Q&A with a West Virginia Graduate Student

Brought to you by WV Higher Education Policy Commission, the National Nanotechnology Infrastructure Network, and Cornell NanoScale Science & Technology Facility

WV ISSUE 2 • 2013

# NANOOZE

John Sibold

SILICON AND THIN FILMS

TINY TOOLS

THREE WV NANOSCIENTISTS

NANO AROUND THE STATE

THE WEST VIRGINIA ISSUE #2

## All about the things too small to see

*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 for 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?

*Regular editions 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**.*

## How about this West Virginia issue?

*This edition of Nanooze was especially created for West Virginia middle school students.*

*Additional copies of this edition may be available by calling 304-558-4128, ext 7. An electronic version can be found at **www.wvresearch.org/nanooze**.*

 Design by Emily Maletz Graphic Design. A project of WV Higher Education Policy Commission and the National Nanotechnology Infrastructure Network (NNIN) with support from West Virginia University, Marshall University, the WV State Department of Education and the National Science Foundation.

This material is based upon work supported by the National Science Foundation under Grant No. EPS 1003907. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Welcome to an extra special edition of Nanooze! This issue is all about nano in the state of West Virginia—cool science and cool people in various places around the state.

West Virginia has a lot of big stuff going on in nano. Colleges, universities, and companies are busy making stuff so small it is the size of an atom. And many of the folks making this small stuff grew up in your own state. One exciting place is the lab Dr. David Lederman runs at West Virginia University. On pages 4 and 5, you'll see lots of pictures of David's lab, the people who work with him, and the equipment they use to do big things with small stuff.

**Nanoscientist David Lederman**
Visit his lab on pages 4 and 5.

Thinking about a career in science, technology, engineering, or math? You don't have to go far to learn more, and there are great careers for you in West Virginia.

John Sibold

**On the Cover**
Gwen Nurkiewicz from Morgantown holds a silicon chip used for growing thin films.

# NANO KNOW-HOW

## Learning about nano stuff is fun, but it can be complex. 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.

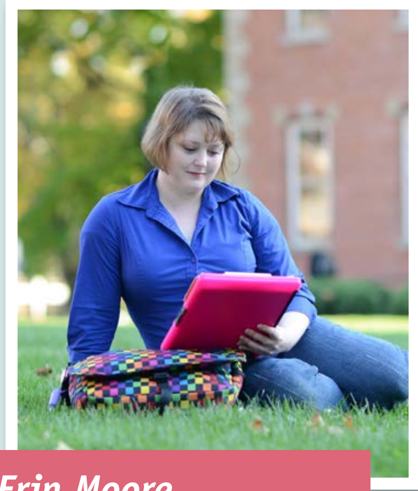
The rules at the nanometer scale are different than what we usually encounter in our human-sized environment. For instance, gravity doesn't count because other forces are more powerful at the molecular level. Static and surface tension become really important. What is cool about nanotechnology is that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

***Things are really different down there!***

# Q&A with Erin Moore

Instruments: iStockphoto

*"I love music and have played clarinet, saxophone, piccolo, piano, percussion, and mandolin. I thought about becoming a musician, but engineering won out!"*



Callie Lindsey

**Erin Moore**
**Graduate Student at WVU**

***Tell us a little bit about your background.*** I was raised in Parsons, a small town in the mountains of West Virginia. As a kid, I loved books and music. My family and teachers encouraged me to pursue my passions and to try new things. I learned how to fail and start over, and that it is OK to be different.

I was a good student and an excellent musician. I thought of becoming a professional musician, but engineering won, because it provided a way to satisfy my insatiable curiosity and creativity.

I studied computer engineering at WVU, and then completed a master's degree in systems engineering from the University of Arizona while working at Raytheon Missile Systems.

***So you were a "rocket scientist?"*** Yes! I wrote software to collect data from missile flights.

***What are you doing currently?*** I am now pursuing a doctorate in computer engineering from WVU. My field of research is called "data mining" or "data science." In data mining, computers are used to look for patterns in information that can be used to make predictions. For instance, if we knew that a person put peanut butter and bread in their grocery cart, we may guess that they would also buy jelly and milk.

