Nanotechnology is in products you use every day

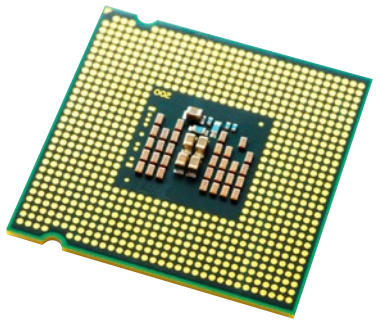
Will nano change my life?

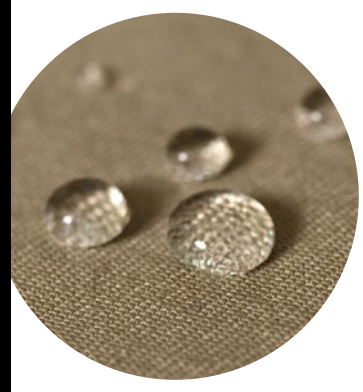
Nanotechnology is a new field of science and engineering that focuses on studying and making very, very small things. Nanotechnologies are devices and materials that are less than 100 nanometers in size. That's about the size of a virus!

Right now, most of the nanotechnologies you come across are incorporated into existing products, making them better. For example, nanotechnology makes computer chips smaller and faster, and golf clubs stronger and lighter. But future nanotechnologies will address issues of global importance, such as energy, medicine, water, and food.

Electronics

Computer chips contain nano-sized parts, so when you use a smart phone, laptop, gaming console, or other electronic device with a chip, you're using nanotechnology.





Clothing

Nano-sized "whiskers" on a fabric's surface make some clothing stain-resistant.

Sports equipment

Tiny carbon nanotubes make some bicycles, golf clubs, and tennis rackets stronger and lighter.

Health and beauty products

Many sunblocks contain nanoparticles of zinc oxide or titanium dioxide, which protect skin from the sun's rays without leaving a visible white film.

Is nanotechnology safe?

Like all technologies, nanotechnology brings both benefits and risks. Nanotechnology takes advantage of special properties at the nanoscale—giving great promise for innovation, but also leading to new kinds of risks.

Many nanotechnologies fall under the same regulations as conventional technologies. But materials can act differently on the nanoscale. So a familiar material that's generally regarded as safe might not be so safe when it's nano-sized. Nanoparticles are also difficult to detect, which makes it hard to monitor their use and dispersal into the environment. Scientists and policy-makers are already working to assess the risks of nanotechnologies, and decide whether special regulations are needed to protect people and the environment.

As nanotechnologies are developed, we'll reap new benefits but also face new risks. And our lives, relationships and ways of looking at the world may change in ways we can't predict. It's important for everyone—individual citizens, companies, governments—to think ahead and plan for these changes.

Nanotechnology is all around you

Will nano change the world?

Think how much the invention of the automobile or personal computer changed things! Some researchers expect nanotechnology to transform our lives just as much, within the next decade or so.

Of course, we don't know if nanotechnology will really change the world. Right now, most nanotechnology products are simply improved versions of things we already have: stain-resistant pants, smoother cosmetics, and antimicrobial socks. But researchers are working to develop nanotechnologies that could revolutionize life all over the globe, by fighting disease, generating clean energy, improving food supplies, and purifying water.

Medicine

Nanotechnology might lead to huge advances in health care, improving methods for detecting and treating diseases like cancer. Already, tiny ferrofluid particles can be used to improve magnetic resonance imaging (MRI).

Energy

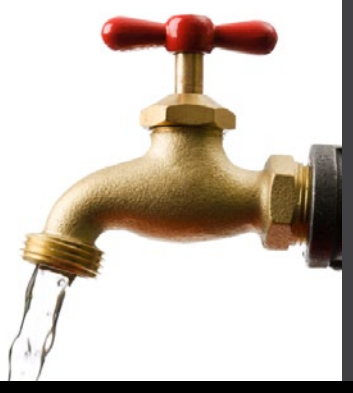
Nanotechnologies could transform the ways we create, transmit, store, and use energy. In the future, nanotechnology might help us make electrical lines, solar cells, and biofuels more efficient, and make nuclear reactors safer.

Food

Nanotechnology is already on the shelves of your supermarket. Tiny nano structures make ice cream look and taste better, while nano particles in plastic bottles keep beer fresh. In the future, nanotechnology could be used in all stages of food production, from cultivation to processing to distribution.

Water

New filters made from nano fibers can remove bacteria, viruses, heavy metals, and organic materials from water. They're relatively inexpensive and easy to use, so nano filters could be widely used in developing countries, helping prevent disease.



