ARGONNE | NOW

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THE SCIENCE THAT STUMPED EINSTEIN

and how it would change the future of energy

also in this issue CITY OF THE BIG DATA • THE VOLCANO OF 100,000 MOUTHS

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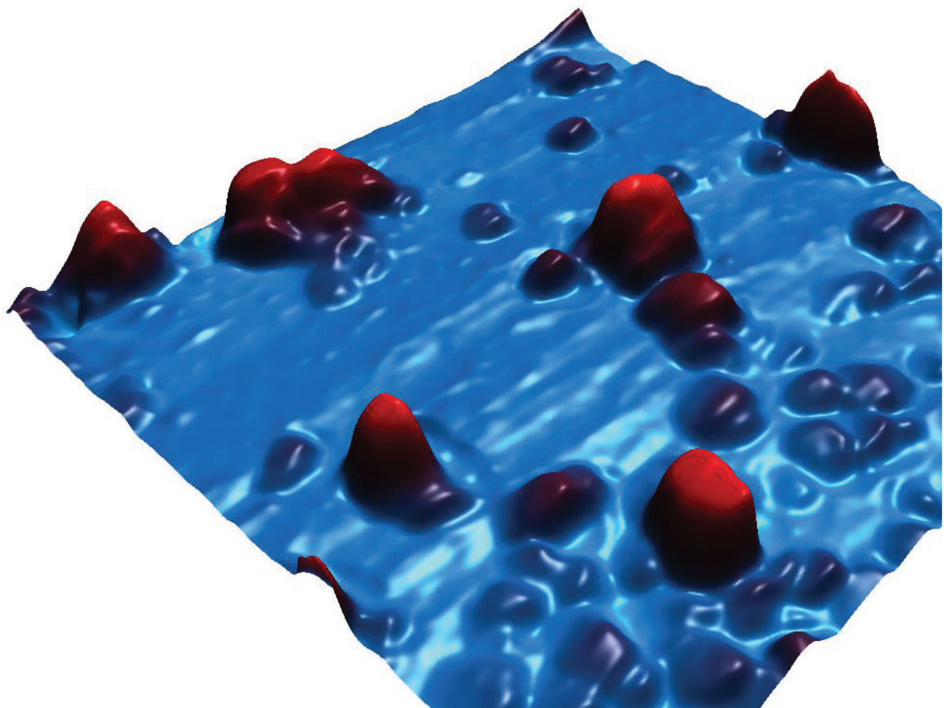
Argonne NATIONAL LABORATORY

COVER STORIES

Treacherous Seas
The reddish reef on this sea of blue is a group of extremely tiny plutonium nanoparticles which are just a few nanometers across (about as much as your fingernails will grow while reading this caption). They spontaneously formed on the surface of this mineral called Muscovite Mica. Research like this helps scientists understand how plutonium behaves, which is important for figuring out ways to decontaminate polluted areas.

Image by Francesco Bellucci, Karah Knope, Sang Soo Lee, Paul Fenter, Lynne Soderholm, and Moritz Schmidt.



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Dear Reader,

At Argonne, our researchers are on a mission to address some of the greatest scientific challenges facing the nation—to discover and innovate new materials, products and systems with the power to change the world.

One of the most intriguing potential game-changers—superconductors—is featured in our cover story, "The Science That Stumped Einstein" (page 16). As you may know, a superconductor is a material that has no resistance to electricity, so current passes through it with no loss of power. Superconductors could be useful in an array of energy technologies, ranging from power grids to wind turbines to ultra-efficient engines. However, it is difficult to put these materials to practical use, because fabricating superconductors that can still carry large electrical currents at commercial scales has been very challenging. Recent research at Argonne, though, may turn out to be transformative.

In "The Volcano of a Hundred Thousand Mouths" (page 26) *Argonne Now* looks at Chicago as it was a century ago, when the myriad smokestacks of the Industrial Age belched thick clouds of soot into the city's skies. Over the past decades, air pollution regulations have helped to clean Chicago's air, but the world still faces serious consequences from the massive amounts of soot and other types of carbon that human activities release into the atmosphere. Today, Argonne researchers are using sophisticated computer models to better understand the impact of those carbon emissions on our climate and our environment, and to find the best possible ways to clean the air we breathe.