I investigate DNA molecules called aptamers. These molecules act like heat-seeking missiles. They find only their specific target and they grab hold and don't let go. They are currently used in nano-chips to measure the amount of the target substance in the environment, and in medicine to treat only the area that has the target molecule (instead of the entire body).

I am looking at the DNA aptamers that we know about to see if I can find a "recipe" for new DNA molecules that act the same way.

***What is your recollection about the first time you did an experiment?*** My grandmother allowed my cousins and me to do "kitchen chemistry" as long as we cleaned up afterward. We would combine ingredients from the cupboard and the fridge and see what would happen. We would dare each other to take a sip. What would it smell like, taste like, look like? Could we make the concoction fizz or smoke? More often than not it was disgusting.

***Who helped shape your decision to go to college and study science?*** In my family, going to college was required. My parents were first-generation college graduates. They understood the value of higher education and wanted us to have good job prospects.

My older brother inspired me to be an engineer. I looked up to my big brother and wanted to try nearly everything that interested him. He introduced me to computers and programming. At one time, he wanted to be an engineer, so I "tried on" engineering and it fit!

***What is a typical day like?*** No two days are alike. My job is to solve new problems and share the solutions. Some days, I read about other's work, and see if I can apply it to my problem. Other days, I am writing computer code and creating papers and talks.

***What are your career goals?*** I aspire to be a professor and researcher. I am passionate about curing disease. I want to investigate biological and medical data with the hope of finding patterns to improve disease diagnoses and treatments. As a teacher, I want to pass on my knowledge and encourage others to pursue their dreams.

***If you were doing science, where might we find you?*** I "do" science anywhere I can plug in a laptop, whether that is in a coffee shop, a research laboratory, or on my couch.

***Who is the coolest scientist that you know?*** Dr. Letha Sooter is a superhero in disguise. She conducts experiments in the laboratory to find DNA aptamers. She has an instinct for her science. She can look at DNA and guess which ones will work.

***What is the smallest thing that you can see with just your eyes?*** Gnat.

***What is the smallest thing that you can think of?*** An electron. Electrons in the aptamer and target molecule attract each other and help form a bond between the aptamer and target.

*Erin and friends*
*Coopers Rock State Forest, WV*

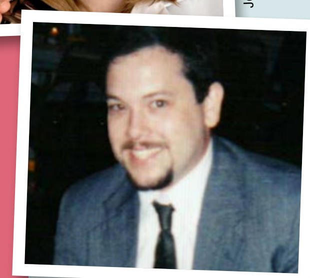
*Erin and friends*
*Ocean City, MD*

Photos courtesy of Erin Moore

## Erin's Inspiration

John Sibold

**Letha Sooter**
*Dr. Letha Sooter inspires me because she is multitalented. Not only does she find aptamers, she is also great at setting up laboratories for others.*



**Older brother Jamie Moore**
*Jamie inspired me to be an engineer. I looked up to my big brother and wanted to try nearly everything that interested him. He introduced me to computers and programming.*

# To make small stuff, you need thin stuff

Nanotechnology is all about manipulating matter at scales of 1-100 nanometers. Suppose you had three silicon atoms. Silicon is the material that makes up a lot of computer and electronic components. Now stack them one on top of another, and you have a pile of atoms that is about one nanometer high. But easier said than done! Moving things around and building things at the atomic scale is a huge challenge, and nanotechnology is the way that we can control matter at this scale.

