What's a nano tattoo and why would you want one?

ISSUE 8 • 2010 www.nanooze.org

NANOOZE

Why do QUANTUM DOTS glow?
and what are they used for?

The Nanomedicine Issue

SEEING INSIDE THE BODY

Q+A WITH A NANOSCIENTIST

TEENIER, TINIER TOOLS

SEQUENCING DNA

ALL ABOUT THE THINGS TOO SMALL TO SEE

Welcome to Nanooze!

What is a Nanooze? (Sounds like nah-news.) Nanooze is not a thing, Nanooze is a place to hear about the latest exciting stuff in science and technology. What kind of stuff? Mostly discoveries about the part of our world that is too small to see and making tiny things using nanotechnology. Things like computer chips, the latest trends in fashion, and even important stuff like bicycles and tennis rackets. Nanooze was created for kids, so inside you'll find interesting articles about what nanotechnology is and what it might mean to your future. Nanooze is on the Web at ***www.nanooze.org****, or just Google "Nanooze"—you'll find interviews with real scientists, the latest in science news, games and more!*

HOW CAN I GET NANOOZE IN MY CLASSROOM?

Copies of Nanooze are free for classroom teachers. Please visit ***www.nanooze.org*** *for more information or email a request for copies to* ***info@nanooze.org****.*

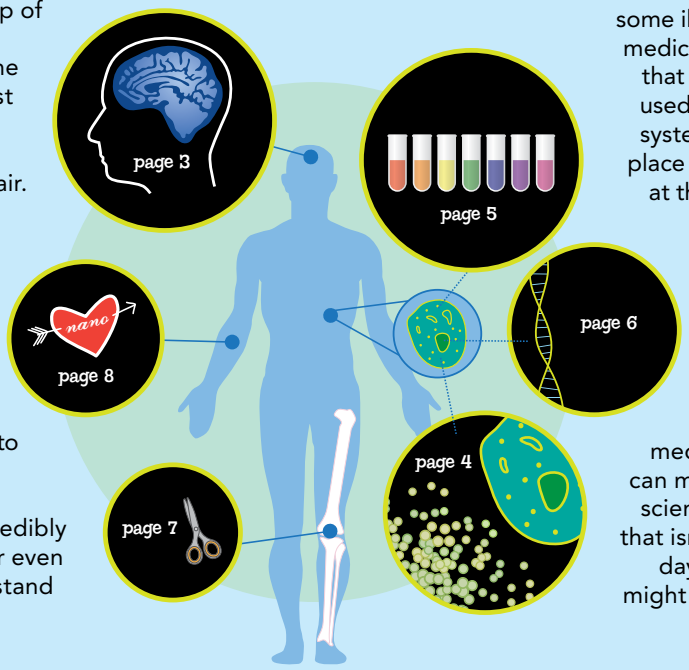
A project of the National Nanotechnology Infrastructure Network (NNIN) with support from the National Science Foundation and the United States Department of Agriculture.

Teeny Tiny Medicine: Nanomedicine

Your body is a complex thing made up of about 50 trillion cells. Fifty trillion is a huge number—about 10,000 times the number of people on the planet! Most cells in your body are about 5,000 nanometers across or less, which is about 1/20 the width of a strand of hair.

Your brain is made up of cells and so is every other part of your body—your muscles, your skin, all made with cells that work together to keep your body going. Your body is like one big machine that operates with lots of little machines, and the instructions for what all those little machines need to do are coded in your DNA.

Nanotechnology is used to make incredibly small things, things the size of cells or even smaller. It can be used to help understand and fix what is going on inside you.



Sometimes when you're sick you need to take medicine. Medicine can sometimes be pretty powerful and with some illnesses it's best if you can deliver medicine only to the place in your body that needs it. Nanotechnology can be used to make smart medicine delivery systems that will not just find the right place but will also release the medicine at the optimal time. This protects the rest of the body from medicine it doesn't need or that could damage healthy cells.

This issue of Nanooze is all about nanomedicine and the ways that nanotechnology can be used to make smarter medicines and understand how they can make us healthier. There is a lot of science fiction out there, far-out stuff that isn't possible today. Perhaps some day? Sure, you never know what we might invent in the future! But for now, let's learn the facts.

NANO KNOW-HOW

Learning about nano stuff is fun but it can be complex, so it helps to keep these four important facts in mind:

1. All things are made of atoms.

It's true! Most stuff, like you, your dog, your toothbrush, your computer, is made entirely of atoms. Things like light, sound and electricity aren't made of atoms, but the sun, the earth and the moon are all made of atoms. That's a lot of atoms! And they're incredibly small. In fact, you could lay one million atoms across the head of a pin.

