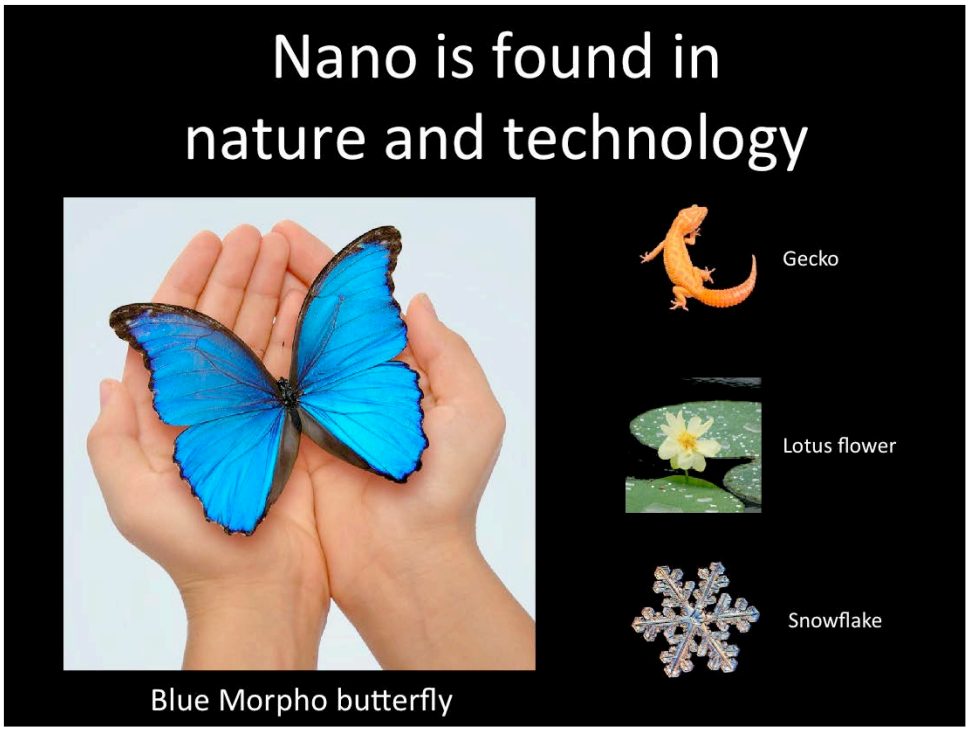
Computer chips are a good example of nanotechnology we use every day.

Intel currently makes computer chips with tiny features that are only around 30 nm across. 60 million transistors this small can fit on the head of a pin! This is about as small as we can go with current manufacturing techniques. To make even smaller, faster chips, we'll need new technologies.

To make tiny new nano-sized devices, researchers are studying *self-assembly*. Self-assembly is a process where things grow themselves. This happens all the time in nature. For example, water molecules self-assemble into ice crystals and fall to the ground as snowflakes. Researchers are learning how to make different objects self-assemble in the lab.

Video of snowflake growing:

This is a video loop of a snowflake self-assembling in a laboratory. Some researchers are working on finding ways to get other kinds of structures to self-assemble. There are already computer chips on the market that are created (in part) through self-assembly of silicon crystals.



Nanoscientists are inspired by other things in nature, too. One example is the Blue Morpho butterfly.

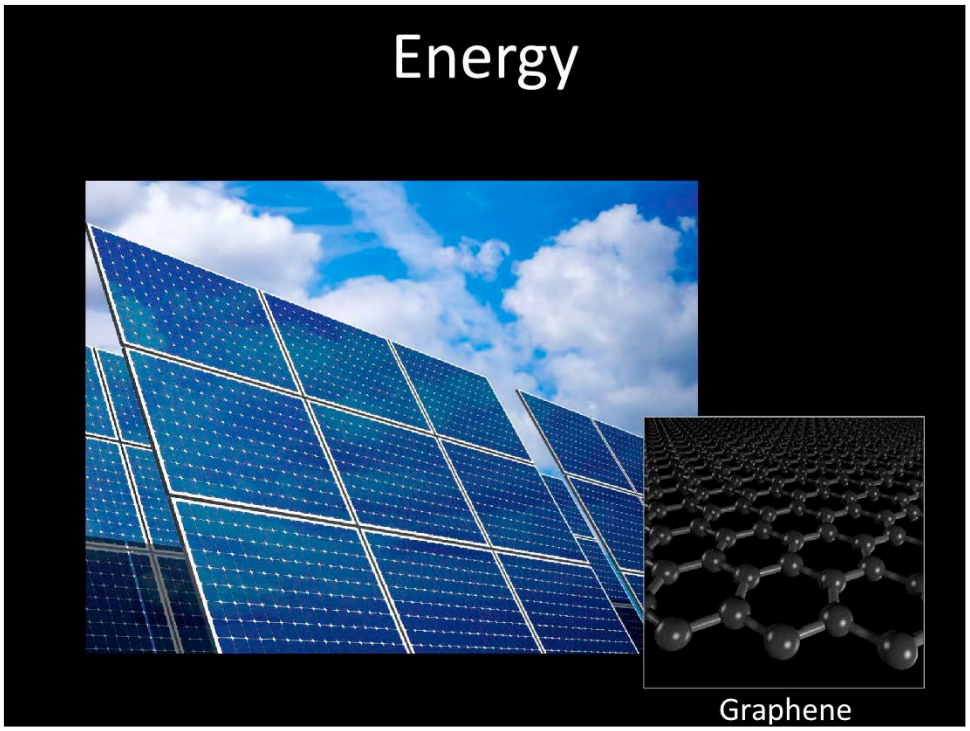
Perform demo: *Exploring Structures—Butterfly*