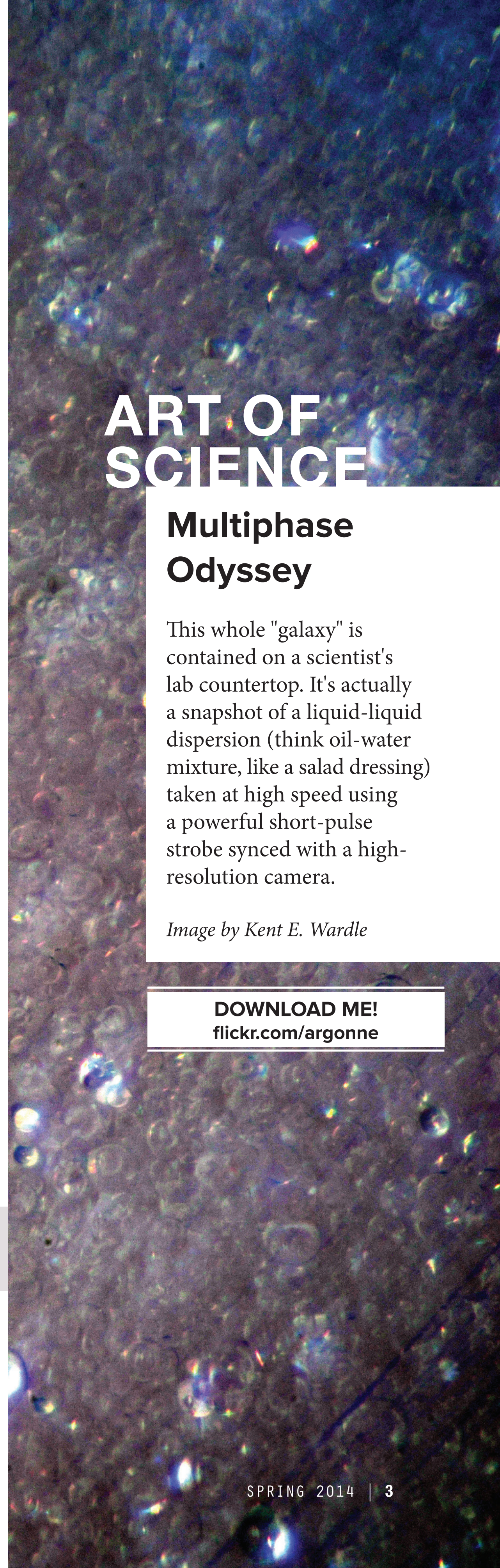
"City of the Big Data" (page 22) looks ahead to a Chicago made safer, more convenient, and more prosperous through supercomputing and analytical tools for big data. Increasingly, giant datasets about cities and the people who live in them are creating opportunities for city planners to make highly informed decisions about transportation, energy, water, waste, and other fundamental infrastructure issues. For example, on Chicago's far South Side, on the site of a former steelworks, Argonne's computational scientists are working with planners and real estate developers to create a sustainable new community from the ground up. Their results could have an immense impact on the ways cities are planned, built, and managed, all around the world.

Each of these stories demonstrates Argonne's mission: To do science and engineering with the potential to solve society's biggest, most challenging problems. As we work to achieve those ambitious goals, we appreciate your interest and your support.

Thank you, and I hope you enjoy this issue of *Argonne Now*.

Peter Littlewood, Director

EDITOR'S NOTE: *Argonne Now* is delighted to welcome our new laboratory director, Peter Littlewood, to these pages. We look forward to sharing more of his thoughts in the coming issues.



ART OF SCIENCE

Multiphase Odyssey

This whole "galaxy" is contained on a scientist's lab countertop. It's actually a snapshot of a liquid-liquid dispersion (think oil-water mixture, like a salad dressing) taken at high speed using a powerful short-pulse strobe synced with a high-resolution camera.

Image by Kent E. Wardle

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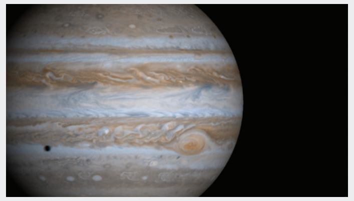
SCIENCE HISTORY

1914

100 YEARS AGO

A new moon of Jupiter
An American astronomer discovers Sinope, a moon of Jupiter that circles the planet in the opposite direction from the planet's rotation. Scientists think it may be an asteroid caught by Jupiter's gravity.