2. At the nanometer scale, atoms are in constant motion.

Even when water is frozen into ice, the water molecules are still moving. So how come we can't see them move? It's hard to imagine that each atom vibrates, but they are so tiny that it's impossible to see them move with our eyes.

3. Molecules have size and shape.

Atoms bond together to form molecules that have different sizes and shapes. For instance, water is a small molecule made up of two hydrogen atoms and one oxygen atom, so it is called H_2O. All water molecules have the same shape because the bonds between the hydrogen atoms and the oxygen atom are more or less the same angle.

Single molecules can be made up of thousands and thousands of atoms. Insulin is a molecule in our bodies that helps to control the amount of sugar in our blood. It is made up of more than one thousand atoms! Scientists can map out the shapes of different molecules and can even build most types of molecules in the lab.

4. Molecules in their nanometer-scale environment have unexpected properties.

The rules at the nanometer scale are different than what we usually encounter in our human-sized environment. For instance, gravity doesn't count because other forces are more powerful at the molecular level. Static and surface tension become really important. What is cool about nanotechnology is that we can make things that don't behave like we expect. **Things are really different down there!!**

Q&A

with Nanoscientist Heather Clark

Tell us a bit about your background. How did you come to your current job?
I went to college and graduate school at the University of Michigan to become a chemist. While in graduate school, I was given a wonderful opportunity to develop a new type of sensor—a nanosensor—for studying what is going on inside a living cell. After working with cells for a few years, though, I decided that I needed to learn more biology to be effective in developing tools for the biological world. I worked as a postdoc at the University of Connecticut Health Center for five years in a lab that was focused more on biology instead of chemistry—and it was a real learning experience!

Now that I lead my own research projects, I am very grateful for these two disparate opportunities. Not only do I try to incorporate what I have learned into my research, but I feel like it has made me a more effective collaborator. This opens the door to entire fields of research that would not be possible if I were working by myself in the lab on one thing.

When you were a kid, did you run around doing science experiments? Not at all! My dream was to be an artist. Science was never even a consideration until I took my first chemistry class as a sophomore in high school. I still remember sitting in class and thinking that there was a whole world of science out there that I just HAD to know more about. For me, science was a natural extension of the artistic side of me—a chance to express my creativity while exploring a new frontier.

What are you working on right now?
I develop nanosensors for use in biological measurements. We are as interested in making a new sensor as we are in trying it out to solve a biological problem. One of the things we are working on is studying how sodium flows into a cell during the beat of the heart—and how blocking it can lead to heart failure.

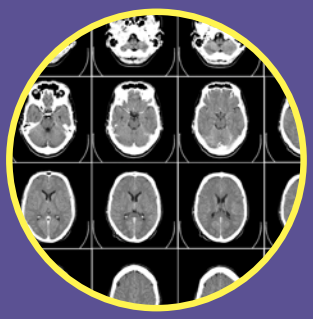
We heard about your work on tattoos and measuring blood glucose. What is that all about? Tattoos are actually little nano- and microscale particles that are inserted into the skin with a tattoo needle. Since we make nanoparticles that measure things, it seemed like a natural extension of our work to put them into the skin like a tattoo to measure glucose. That way, people with diabetes would have a more convenient way to monitor their blood sugar levels. There is one major difference, though. These are NOT permanent tattoos, since the plan is to inject them into a layer of skin nearer the surface than regular tattoos are injected. This layer, the epidermis, sloughs off after about a week. The other advantage is that it should hurt a lot less than a tattoo, since it is not injected as deeply.

Do you have a tattoo? No way! My friends tell me that regular tattoos hurt. *(For more on nano tattoos, turn to page 8).*

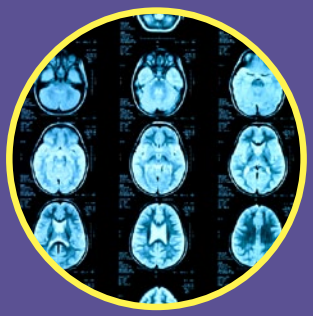
If you weren't a scientist what do you imagine you might be doing?
Hard to even imagine, since I have wanted to be a scientist for such a long time. Every now and then I wonder if it is too late for me to join the LPGA. Judging by my golf score, I should stick to science.

