ANCIENT STAINED GLASS and THE FIRST NANOTECHNOLOGISTS

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NANOOZE

THE FIVE SENSES PART 1

ATOMS: SEEING THE UNSEEN HOW EYES WORK WHAT IS A PIXEL?

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**.*

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THE FIVE SENSES PART 1

THE NEXT THREE ISSUES OF NANOOZE WILL BE DEVOTED TO OUR FIVE SENSES: SIGHT, HEARING, SMELL, TASTE AND TOUCH.

Each of our senses allows us to experience our surroundings in very different ways. A hot summer day can engage all the senses as we feel the heat, wear sunglasses against the brightness, smell the hot asphalt, and hear the ice-cream vendor coming with the promise of a refreshingly tasty treat. Or a winter day can thrill with the sight of a beautiful snow-covered wonderland, but serve up a vicious bite when we feel the blast of freezing wind.

WHAT IS ACTUALLY HAPPENING INSIDE OUR BODIES WHEN WE SENSE SOMETHING?

We have lots of different kinds of cells in our body. Some of these cells help with our different senses and each sense involves a special kind of cell. Cells inside our eyes detect photons of light, while tiny, delicate parts of our ears sense the different vibrations of sound waves. All those cells are hooked up to our central nervous system, which relays the signals triggered by those special cells to our brain where they're processed into a response. It may sound simple—touch an ice cube and your brain tells you is "it's cold"—but it involves a lot of specialized cells and a complex transfer system to transmit signals to the brain.

Then once the signal arrives, your brain needs to figure out what's going on and give you the right picture, sound, smell, taste or feeling. And it all happens at lightning speed!

SO, WHAT DO OUR FIVE SENSES HAVE TO DO WITH NANOTECHNOLOGY?

Scientists study our five senses to learn more about how these complex systems work, so nanotechnology helps shed new light on what's really happening in the tiniest parts of our bodies and can help us develop new tools that can sense like our bodies do.

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 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 of all 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 angle of the bonds between the hydrogen atoms and the oxygen atom are more or less the same. 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 Nanotechnologist Nick Kotov

Nick is a professor in the Chemical Engineering Department at University of Michigan. He teaches courses in chemical engineering and nanotechnology, and studies how to make useful nanomaterials that are strong, efficient, and have the potential to work within the body.

Tell us a bit about your background, where did you grow up? I grew up in Russia, when it was still the big, almighty Soviet Union. We lived in Moscow and it was better than is often portrayed in media, although my family had very modest means. Most of my family members were in science or medicine. I still remember that on the nightstand of my mom and dad there was a book on electron spin resonance of free radicals. I felt very much encouraged to go into inventions and science.

When I was growing up, I had a big issue with stuttering, especially in school. When you are a kid, this is a huge problem. When you are adult, this does remain a problem but I learned to focus on what is important to me and go for it regardless. Quite often our weaknesses are our excuses not to try. This is wrong!

What was your first impression when you came to the United States? My first impression about the USA was that of downtown New York City, in 1992. I had a few hours before the bus to walk around the 42nd Street bus terminal and Times Square in Manhattan. This place was pretty crazy at that time! Nothing like what I expected. To start, there were a lot of foreigners and nobody spoke the perfect English there.

How did you come to your current job? I love science. I want to do something for mankind. I followed what I wanted to do and the job found me. It is much easier to live life this way.

Geographically, coming to my current job involved a bit of travel. Initially I moved from Moscow, Russia, to Syracuse, New York, then to Stillwater, Oklahoma, and then to Ann Arbor, Michigan. It is fun to travel and to change places—keeps you from getting too comfortable.

When you were a kid, were you into science? Did you do experiments? Yes, I did. I was interested in chemistry, and as many kids, enjoyed blowing things up. Not that I can advocate it now. It did give me an introduction to safety and I still have small scars from that period. After that I was more interested in life and living cells.

What are you working on right now? I have many projects now. They all come under one umbrella of organization of matter at nanoscale, my know-how to control structure of atoms at angstrom scale. Same for structural elements and devices at micrometer scale. But nanoscale is a different beast. We need to learn from cells and biology how to do it.