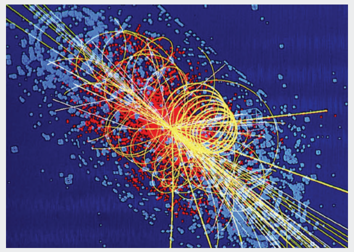


An image of Jupiter pieced together from images taken by the Cassini spacecraft. The ninth of Jupiter's 50 moons was discovered 100 years ago. Image by NASA/JPL/University of Arizona.

1963

50 YEARS AGO

First hints of Higgs
The University of Edinburgh's Peter Higgs, along with François Englert and Robert Brout, publish the first papers suggesting the existence of the Higgs particle, which would take 49 more years and a massive 17-mile long accelerator to prove. Higgs and Englert received the Nobel Prize last year for this research.



A computer simulation showing a collision at the Large Hadron Collider that produced a Higgs boson. Image by CERN/Lucas Taylor.

1969

45 YEARS AGO

A new director
Walter Massey is named director of Argonne. Massey, then a professor of physics at Brown University, later went on to head the National Science Foundation and is currently the president of the School of the Art Institute of Chicago.

Argonne director Walter Massey greets President Jimmy Carter at the White House on Feb. 28, 1980.

2004

10 YEARS AGO

The lost "hobbits"
Bones from an extinct species of early human called *Homo floresiensis* are discovered in Indonesia. Scientists think the ancient humans would have stood about three and a half feet tall—hence the nickname "hobbits"—and lived between 95,000 and 17,000 years ago.

A nearly complete skull of Homo floresiensis, which stood about three and a half feet tall and lived in Indonesia. Image by North Carolina School of Science and Mathematics.

U.S. SENATOR DICK DURBIN LEADS SUPERCOMPUTER DEDICATION EVENT | by Brian Grabowski

The fifth-fastest supercomputer in the world, called Mira and housed at the Argonne Leadership Computing Facility, went into full production mode this year, marking an important milestone for the facility and the lab.

Now that Mira is in full production mode, several projects are using the system's vastly increased power and capabilities to run such complex simulations as the physics of blood vessels, the origins of the universe, and global climate models.

In early July, U.S. Sen. Dick Durbin (D-IL) led the dedication of Mira and remarked on the importance of high-performance computing to scientific research, industrial innovation, and the nation's economic future.

"Argonne National Laboratory is one of Illinois' and the country's great assets," said Durbin. "Mira ensures the lab remains a linchpin of scientific research, enabling researchers to tackle extremely complex challenges ranging from improving combustion efficiency in car engines to modeling the progression of deadly diseases in the human body.

"High-performance computing is crucial to U.S. economic growth and competitiveness, saving time, money, and energy, boosting our national security, and strengthening our economy," he said.

U.S. Senator Dick Durbin speaks at the dedication of the lab's new supercomputer.

Mira is an IBM Blue Gene/Q system. It consists of 48 racks of computers holding 786,432 processors and 768 terabytes of memory and can solve 10 quadrillion calculations per second.

To put those capabilities in perspective, Mira is 20 times faster than its IBM Blue Gene/P predecessor, Intrepid, which was ranked third in the world when it was installed at Argonne in 2008. Mira also represents a significant step forward in green computing; with a highly efficient water-cooling system, it operates five times more efficiently than Intrepid.

Moving forward, Mira will be open to researchers across the world through the INCITE program, which awards computing time on Energy Department-funded supercomputers to researchers. In 2014, it will allocate 5 billion computing hours.

Mira and the Argonne Leadership Computing Facility are supported by the Department of Energy's Office of Science.

Watch the ceremony: http://bit.ly/miradedication
Learn about Mira: http://bit.ly/meetmiravideo

CLIMATE STATION HEADS TO FINLAND | by Louise Lerner

Last year, the mobile climate-sensing facility called AMF2 spent its days cruising Pacific waters, fixed aboard a working cargo ship traveling back and forth between Hawaii and Los Angeles. Its next stop is a little less warm, but just as scenic: deep in the forested countryside of Finland.

"We are proud to support our next ARM field campaign's mission to collect data on the interaction between forest and climate," said Nicki Hickmon, an Argonne meteorologist who is the site manager for the facility. "Then the science team will analyze the interaction between tiny biological particles released by the forest and their impact on clouds, precipitation and climate."