IMAGING THE BODY

X-RAY
X-radiation
Invented in 1895
Uses a beam of electromagnetic radiation (x-ray) to create a single image at a time.

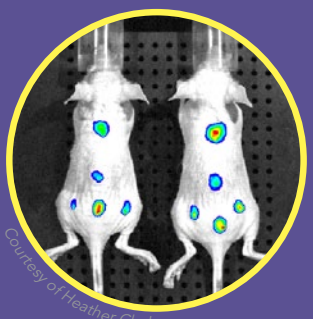


CT
Computed tomography
Invented in the 1960s
Uses x-rays to create a series of cross-sectional images that can provide a much more detailed view of the body than a single x-ray.



MRI
Magnetic resonance imaging
Invented in the 1970s
Uses powerful magnetic fields and radio waves to create a series of cross-sectional images that are very detailed.

ULTRASOUND
Invented in the 1950s
Uses sound waves to produce a real-time moving image.



Courtesy of Heather Clark

What new ways of imaging the body will nanotechnology bring us in the future? Fluorescent nanoparticles are currently being tested and may provide new ways to image the body.

See it, fix

You don't feel well and so you go to the doctor. To diagnose what is wrong with you, a doctor can do tests from the outside by looking in your ears and down your throat. But sometimes that's not enough because there's a limit to what the doctor can see from the outside and getting inside is painful.

SEEING INSIDE THE BODY

One way to see inside is to use X-rays. This diagnostic tool was invented back in 1895 and while X-rays are great for seeing dense things like bones, they don't do a great job looking at softer things like your brain. For that there are MRI (magnetic resonance imaging) and CT (computed tomography) machines, which provide images showing differences between healthy and sick cells that a doctor may want to take a closer look at.

While some kinds of cancer are easy to spot with MRI or CT results, others are really too small to show up on the images. What doctors need is something to make the cells they want to see appear different from the rest of the cells. Scientists are using nanotechnology to create different kinds of nanomaterials that will help doctors see inside the body in more detail.

HOW CAN NANOPARTICLES HELP?

Your body was designed to keep things on the outside out and keep most of the stuff on the inside in. The various cells that make up your skin, the lining of your intestinal tract and other places in your body form a tight protective barrier. To get past these barriers devices need to be very small. Nanoparticles are very,

it

very small—around 100 manometers wide, or about 1/1000 the width of a hair—so they could do the job because they can make their way in and around cells.

Scientists today are making lots of different kinds of nanoparticles. The newest work is focused on theranostic particles, which can be used to both diagnose and treat, hence the name theranostics = therapy+diagnostics. These theranostic nanoparticles are designed to be smart so they can be targeted to a specific disease.

To fight cancer, theranostics could carry antibodies that would home in on cancer cells. Once on site these nanoparticles would release a payload of medicine right at the site of the disease.

Some theranostics are made to be sensitive to microwaves so that they heat up and release their payloads, while others are triggered by light. They can also be made from metals like iron that can be seen using MRI.

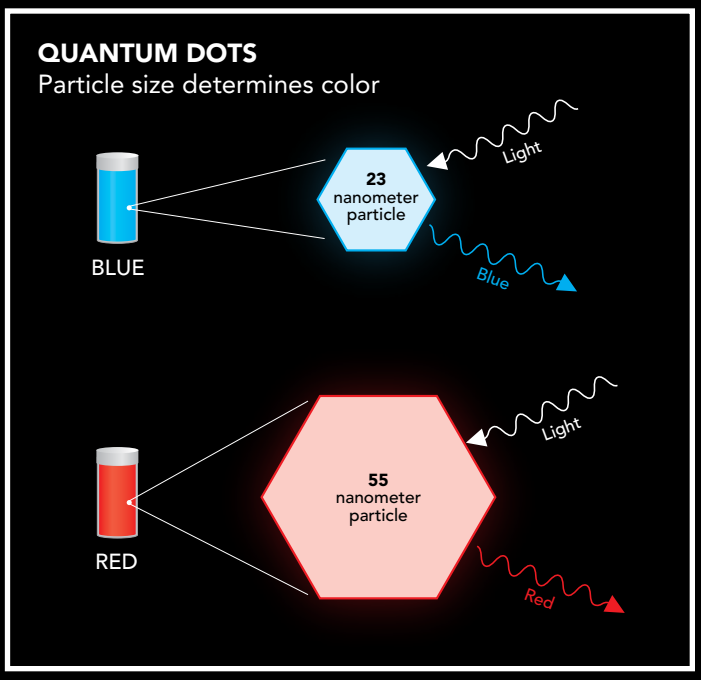
With nanotechnology some day doctors will have a whole new set of tools to treat disease that will be more effective and work in ways we can only imagine.