Is nanotechnology safe?

Like all technologies, nanotechnology brings both benefits and risks. Nanotechnology takes advantage of special properties at the nanoscale—giving great promise for innovation, but also leading to new kinds of risks.

Many nanotechnologies fall under the same regulations as conventional technologies. But materials can act differently on the nanoscale. So a familiar material that's generally regarded as safe might not be so safe when it's nano-sized. Nanoparticles are also difficult to detect, which makes it hard to monitor their use and dispersal into the environment. Scientists and policy-makers are already working to assess the risks of nanotechnologies, and decide whether special regulations are needed to protect people and the environment.

As nanotechnologies are developed, we'll reap new benefits but also face new risks. And our lives, relationships and ways of looking at the world may change in ways we can't predict. It's important for everyone—individual citizens, companies, governments—to think ahead and plan for these changes.

Scientists working in a clean room

Cornell NanoScale Science & Technology Facility Cleanroom/Charles Harrington Photography

How do we study and make nanotechnology?

Nanoscientists and engineers study and make tiny things too small to see—less than 100 nanometers in size. Some nanotechnologies and nanomaterials can be built from individual atoms! To work at such a small scale, researchers have developed new ways to investigate and build tiny things.

Building at the nanoscale

The building blocks for nanotechnologies include individual atoms and molecules. There are two main ways to build nano-sized things, known as *top-down* and *bottom-up*.

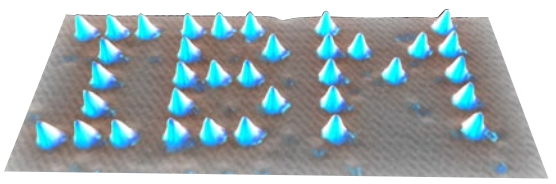
Top-down techniques begin with bigger chunks of materials and then remove pieces to create a smaller structure. Computer chips are a good example of top-down fabrication. To make computer chips, scientists print and etch many layers of tiny patterns on a silicon wafer.

Bottom-up techniques begin with small pieces and assemble them into a bigger structure. One example of this is *self-assembly*, where tiny things actually build themselves! Self-assembly occurs all the time in nature. For example, water molecules self-assemble into snowflakes.

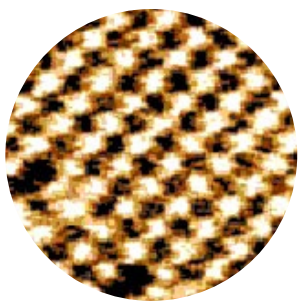
"Seeing" at the nanoscale

Nano-sized things are too small to see with just your eyes, or even with regular light microscopes. Researchers use special tools to explore and move tiny things. One important set of tools is called *scanning probe microscopes* (SPMs).

Scanning probe microscopes can detect and make images of things as small as a single atom! SPMs have a sharp tip that moves back and forth across a material. As it moves, the tip "feels" and measures changes in the surface. A computer combines the information gathered by the tip and makes an image. Some kinds of SPMs can also be used to move atoms around. This allows researchers to build tiny things one atom at a time.



IBM logo created by moving individual xenon atoms with an SPM



SPM image of salt

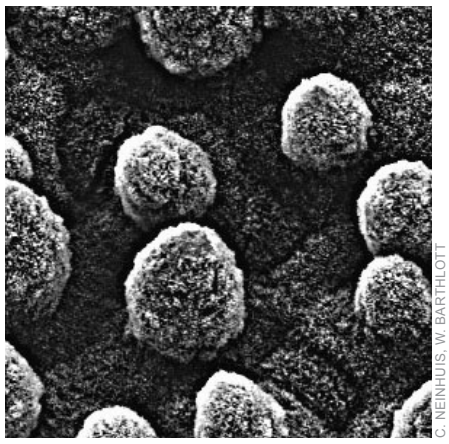
SPM tip

SPM Tip: SecretDisc, Salt: Ernst Meyer, University of Basel, IBM: Don Eigler/IBM

Gecko feet are an example of nano in nature

How is nano inspired by nature?

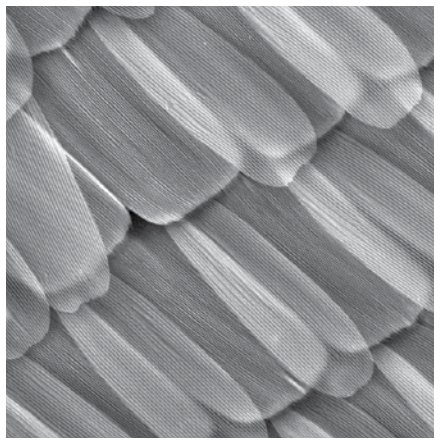
Some of the beautiful and surprising things we observe in nature are due to special nanoscale properties. Researchers can be inspired by nature to create new nanotechnologies and nanomaterials.