## GROWING THIN FILMS

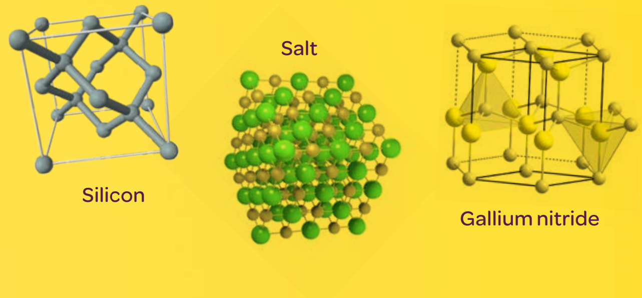
Why is tiny stuff important? The switches in today's computer chips are about 32 nanometers in one dimension. Do the math (32 nanometers x 3 atoms per nanometer) and you come up with something that is made from about 100 atoms. Building with silicon atoms one by one would be extremely difficult and time consuming. Instead, scientists have figured out how to grow thin films of silicon and other materials that are only a few atoms thick, which means they can make devices that are really, really, really tiny. In some devices the insulator layer (the layer that keeps two materials that can conduct electricity apart—think short circuit!) is only a few atoms thick. That is pretty mind boggling, and scientists and engineers are continuing to make things even smaller. But being small isn't the only reason to use nanotechnology.

## UNEXPECTED PROPERTIES

At the nanometer scale, materials have unexpected properties. Electrons confined in thin layers can "tunnel" from one layer to another, jumping across the insulator. Tunneling is used to control the transistors that make up the processors in all of your electronic gadgets. Using nanotechnology, you can trap light and move it around the way we control electrons. Controlling light at the nanometer scale can be used to make lasers. Thin films also have strange magnetic properties that allow us to store and read enormous amounts of data ("bits") in computer hard drives.

**Preparing a wafer**
A researcher at West Virginia University prepares a silicon wafer for growing an aluminum thin film. The yellow light in the lab is used when working with photosensitve materials that would be damaged by normal light.

Lab images: John Sibold




**Crystal structures**
Atoms in crystals align in a regular pattern.

## GET THE AIR OUT OF THERE!

In West Virginia, scientists are working on new ways to control matter at tiny length scales. Part of the challenge is making things, the other part is seeing them and also understanding how they work. To make things on the atomic scale you need to be able to make sure that your starting materials are pretty pure and not full of contaminants. Nanoscientists work using tools that operate under a very low vacuum, meaning that most of the atoms in the air have been sucked out so they don't get in the way of the atoms the scientist is working with.

*Josef Loschmidt*

We don't think about air having atoms, but your average cubic meter of air has about $2.7 \times 10^{25}$ atoms. That's 270,000,000,000,000,000,000,000,000 atoms. It is known as *Loschmidt's number* and is named for a famous guy who first figured out how big an atom might be back in 1865. With this many atoms, a surface is hit by an atom every nanosecond ($10^{-9}$ seconds). This makes it impossible to build anything at that scale. So you need a big vacuum to suck the air molecules out of your machine. West Virginia scientists can decrease the number of atoms in the air by a factor of $10^{12}$ or more, so that a surface is only hit at most every 1,000 seconds (which is longer than 16 minutes). This means that if you can make a film in less than 16 minutes, not a single atom of air will contaminate the film, and you can make ultrapure stuff.

## WHAT ARE SCIENTISTS BUILDING?

In this vacuum scientists can then grow thin films of stuff like silicon, germanium, or other materials, including crazy stuff like gallium nitride (the stuff that blue lasers are made out of). Gases are made from these materials by blasting them with powerful lasers, electron beams, or plasmas, or heating them up to high temperatures in mini-ovens. The atoms in those gases are collected on a "substrate," a solid surface upon which these atoms form crystal structures. These crystals form pretty much on their own because the atoms line themselves up according to their bonding pattern.

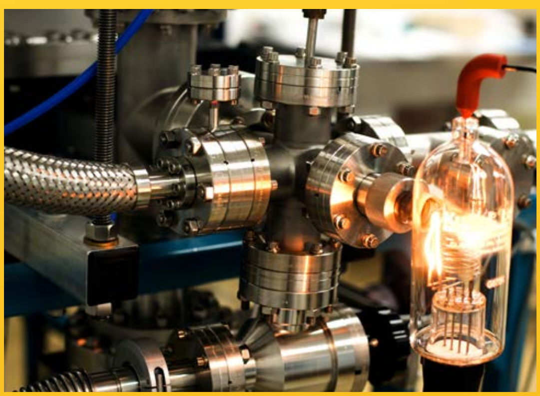
*Table salt crystals*

Think about salt and how it looks like tiny little cubes. Table salt is made up of nicely lined up crystals of sodium and chlorine atoms. Crystals are nice because all of the atoms are lined up in perfect array, so things are really flat. They're so flat that over a distance of a meter, the surface doesn't vary more than 2,000 nanometers, which is about 0.0002% roughness—that's nice and smooth.