(Shine the light through the yellow butterfly). When I turned on the light, the yellow butterfly stays yellow. That's because the yellow color comes from pigment. This is like the color in paint.

Let's look at what happens when I shine the light through the blue butterfly. (Shine the light through the Blue Morpho butterfly from the back.) Where the light shines through, the blue color disappears. That is because Blue Morpho butterflies have colorless scales with nano-sized ribs.

The blue color you see is created by the reflection of light off these tiny nanostructures. Scientists are using similar colorless nanostructures in low energy displays.

Scientists and engineers are developing new nanotechnologies.



Nanotechnologies could transform the ways we create, transmit, store, and use energy. Some scientists think nanotechnology will allow us to build ultra-efficient transmission lines for electricity, produce more effective and inexpensive solar cells, make cheap, efficient biofuels, and improve the safety of nuclear reactors. But more research and investment is needed before nano energy solutions can be developed or widely distributed.

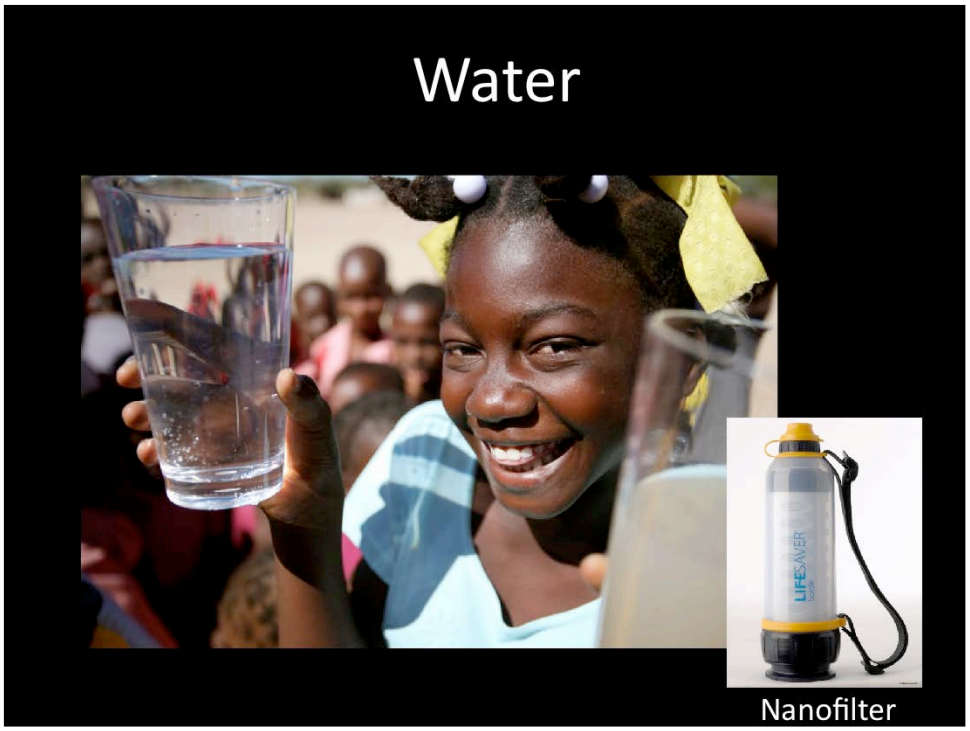
Perform Demo: *Exploring Materials—Graphene*

This demonstration is with graphite, which is made of many layers of graphene.

To get a light bulb to light up, you need to complete the circuit. Wires need to connect the light bulb and the battery. If I touch the wires to this area where I drew with a pencil, the graphite is a conductor, just like a wire, completing the circuit and lighting the bulb.

The 2010 Nobel Prize in Physics was awarded to two scientists for producing and studying graphene. Graphene is a sheet of carbon, like the graphite in pencils, but it is only one atom thick. Why is this interesting? Graphene can be used in very small computer chips because it can be made into a tiny semiconductor.