C. NEINHUIS, W. BARTHLOTT

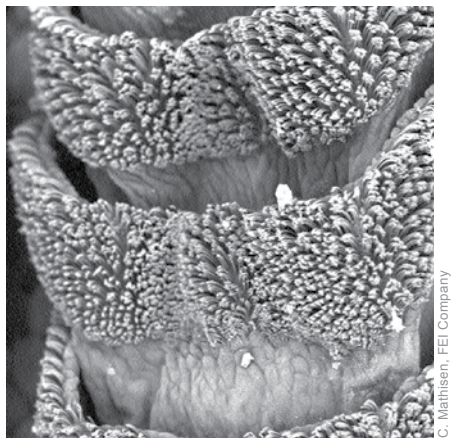
Lotus leaves

Lotus, nasturtiums, and some other plant leaves have small bumps covered in nano-sized whiskers.These tiny nanostructures keep water and dirt from sticking to the leaves. Water just beads up and rolls off! Scientists call this the *lotus effect*. Stain-resistant fabrics, self-cleaning windows, and other nano products mimic the water-repelling properties of lotus leaves.



Butterfly wings

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. Researchers are working on new nanotechnologies that mimic the Blue Morpho's wings. They've already invented paints, fabrics, and low-energy electronic displays that use the spacing of nanostructures to create color.



C. Mathisen, FEI Company

Gecko feet

Geckos can climb up walls and across ceilings, but there's no glue on the bottom of their feet! Instead, millions of tiny nano-sized hairs bond with the wall. To move, the gecko tilts it foot, breaking the bonds. Special "gecko tape" uses the size and shape of nanostructures to stick, just like gecko toes do! Researchers are experimenting with using gecko tape on the feet of climbing robots.

Kenneth Libbrecht, Caltech, www.snowcrystals.com

Snowflake growth

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! Already, there are computer chips with self-assembled nanocrystals.

Carbon atoms form diamond and graphite

What is stuff made of?

Everything on Earth is made of *atoms*, which are tiny particles smaller than a nanometer. (A nanometer is a billionth of a meter.) Examples of atoms include carbon, oxygen, and hydrogen.

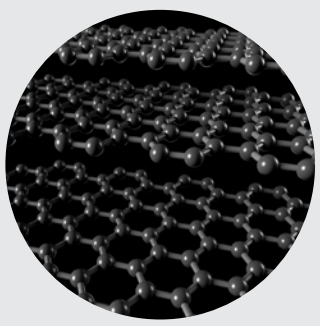
Atoms and molecules

Atoms join together in different ways to form *molecules*. The way that these tiny building blocks are arranged helps determine the *properties*, or behavior, of a material.

Carbon is a good example of how one kind of atom can combine in different ways to make very different materials. Carbon atoms can form diamond, the hardest natural material known on Earth, but they can also form graphite, one of the softest materials.

Both diamonds and graphite (pencil lead) are made entirely from carbon. They have different properties because the carbon atoms are arranged differently.

Diamonds are hard and shiny because they have a sturdy molecular structure.



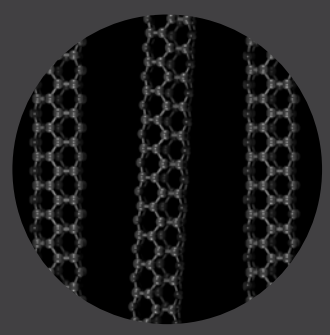
Graphite is soft and slippery because its carbon atoms are stacked in sheets.

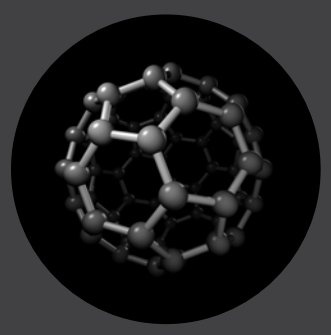
Nano structures

Carbon can also form structures that are too small to see: carbon nanotubes, buckyballs, and graphene. These tiny nanostructures have special properties due to the way their carbon atoms are arranged.

Carbon nanotubes, buckyballs, and graphene all occur naturally. Researchers are studying how to grow them and use them to build nanotechnologies.