You work on potential ways to help correct problems with vision. Can you tell us a bit about this? My students and I are developing methods to interface with neurons responsible for transport of visual information. The materials that are

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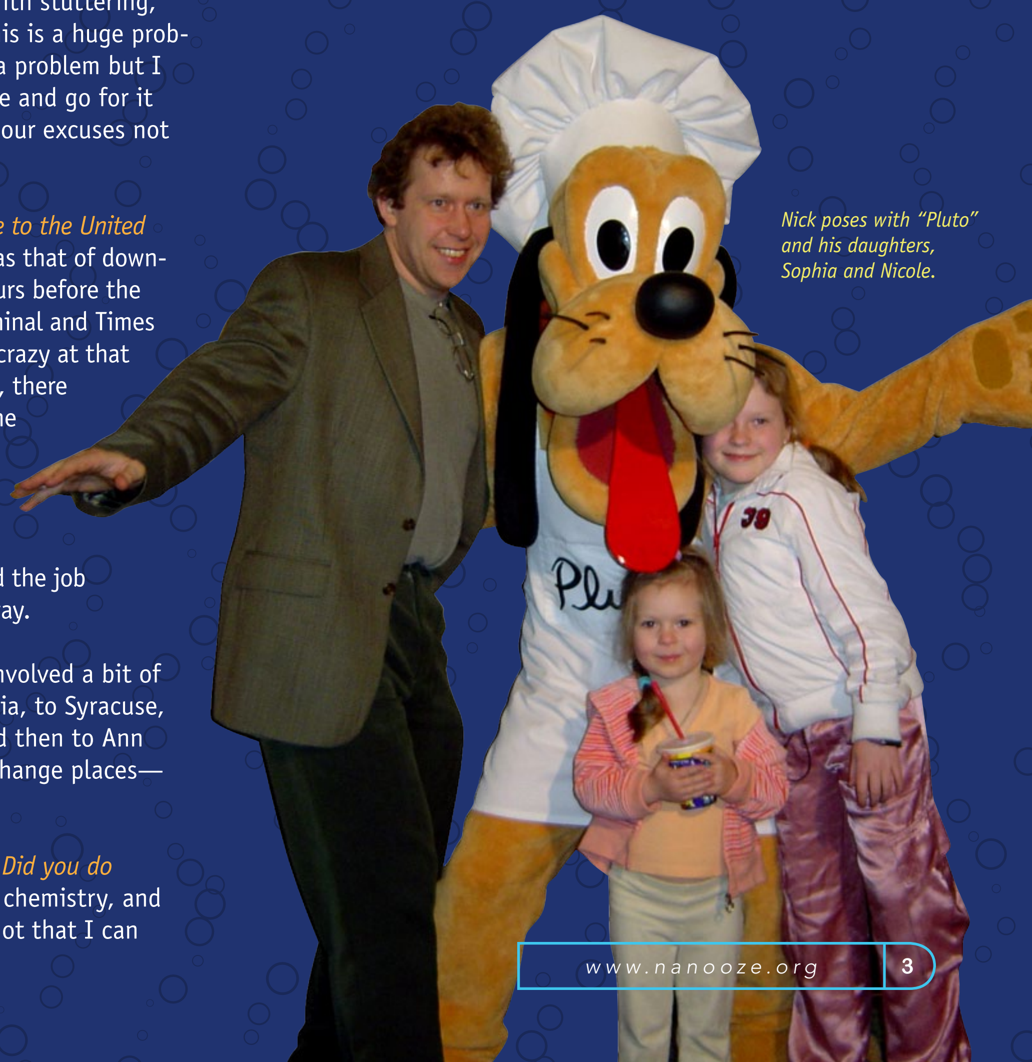
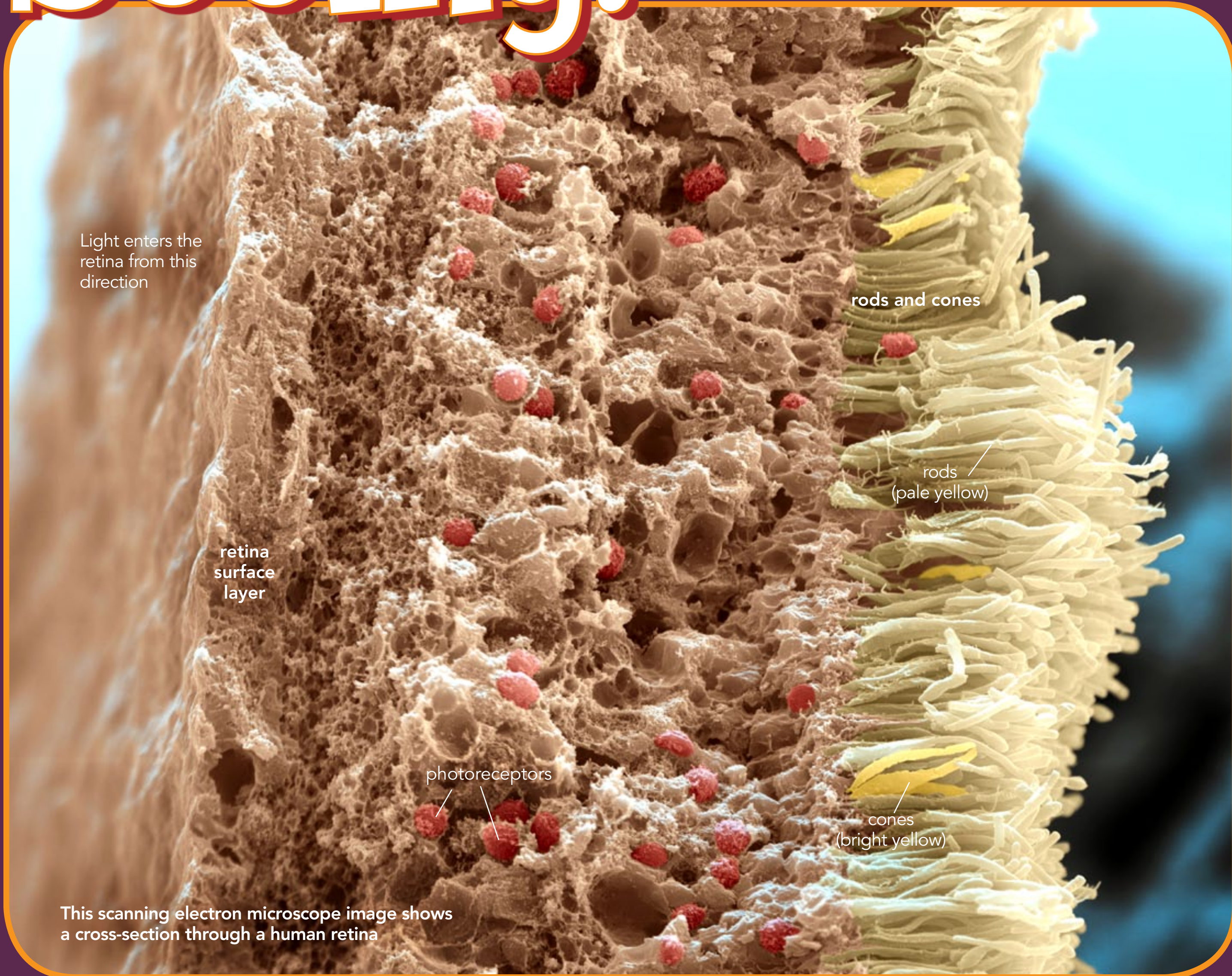