## HOW THIN CAN WE GO?

The ultimate thin film crystal is made of a single layer of atoms. This is *really* hard to do, but nature has provided us with some materials that can be made this way. For example, graphene, a layer of carbon just one atom thick, is really good at conducting electricity and is super strong. Scientists in West Virginia are working to make these layers even thinner and out of different kinds of materials that have powerful electronic, magnetic, or even optical properties. This will allow us to make phones and computers with even more data storage capability and make future electronic devices (computer chips directly implanted on the brain?) that we can now just dream about.

Physics graduate student working on an ultra-high vacuum molecular beam epitaxy (MBE) system used to grow thin films.



Vacuum ion gauge used to measure pressure inside the vacuum chamber.

Growth of thin film by generating plasma on source material.

Loschmidt; silicon, gallium nitride: Wikipedia, salt crystal: Martin McCarthy, salt SEM: Jon Hunt

# TOOLS FOR BUILDING NANO PARTS


iStockphoto

How do you build something you can't even see? Hammers, screwdrivers, and saws are not going to get the job done when you need to build at the nanoscale. To make advances in nanotechnology, scientists and engineers have had to design new tools and equipment that can see and build nanometer-sized things.

More than 50 years ago, scientists tried to predict how small the smallest thing we could make might be. Richard Feynman, a famous physicist, once put up a $1,000 challenge to anyone who could build a tiny motor no bigger than a cube measuring 1/64 inch on each side—that's smaller than a poppy seed! He hoped to get people to think about how to build new things that were the size of atoms. The guy who won the contest was a very talented machinist. Much to Feynman's disappointment, he somehow managed to use ordinary tools to make a tiny motor. The motor worked, and Feynman made good on his $1,000 reward.

## PHOTOLITHOGRAPHY

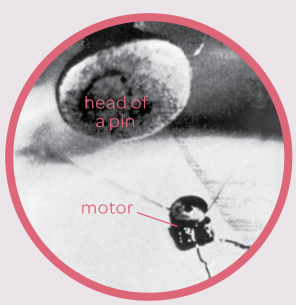
The smallest parts made are found in computer chips where transistors—the tiny switches that digital things are based on—are less than 32 nanometers. You could fit more than 3,000 of these transistors across the width of a hair. Most transistors are made using a process called photolithography, which uses light and lenses to shrink patterns down to a few nanometers. Think of a microscope working backward, making big things small. Photolithography uses light-sensitive chemicals whose properties change when they are exposed to a specific wavelength of light. So they might become a solid that can't be washed away after being exposed to light. To make patterns, engineers use masks that are stencils that let light through only in certain places.

## BREAKING THE LIGHT BARRIER

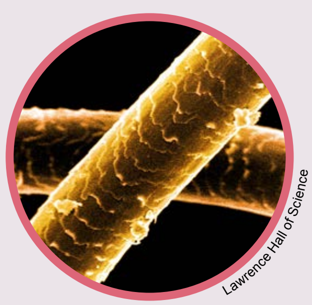
It was once believed that the smallest object you could make by photolithography was limited by the wavelength of light. So with ultraviolet light of around 250 nanometers, you couldn't make things much smaller than that. But some clever scientists figured out a way to predict how light would behave at dimensions much smaller than their wavelength and now we are making stuff almost 10 times smaller. Still, using photolithography will only get you so far, and to make even smaller things, engineers use machines that shine electron beams instead of light. Electron beams can be focused down to less than 1 nm using electric fields, and very small features can be made in this way.