QUANTUM DOTS

Another promising nanomaterial is quantum dots. Quantum dots are sometimes called artificial atoms and are made of chemicals like cadmium and selenium. These tiny particles are only a few nanometers in size. They are so small that they contain only a thousand or so atoms. Quantum dots are fluorophores, which means that they can absorb light at one wavelength and emit light at another wavelength. Some quantum dots absorb and emit light with long wavelengths in the infrared spectrum.

What makes quantum dots potentially useful for imaging the body is that infrared light can penetrate deeper into the body than visible light. So if quantum dots can be directed to cancer cells, doctors could image tumors deep inside the body.

To do this, scientists would attach special molecules to quantum dots that would find and stick only to cancer cells. Antibodies are one kind of special molecule used to target and bind to cancer cells. When the antibodies find their target, the quantum dots attached to them could be tracked by their fluorescence, providing a deeper look inside the body than what is currently available today.



A doctor uses an otoscope to check out your ears and throat. To see deeper inside the body, other diagnostic tools are needed.

Courtesy of Xiaohu Gao

Quantum dots are fluorophores and glow in different colors depending on the particle size. The larger the dot, the redder it glows.

Sequencing DNA:

THE FASTER THE BETTER

What makes you...you? Well, it's your DNA, of course. Deoxyribonucleic acid is a mouthful but it is the blueprint for all biology. Everything from the color of your eyes to how fast a cheetah can run is all programmed into DNA.

In the last 20 years, scientists and engineers have created machines to sequence DNA, which lets them read it much like you read a book, except it's too hard to read your DNA from front to back in one long stretch. So the DNA is first chopped up so the pieces can be read individually, then finally the whole thing is put back together. That's hard to do because there are 3 billion nucleotides (the building blocks of DNA) in your genome and the pieces that are being read are only a few hundred nucleotides long.

Imagine taking a book and ripping it up into a zillion pieces, reading each piece and then figuring out what the story was all about. One of the most important developments in reading the human genome was in creating the computers and software used to figure out how to put the pieces back together.

Nanotechnology is now being used to create the next generation of DNA sequencing machines that will be even faster than the ones used today. The current machines read these tiny pieces of DNA too slowly (and too expensively) to make it possible to read each person's own genome.

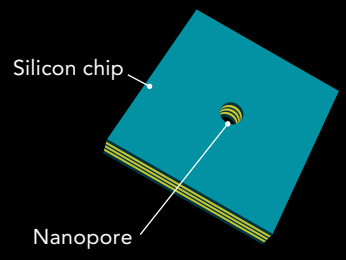
One way that nanotechnology is being used is to create *nanopores*, tiny little holes just big enough for a piece of DNA to slide through.

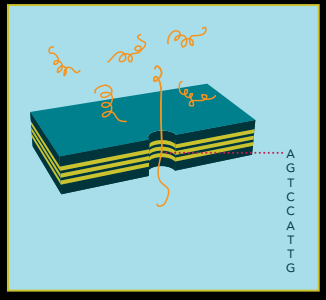
DNA is only 3 nanometers wide, that means about 3,000 strands would fit across the width of a hair.

Using some very neat electronics, these machines can read individual nucleotides as they slide through the hole. Get a few thousand or a few million holes lined up and you can read lots of DNA all at one time. You still need a very powerful computer to put all these pieces together, but someday in the not too distant future you will be able to get your own genome figured out.

Why is this important? Well, a lot of diseases are caused by changes in your DNA. Also, the way certain medicines work depends upon your genetic makeup. So in the future, medicine will be more personalized and more effective once the doctor knows your genome, or genetic blueprint.

A FASTER DNA READER





An electrical field pulls pieces of DNA through the nanopore.

The path to less invasive surgery:

BUILDING TEENIER, TINIER TOOLS

In the old days, surgery was a nasty business. To work inside your body, doctors needed to make a hole in you large enough for their hands or at least the tools that they needed to use to perform the surgery. So to work on your heart, for instance, they needed to make a hole that was really big and most of the recovery time after the operation was for recuperating from the hole that was made in your chest.

Smaller tools have been developed in the past 20 years and now "minimally invasive" surgery is used for a lot of different kinds of operations, like to fix a knee or to remove a gall bladder. The holes made to get to the problem are usually around a few millimeters and a few of them are made—one for the tool, another for a camera and maybe one for something to light up things inside. But small holes in the body heal much faster and easier than big ones!