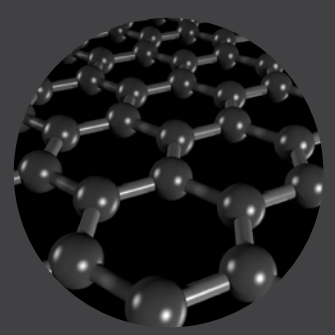
Carbon nanotubes are long, hollow tubes. They're very strong and light, and can act as semiconductors or conductors. Carbon nanotubes are used to strengthen materials. Researchers are studying ways to use them in electronics, fuel cells, and other technologies.





Buckyballs look like tiny soccer balls. They're good lubricants because of their spherical shape. Their hollow structure could make them useful for delivering medicine.

Graphene is a thin, flat sheet only one atom thick. It's strong and flexible, and it conducts electricity and heat. Single graphene sheets could be used in integrated circuits in computers and in sensors that detect gases.

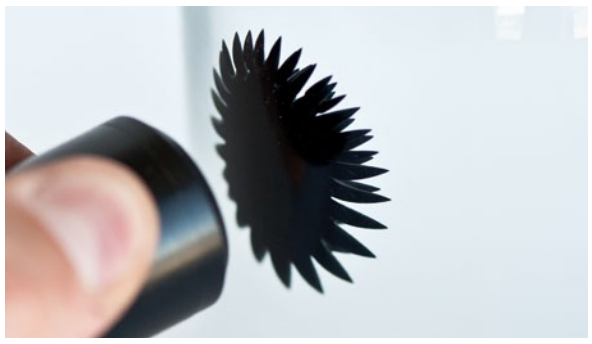


Molecule illustrations: Martin McCarthy www.theasis.co.uk

Ferrofluid is a liquid that acts like a magnet

What's surprising about nanomaterials?

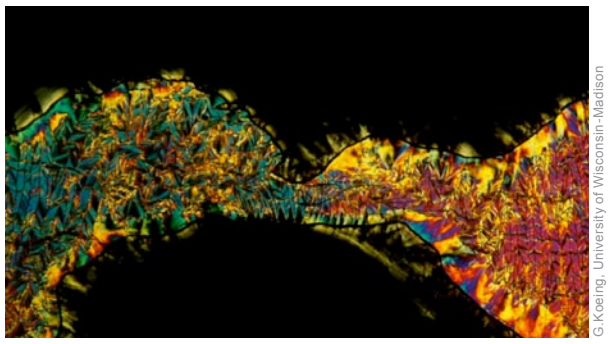
When things are very, very small, they sometimes behave in different and surprising ways. For example, some materials are different colors when they're nano-sized. Nanotechnology takes advantage of the special properties at the nanoscale to create new materials and technologies.



Ferrofluid is the only liquid that's magnetic! All other magnetic materials are solid. When there's no magnet around, ferrofluid is a thick fluid. But when a magnetic field is nearby, ferrofluid stiffens up and behaves like a solid.

This surprising property, called *superparamagnetism*, is found only at the nanoscale. Ferrofluid is made of tiny, nano-sized particles of iron oxide suspended in liquid.

Ferrofluid was invented by NASA in the 1960s as a way to control liquids in space. Nowadays, it's used in loudspeakers to dampen vibrations, in car brakes, and in the rotary seals of computer hard drives. In the future, ferrofluid might be used to carry medications to specific spots in the body.



G.Koeing, University of Wisconsin-Madison

Liquid crystals aren't liquid, and they aren't solid. They're somewhere in between! The molecules in a liquid crystal can move around independently, like a liquid, but they still remain somewhat organized, like a solid (crystal).

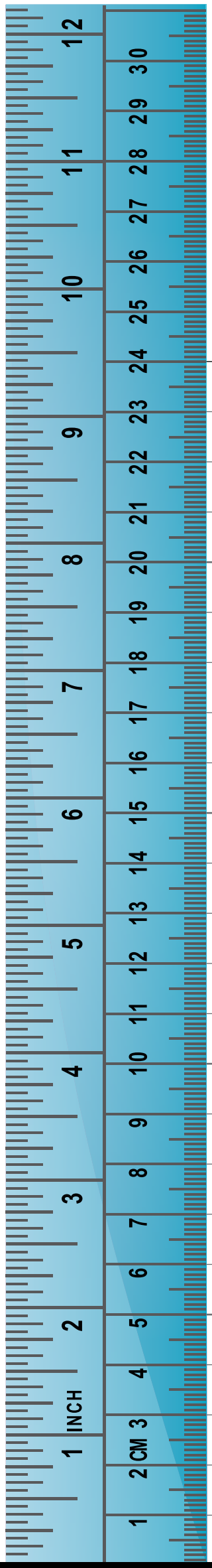
Liquid crystal molecules can respond to their environment by rearranging themselves. We perceive this as a change in color, because liquid crystals reflect light differently when their molecules are arranged differently. Some liquid crystals react to an electrical current, as in liquid crystal displays (LCDs). Others react to changes in temperature or the presence of certain gases in the air.