## A SINGLE-ATOM TRANSISTOR?

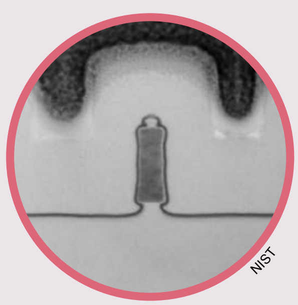
We can even make transistors out of single atoms. In the laboratory scientists have demonstrated that single-atom transistors can work. For now, however, single-atom transistors aren't practical. And while we can pack a few hundred million transistors into a computer chip, there is more exciting work to be done, and cool new tools to be designed!




**Tiny motor**
16,256,000 nm



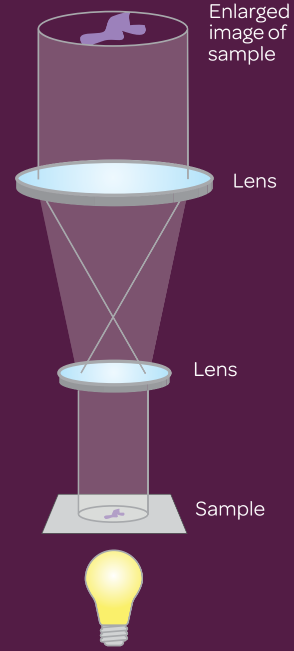

**Human hair**
100,000 nm



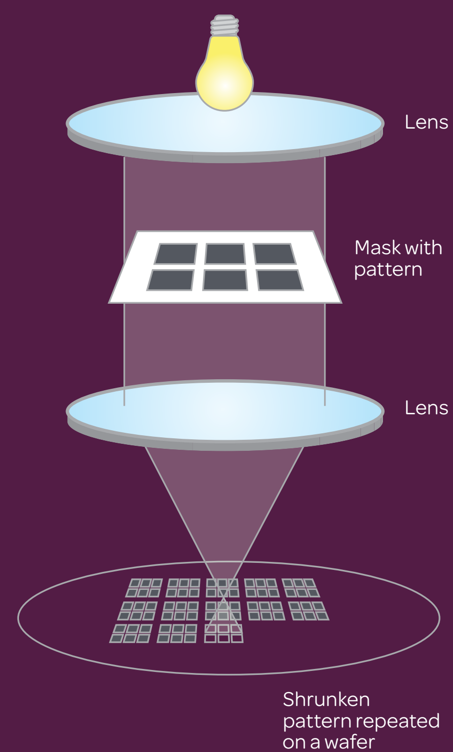

**Transistor**
32 nm

Tiny motor: Courtesy of the Archives, California Institute of Technology

### Optical microscope

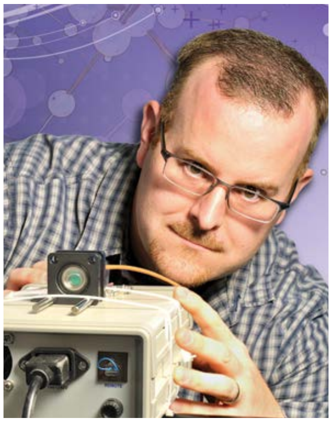



### Photolithography




Photolithography works like a microscope in reverse. Instead of enlarging something tiny, photolithography takes a pattern and shrinks it down many times smaller. This allows scientists to create incredibly small patterns on silicon to form tiny chips and devices.

# 3 WEST VIRGINIA SCIENTISTS
## AND THEIR CURRENT WORK


John Sibold

## *Shining Light on the Problem*
### Jeremy Dawson and Photonic Crystals

Most of the advances in nanotechnology have come from making electronic components smaller and smaller. I work on *photonic crystal structures* that can direct the movement of light much the same way that we control the flow of electrons in a computer chip. With photonic crystals we can build tiny biosensors that can measure the intensity of light generated by things such as fluorophores, which can be used to tag different molecules you are trying to detect. Large instruments that can currently only be operated in a sophisticated laboratory are some day going to be devices you can carry around in your pocket.