"Little particles like pollen from the forest—which is mostly birch and Scots pine—become a source of nuclei for clouds to form around," she said. "The idea is to see how gases escaping from the forest affect climate and atmospheric conditions." >>>

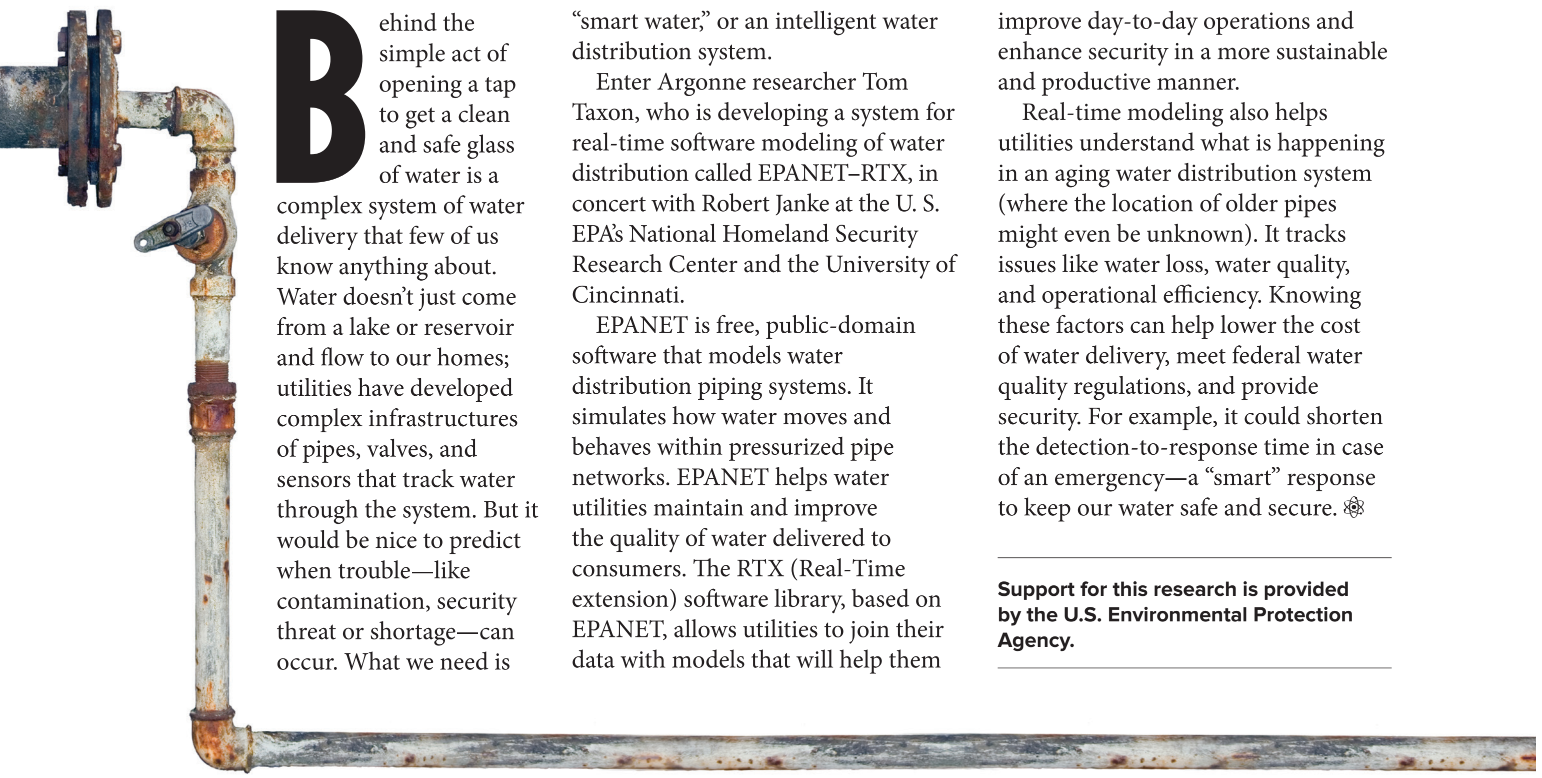
Each new location for the mobile facility comes with its own challenges. To make sure the radar isn't obscured by the tall pines of the mature Finnish forest, one calibration reflector will be mounted atop a tower more than 400 feet (127 m) high by staff at the host site, the Station for Measuring Ecosystem-Atmosphere Relations II, run by the University of Helsinki.

The facility began taking data in Finland on February 1 and will remain there for eight months. After that, the AMF2 is back on the move to a marine platform and then it's getting colder: the following stop is Antarctica.