Liquid crystals are used in displays for cell phones, laptop computers, and other electronics.

Gold is a familiar metal…but when it's nano-sized, it has some unfamiliar properties! Big pieces look shiny and golden, but nano-sized gold can be red, purple, or blue, depending on the size of the particles. Nano gold has been the secret ingredient in red stained glass since the Middle Ages.

Today, nano gold is being used in an experimental cancer therapy that targets tumors, leaving healthy tissue unharmed. Nano gold is also used to detect specific strands of DNA.

Try measuring in nanometers!



How big is your hand?

Your hand is millions of nanometers long! That sounds amazing, but it doesn't mean that your hand is super big—it means that a nanometer is super small.

A nanometer is a billionth of a meter
Nanometers are used to measure things that are too small to see. It takes a lot of nanometers to measure something relatively big, like your hand.

240 million nanometers

230 million nanometers

220 million nanometers

210 million 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

How small is nano?

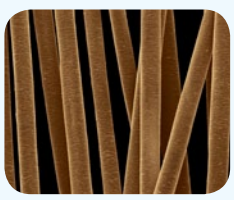
The world is full of things of all different sizes! In your everyday life, you come across things in at least three different size scales: the *macroscale*, the *microscale*, and the *nanoscale*.

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

Hand
A hand is about 1 decimeter wide
1 decimeter = 100,000,000 nm (100 million nanometers)

Pinky Finger
A pinky finger is about 1 centimeter wide
1 centimeter = 10,000,000 nm (10 million nanometers)

Freckle
A freckle is about 1 millimeter wide
1 millimeter = 1,000,000 nm (1 million nanometers)

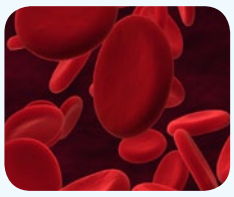


Strand of Hair
A hair is about 0.1 (one tenth) of a millimeter wide
0.1 millimeter = 100,000 nm (100 thousand nanometers)

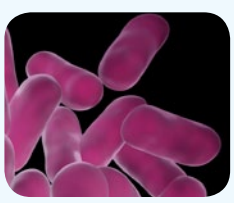
Macroscale

The macroscale includes things we can see with our eyes, from big to small. There are lots of ways to measure macroscale things, including *meters*. Meters are about the same size as a yard.

Kids around six years old are about a meter tall. A strand of hair is just a fraction of meter, 0.1 millimeters.



Red Blood Cell
A red blood cell is about 10 micrometers wide
10 micrometers = 10,000 nm (10 thousand nanometers)



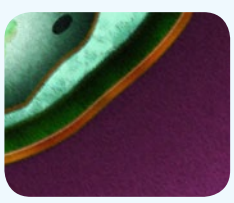
Bacteria
A bacteria cell is about 1 micrometer wide
1 micrometer = 1,000 nm (1 thousand nanometers)

Virus
A virus is about 0.1 (one tenth) of a micrometer wide
0.1 micrometer = 100 nm (1 hundred nanometers)

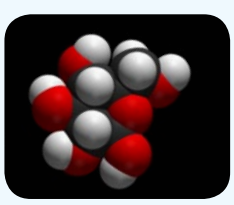
Microscale

The microscale is smaller than the macroscale. To see microscale things clearly, we need tools like microscopes. We measure them using *micrometers*.

A micrometer is a millionth of a meter. Red blood cells are about 10 micrometers wide.



Cell Membrane
A cell membrane is about 10 nanometers wide
10 nanometers = 10 nm



Sugar Molecule
A sugar molecule is about 1 nanometer wide
1 nanometer = 1 nm

Atom
An atom is about 0.1 (one tenth) of a nanometer wide
0.1 nanometer = 0.1 nm

Nanoscale

There's an even smaller scale, the nanoscale! Nanoscale things are so tiny, we can't see them with just our eyes, or even with light microscopes. We need special tools to make images of them. We measure nanoscale things using *nanometers*.

A nanometer is super small—a billionth of a meter! DNA is just two nanometers wide.

What's a nanometer?

A nanometer is a billionth of a meter. That's really tiny! Nanometers are used to measure things that are too small to see, like parts of a cell or DNA.

Strands of hair: Dennis Kunkel Microscopy, Inc. / www.dennniskunkel.com