**Job:** Research Assistant Professor at West Virginia University
**Degree:** Ph.D., Electrical Engineering
**Hometown:** Keyser, West Virginia

*"Nanotechnology impacts many things, from the food we eat to the clothes we wear."*

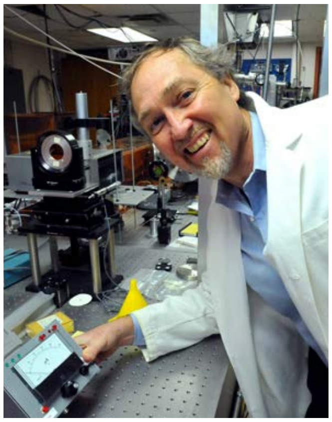

WVU Photography services

## *Shocking!*
### Cerasela-Zoica Dinu and Impedance Sensing

We usually think about looking at cells using microscopes. But we can also "see" how cells respond to the changes in their impedance. *Impedance* is an electrical measurement—the resistance to the flow of alternating current. I use cells as "tiny sensors" measuring the change in impedance when they are exposed to different hazardous toxins. This change in impedance can be measured in real time as the cell physiology is affected by the toxins.

**Job:** Chemical Engineering Assistant Professor at West Virginia University
**Degree:** Ph.D., Biology
**Hometown:** Braila, Romania

*"To think nano, consider that your fingernails grow at about 1 nanometer per second."*


Rick Haye / Marshall University

## *Far Out Lasers*
### Thomas Wilson and Terahertz Lasers

Flashlights produce white light, which has all of the visible wavelengths of light (400-700 nanometers), but a laser produces light at only a single wavelength. Depending upon the wavelength of the laser, you can "see" different things. Ultraviolet lasers and detectors can see things at wavelengths below visible light (less than 400 nanometers). *Terahertz lasers* produce light in the terahertz range (300-1,000 micrometers or 300,000-1,000,000 nanometers). I am using terahertz lasers to look for specific chemicals that give off a signature when illuminated in the terahertz range. Using terahertz detectors you can identify certain kinds of explosives and other dangerous chemicals in the field.

**Job:** Physics Professor at Marshall University
**Degree:** Ph.D., Physics
**Hometown:** Evansville, IN

*"A terahertz imaging microscope gives us new perspectives at the nanoscale!"*

# WHERE IS NANO HAPPENING IN WEST VIRGINIA?

## NETL, DOE Lab
*National Energy Technology Lab*

NETL scientists and engineers are researching efficient ways to provide environmentally friendly energy.

## NanoSAFE
The Nanotechnology Sensing Advances in Field and Environment (NanoSAFE) program at WVU focuses on bionanotechnology for environmental threat-sensing devices. NanoSAFE integrates research with education, outreach, and workforce development activities.