Nanotechnology might lead to improvements in healthcare. Remember the red-colored nano gold? That might one day be used to treat cancer! Therapies using nano gold are currently in clinical trials with humans. In the therapy, nano gold is injected in the blood and used with near-infrared light to heat and kill tumors with very little harm to nearby tissue.



Another new use for nanotechnologies is in water filters.

Perform Demo: *Exploring Size—Ball Sorter*

In this container, I have different sizes of balls. To separate the balls by size I can use this stacked set of sieves.

Just as I was able to use sieves to separate the different sizes of balls, a nanofilter could remove very small things like viruses or salt from our drinking water!

Nanotechnology will affect our economy, environment and personal lives.

Thinking ahead with nanotechnologies

Balancing costs, risks, and benefits

Many technologies can be viewed as either good or risky, depending on the circumstances. Can you think of a time when fire is a good or useful thing? (Heating, cooking) What do we do to protect ourselves when fire is not a good thing—when it's dangerous? (Fire extinguisher, fire department)

Nanotechnology has potential for new and improved technologies, but we may also have to think about potential risks and how to protect ourselves.

Everyone has a role in shaping nanotechnology

Citizens, scientists, governments, and companies

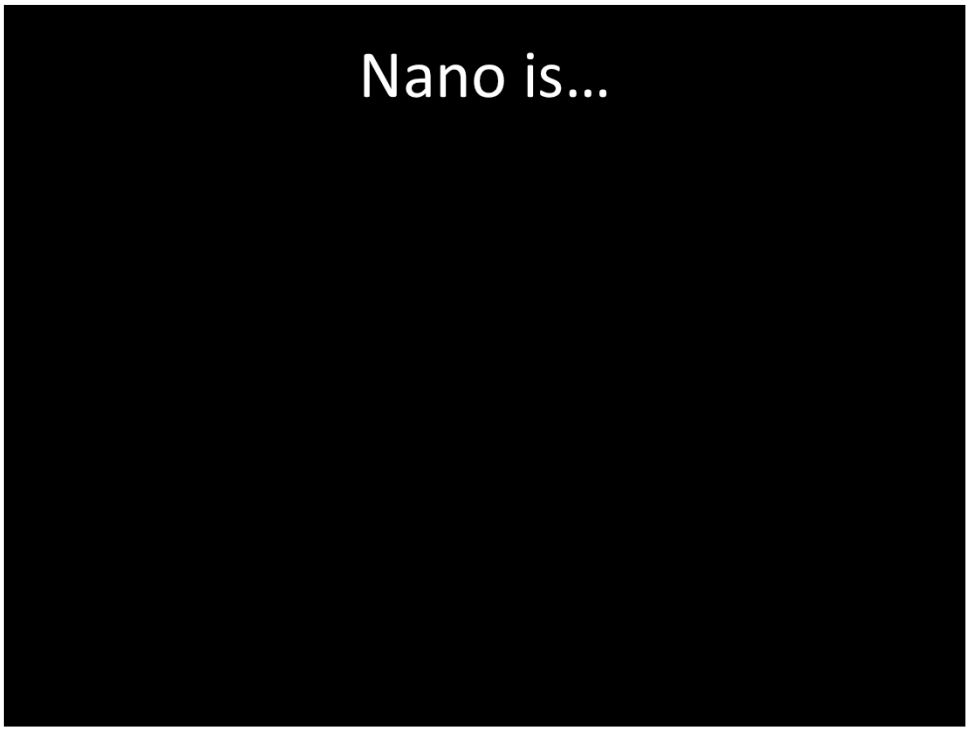
The discussion of how nanotechnology is to be part of our society and our future is the responsibility of everyone, not just scientists and engineers. You are already making decisions about whether or not to use nanotechnologies, though you may not always know it.

How many of you use sunblock? Many sunblocks contain nano-sized particles of zinc oxide or titanium dioxide.

Perform Demo: *Exploring Products—Sunblock*

The sunblock rubs in better than the ointment because it contains tiny, nano-sized particles of zinc oxide. 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. Both products are equally effective at absorbing UV radiation and keeping it from reaching your skin. Many people prefer sunblock that rubs in clear, but some are concerned about having nanoparticles in the products they use.



Let's review what we've learned. What do you remember about nano?

Nano is:

1. Small and different
2. Studying and making tiny things
3. New technologies
4. Part of our society and our future

Do you have any questions?

Thanks for stopping by today!

Credits

Autumn, K. et al. 2002. Evidence for van der Waals adhesion in gecko setae. Proc. Natl. Acad. Sci. USA 99, 12252-12256.

nanoComposix

A. Kellar, Lewis & Clark College

A. Dhinojwala, University of Akron

M. Cutkosky, Stanford University

U.S. Chemical and Safety Board

K. Molhave, Open Source Handbook of Nanotechnology

K. Libbrecht, www.snowcrystals.com

G. Jenkins, Montezuma's Reptiles

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Lifesaver Systems, Ltd.

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