Nick poses with "Pluto" and his daughters, Sophia and Nicole.

Seeing:



This scanning electron microscope image shows a cross-section through a human retina

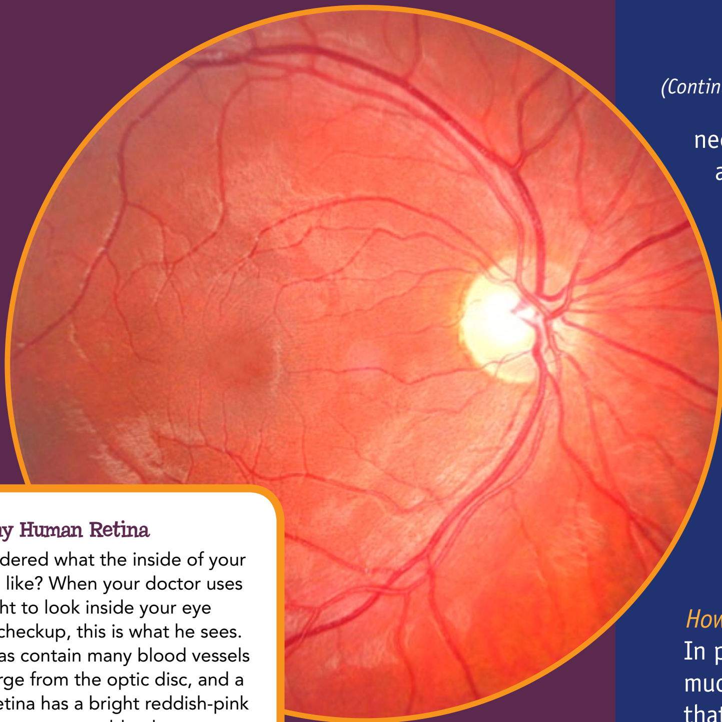
Eye of Science / Photo Researchers, Inc.

A Lot More Than Believing

Sight is one of our five senses, and it's kind of important for getting around. What can scientists learn from studying the tiniest parts of our eyes?

Almost all animals have some kind of ability to see, with hawks and eagles having some of the best vision and rats having some of the worst. And then there are moles that can hardly see at all!

To better understand exactly how we see, scientists have been studying the way the retina works. The retina is the part inside your eye that responds to light and helps to collect images that allow you to see. The retina is made up of cells called cones and rods that respond to light. The average human eye has about a million cells and each cell contains about 150 million photoreceptors. Nerve cells then connect these photoreceptors to your brain. There is a lot of information that moves from your eyes into your brain and scientists have estimated it to be around 8.75 megabits per second—that's around 5-10 times faster than the fiber optic cables used for high-speed Internet connections!



A Healthy Human Retina

Ever wondered what the inside of your eye looks like? When your doctor uses a little light to look inside your eye during a checkup, this is what he sees. Our retinas contain many blood vessels that emerge from the optic disc, and a healthy retina has a bright reddish-pink color with no spots or blotches.

Can nanotechnology help create artificial eyes?

If scientists can find out more about how the eye works, maybe someday they will be able to build artificial parts that will help people with visual impairments to see better. So far they've made some progress using technology that's similar to the kinds of chips that are found in digital cameras.

The big challenge, though, is not capturing the image since nanotechnology has already been used to make very small artificial retinas that are only a few millimeters across. The real challenge is taking the information collected on the artificial-retina chip and somehow directing that information to the brain.

Clinical trials have already been started with the artificial retina mounted on a pair of glasses, with electrodes then wired into the faulty retina of the patient. What do the patients see? Not real images but bits and pieces that mainly correspond to light and dark. Part of the challenge for the patient is retraining the brain to understand this information. There is still a lot of work to be done, but things are definitely moving along!

(Continued from page 3)

needed for that have to have many advanced properties such as strength, high conductivity, biocompatibility, and also being quite thin to resemble the retina. We think that carbon nanotubes can be quite useful for that because they have many of these properties. The challenge is to make the actual macroscale materials from them that display these properties, too.

Some of your work seems almost science fiction. Do you think about doing things that might give people superpowers? Of course! Wouldn't that be wonderful? The superpower I favor in particular is flying but I don't know how to make it happen. The one which is more realistic is infrared vision, seeing in the dark.

How long until you think this work might have some practical use? In principle it can be realized within 10 years. It depends how much need this ability presents. You see, this is not something that you can realize in your garage. A lot of people and a lot of effort need to be put in it to make it happen. Sometimes we need to make a choice what do we want to spend the time on: curing cancer; making a stronger, more efficient car; or... infrared vision.

If you weren't a scientist what do you imagine you might be doing? I kind of like the idea of being a drummer in a rock band. You don't want to hear me singing, though!

Nanotechnology Mimics Nature

Nick holds one of the nanomaterials his team has been working on. Nacre (*pronounced nac-er*) or Mother of pearl is created in nature by oysters. By mimicking the layer-by-layer building process that an oyster uses, scientists can create a material that is super thin, extremely durable, and non-toxic. This material has many potential uses in the medical and aerospace fields. It's very thin, but constructed gradually with at least 2,000 tiny layers!