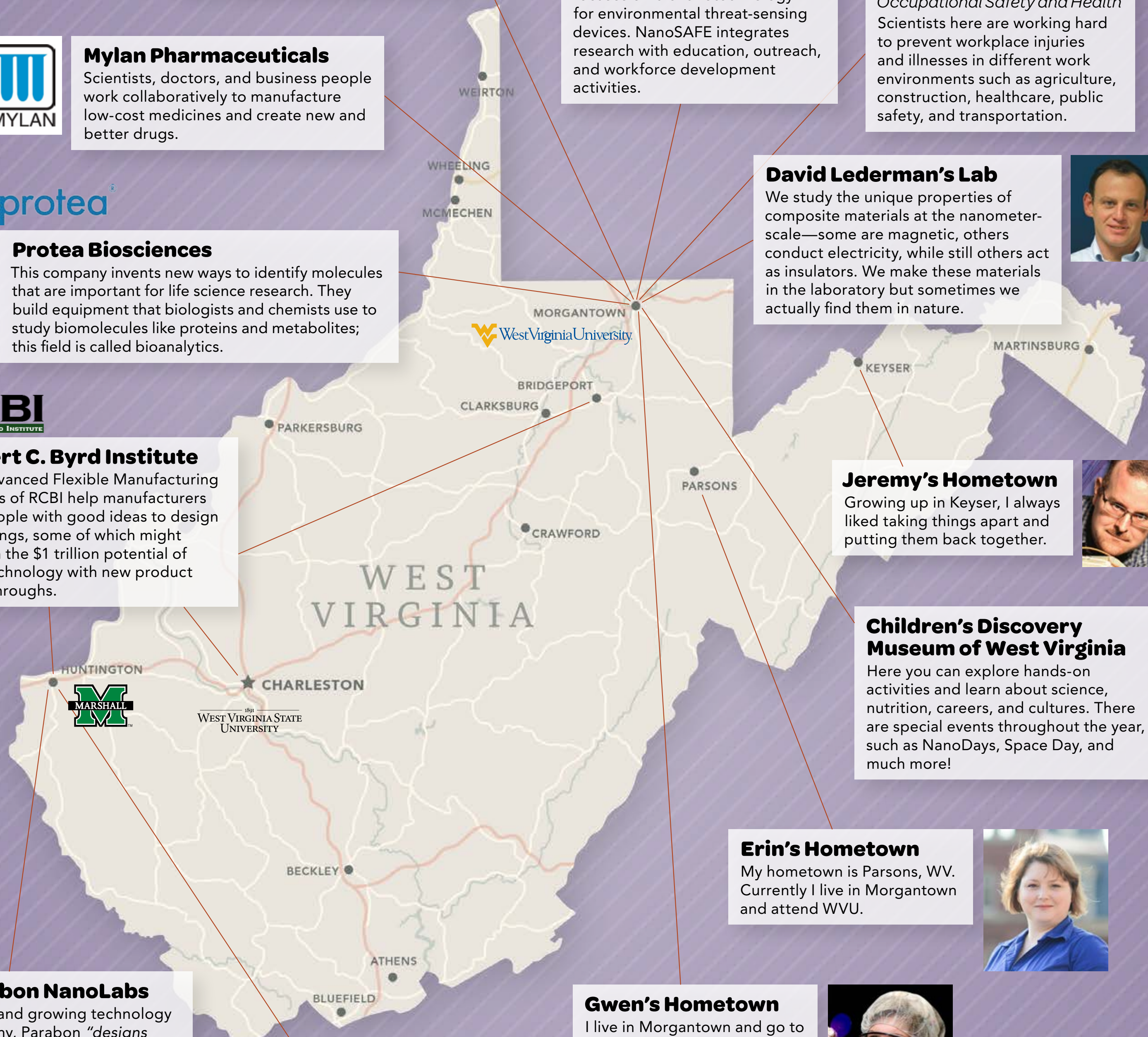
## NIOSH, CDC lab
*National Institute for Occupational Safety and Health*

Scientists here are working hard to prevent workplace injuries and illnesses in different work environments such as agriculture, construction, healthcare, public safety, and transportation.

## Mylan Pharmaceuticals
Scientists, doctors, and business people work collaboratively to manufacture low-cost medicines and create new and better drugs.

## David Lederman's Lab
We study the unique properties of composite materials at the nanometer-scale—some are magnetic, others conduct electricity, while still others act as insulators. We make these materials in the laboratory but sometimes we actually find them in nature.

## Protea Biosciences
This company invents new ways to identify molecules that are important for life science research. They build equipment that biologists and chemists use to study biomolecules like proteins and metabolites; this field is called bioanalytics.




## Robert C. Byrd Institute
The Advanced Flexible Manufacturing facilities of RCBI help manufacturers and people with good ideas to design new things, some of which might unleash the $1 trillion potential of nanotechnology with new product breakthroughs.

## Jeremy's Hometown
Growing up in Keyser, I always liked taking things apart and putting them back together.

## Children's Discovery Museum of West Virginia
Here you can explore hands-on activities and learn about science, nutrition, careers, and cultures. There are special events throughout the year, such as NanoDays, Space Day, and much more!

## Erin's Hometown
My hometown is Parsons, WV. Currently I live in Morgantown and attend WVU.

## Gwen's Hometown


I live in Morgantown and go to Morgantown High School.

## Parabon NanoLabs
A new and growing technology company, Parabon *"designs drugs one molecule at a time."* Huffington Post named one of their products *"among the best inventions of 2012."*

## Vandalia Research
A spin-out of Marshall University, Vandalia is a biotechnology custom manufacturing organization that can produce DNA sequences on a large scale.