Nanotechnology can be used to make very, very small things, including surgical tools.

Scientists are building all sorts of devices that will hold, cut and mend very small parts inside your body—parts the size of a single cell, or even smaller. The big challenge in building nanometer-scale devices is assembling the parts that are needed to move them and figuring out how to power them.

One way to provide power is to use polymers that respond to heat or some external chemicals. The polymer changes its shape and causes the parts that the polymer is attached to—for instance, the arms of a gripper—to close.

Nanotechnology is helping scientists create new tools that are much, much smaller than typical surgical tools like these.

These tiny grippers might be used to grab cancer cells and then bring back samples for analysis.

Other tools being developed are very tiny cutters made by using piezoelectric material. Piezoelectric materials take electrical energy and convert it into mechanical energy, so when a little electricity is added they vibrate. Put a sharp edge on a device that's vibrating and you have something that can now be used for cutting.

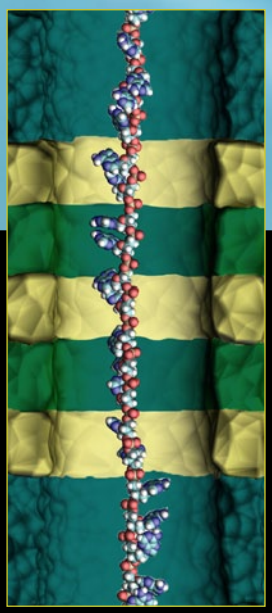
Replacing the surgeon's hand is another big challenge. The hands of a surgeon help guide surgical tools and also provide the pressure required to keep the cutting tool in place. For the time being, doctors still hold these tools to put them where they belong and manipulate them to make them work. How these nanometer-scale tools will accomplish that has not yet been figured out, but there are a lot of scientists working on it.

DID YOU KNOW?

A strand of your DNA is about 3 nanometers wide.

A single uncoiled strand of your DNA would measure about 10 feet in length!

If all your uncoiled DNA was lined up end to end, it would be 2,000,000,000 miles long! That's about the distance from the Sun to Pluto.



Courtesy of IBM

The nanopore is about 3 nanometers wide.

A TINY MICROGRIPPER IN ACTION

This experimental microgripper is closing around live cells. It is so small, it could be swallowed or injected into the bloodstream.

Glucose meters measure the amount of glucose in the blood.

Nano Tattoos

GLOW IN THE LIGHT!

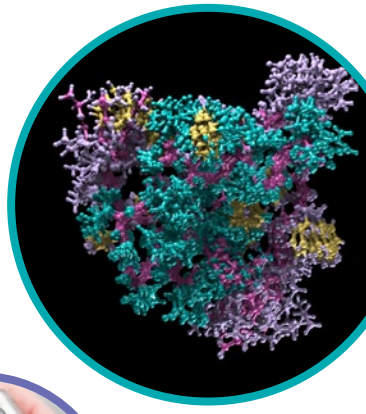
If you have a certain kind of diabetes you already know this—getting a tiny bit of blood and then testing it for glucose is a daily ritual. People with diabetes have to test their blood a lot because if their blood sugar goes out of whack it can cause serious trouble and make them very sick.

New instruments to test blood glucose and make it less painful have been developed using some things from nanotechnology. Nanotechnology has also been used to build tiny pumps that deliver insulin, the molecule your body uses to control blood glucose. But wouldn't it be neat if you didn't have to prick yourself? What if there was some kind of gizmo that would automatically tell you what your blood glucose level was? How about something cool like a...tattoo?

Scientists have been working on tattoos that instead of using ordinary ink use nanoparticles that can sense the level of glucose in your blood. These nanoparticles are made of a special polymer that is biocompatible and contains a molecule that fluoresces in the presence of glucose. Shine a light on the nano tattoo and it tells you how much glucose is in your blood.

The tattoos are fluorescent so you can only see them under the special light. And that's probably okay, since you don't want to broadcast to your friends (and strangers) what's going on with your body. There are still lots of things to be worked out, but the idea is neat and there are a lot of different kinds of tests that could be done with this sort of nanotechnology.

Insulin is a molecule in the body that helps cells absorb glucose.



Currently, people with Type 1 diabetes may have to prick a finger 10 times a day. Nano tattoos could provide an easier, more comfortable alternative.

An insulin pump can deliver insulin to the body.