UM Photo Services, Martin Vloet

CHARTES CATHEDRAL
The 176 stained-glass windows in this cathedral in Chartres, France, contain original colored glass from the 13th century.

Nanotechnology as an

Ancient Art?

Is nanotechnology something new? Not really, but what is new is our understanding of how atoms and molecules do neat things at the nanometer scale. Before anyone understood exactly how and why atoms behave like they do, people were making stuff by taking advantage of the way materials behave at the nanoscale—stuff like stained glass.

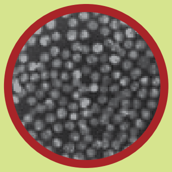
More than 1,000 years ago, artists discovered that they could create different colors by mixing tiny amounts of gold or silver with hot, molten glass. The magnificent stained-glass windows these artists created can still be found throughout the world in many different countries. Chartres Cathedral in Chartres, France, has 176 brilliantly colored stained-glass windows, most of which contain original glass from the 13th century.

Recently, scientists have analyzed ancient glass using powerful microscopes and can see the nanometer-sized particles of gold and silver that give the stained glass different colors. Particles of gold that are just 25 nanometers in size give the glass a red color. Silver particles that are about 100 nanometers in size make the glass look yellow.

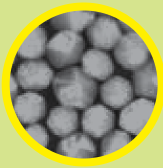
The glass artists of the 13th century didn't know it, but they were creating nanometer-sized particles using a combination of different elements and heating methods.

During the heating process, the silica used to make glass melted with the added metals to form tiny particles—when the glass cooled the colors appeared. The results are beautiful pieces of art that have kept their vivid color for us to see and enjoy hundreds of years later.

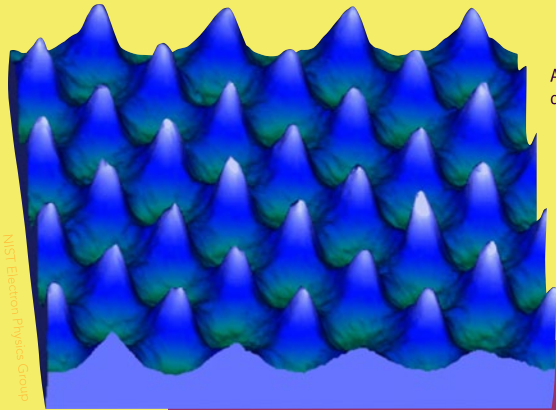
OPTICAL "LIGHT" MICROSCOPE
It is not possible to see nanometer-sized particles or atoms with an optical microscope such as this one that uses light and lenses to magnify a specimen.



Seeing Red
Nanoparticles of gold in stained glass that are 25nm across reflect the color red.



Seeing Yellow
Nanoparticles of silver in stained glass that are 100nm across reflect the color yellow.



NIST Electron Physics Group

An atomic force microscope image of chromium patterns on a silicon surface.

ATOMS:
Seeing the Unseen

As early as 600 BC, great thinkers and philosophers theorized that tiny parts of matter must exist. Around 450 BC, a Greek philosopher named Democritus coined the term "átomos," which means "uncuttable" or "the smallest indivisible particle of matter" in Greek, and it stuck!

In 1808, a scientist by the name of John Dalton proposed what became the modern atomic theory. Even though he had never seen an atom, Dalton took a lot of data from experiments and proposed a set of theories that still hold true today. He could "see" atoms almost 200 years before anyone *really* could "see" atoms.

SO WE CAN REALLY "SEE" ATOMS?

Well, only sort of. We can't see atoms with our eyes, and we can't even see them with simple light microscopes like you use in school. We can only "see" atoms using very powerful tools, such as a scanning tunneling microscope. Scientists use these powerful tools to collect data about atoms, and then use the data to create visualizations of atoms. These visualizations are the pictures of atoms that we can see, but they are quite different from a typical photograph!

OK, SO SCIENTISTS DON'T SEE ATOMS DIRECTLY.

They don't even have teeny, tiny cameras. The pictures of atoms they create are based on results from many experiments. This process is a type of inference, meaning that conclusions are made based on what experiments have shown us, eventually developing a theory that helps to explain what's going on. So all science is based on previous results from experiments, slowly building our knowledge.

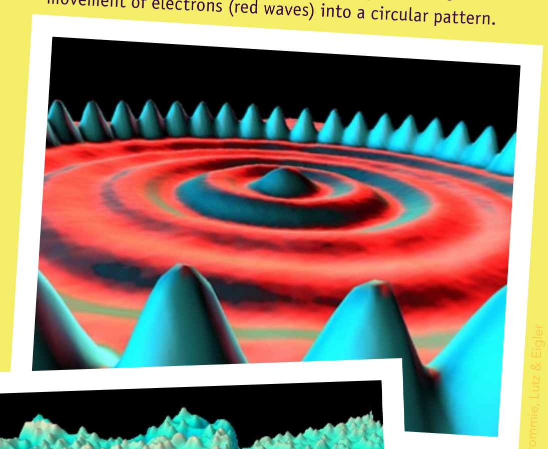
The pictures you see of atoms are based on an inference of data obtained from a powerful microscope. The data, for example, from a scanning probe microscope is converted into a picture based on things that scientists infer from the way an atom interacts with the tip of the scanning probe microscope.

SO IF I WAS AS SMALL AS AN ATOM, IS THAT EXACTLY WHAT I WOULD SEE?

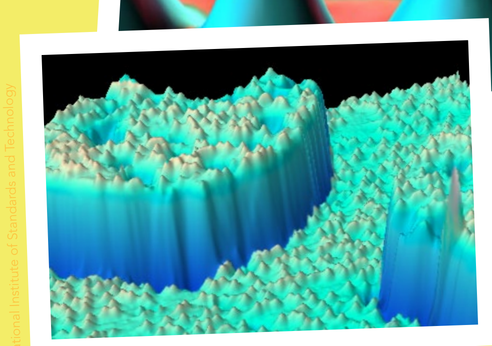
Well, it gets even more complicated. At the atomic scale there is no color because atoms are much smaller than the wavelength of light that we "see" as colors. So where do the colors that you see in these microscopic images of an atom come from? They are really just made up by scientists to either help illustrate a point or sometimes just because they look cool!

Atomic Snapshots

Iron atoms (blue peaks) arranged in a ring corral the movement of electrons (red waves) into a circular pattern.



Crommie, Lutz & Eigler



National Institute of Standards and Technology

A scanning tunneling microscope image of chromium atoms (yellow peaks) on an iron surface.

PIXELS: BREAK IT DOWN!

That new digital camera... 10 million pixels.
Your computer's LCD screen... 1440 x 900 pixels.

So what's a pixel?

A pixel is the smallest single part that makes up an image. The word "pixel" is short for "**picture element**" (**pix**+**el**ement=pixel). A pixel is not really something exactly measurable like an inch or an ounce. It's just a way of breaking down a picture into very small pieces of data.

THE AVERAGE COMPUTER SCREEN CAN DISPLAY MORE THAN A MILLION PIXELS. More pixels means a better picture with more detail. The images and the colors that you see on a TV or computer screen are created when the digital pixel information is translated into little electrical signals that cause the screen to display a specific color. There are different ways to do that—some involve crystals that change their ability to let light pass (LCD, liquid crystal displays), while others involve chemicals that give off light when they are charged by the electrical signals (LED, light-emitting diodes).

SOME DIGITAL CAMERAS CAN TAKE PICTURES WITH OVER 10,000,000 PIXELS. That's 10 million little tiny bits of data in every snapshot! That's a lot of data. Cameras with the capability of capturing more and more pixels are a result of improvements in nanotechnology. Inside a digital camera is something called a charged coupled device (CCD). A CCD is a gizmo that takes light and converts it into digital bits of information that can be stored. The CCD has a million or more of these sensors, each of which records a portion of the light from an image. So the more sensors on the CCD, the more pixels of data can be captured, the better the picture looks.

SO HOW MANY PIXELS CAN THE HUMAN EYE CAPTURE? Well, it does depend on how good your eyes are, but estimates are in the range of 300-500 million pixels. That means when you look at something your eye breaks it down into 300-500 million different pieces of information that your brain puts together into one big picture—a picture that's a lot more impressive than most of the digital cameras or computer screens around!