Researchers launch a sonde balloon to take data over the Pacific Ocean during the AMF2's last deployment.

AMF2 is part of the Atmospheric Radiation Measurement Climate Research Facility, whose mission is to take data around the world to help modelers build simulations of how climate works (see page 26 for more). The campaign is funded by the Department of Energy's Office of Science. Find out more at www.arm.gov.

BUILDING A "SMARTER" WATER GRID | by Else Tennessen



Behind the simple act of opening a tap to get a clean and safe glass of water is a complex system of water delivery that few of us know anything about. Water doesn't just come from a lake or reservoir and flow to our homes; utilities have developed complex infrastructures of pipes, valves, and sensors that track water through the system. But it would be nice to predict when trouble—like contamination, security threat or shortage—can occur. What we need is "smart water," or an intelligent water distribution system.

Enter Argonne researcher Tom Taxon, who is developing a system for real-time software modeling of water distribution called EPANET–RTX, in concert with Robert Janke at the U. S. EPA's National Homeland Security Research Center and the University of Cincinnati.

EPANET is free, public-domain software that models water distribution piping systems. It simulates how water moves and behaves within pressurized pipe networks. EPANET helps water utilities maintain and improve the quality of water delivered to consumers. The RTX (Real-Time extension) software library, based on EPANET, allows utilities to join their data with models that will help them improve day-to-day operations and enhance security in a more sustainable and productive manner.

Real-time modeling also helps utilities understand what is happening in an aging water distribution system (where the location of older pipes might even be unknown). It tracks issues like water loss, water quality, and operational efficiency. Knowing these factors can help lower the cost of water delivery, meet federal water quality regulations, and provide security. For example, it could shorten the detection-to-response time in case of an emergency—a "smart" response to keep our water safe and secure.

Support for this research is provided by the U.S. Environmental Protection Agency.

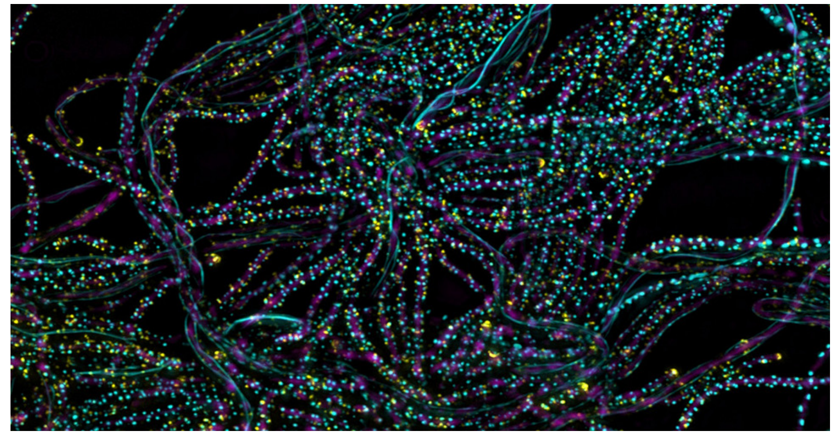
PUMPING OUT PROTEINS FOR DRUG RESEARCH | by Chelsea Leu

Many pharmaceuticals may soon become more effective with the help of new technology developed at Argonne. Developed by Argonne biologists Philip Laible and Deborah Hanson, the kit lets its users easily generate large amounts of membrane proteins.

Membrane proteins are proteins embedded into the surfaces of cells that carry out vital processes necessary to the cells' survival. They act as gatekeepers, controlling which drugs can access the cell. These proteins can make or break a drug, and are so important in disease that more than half of all new drugs in development target membrane proteins.

For researchers to design better targeted drugs, they need to know the structure and functional characteristics of these membrane proteins. But this is difficult, because research requires large amounts and sources are scarce.

Few prior technologies were able to produce membrane proteins in large amounts, in part because membrane proteins are finicky and difficult to work with. They cannot function in water, so the proteins must be protected by a layer of membrane almost immediately after they are generated inside the cell. Otherwise, they will degrade from exposure to an incompatible environment.



Filamentous cells of the bacterium Rhodobacter sphaeroides. *Argonne scientists received an R&D 100 award for using Rhodobacter to develop a new system for growing membrane proteins used in drug discovery research. Image by Sheng-Wen Chui, University of Oxford.*

Laible and Hanson sought to change this. Their new kit, which won a 2013 R&D 100 Award, can produce membrane proteins in unprecedented quantities. "This kit is the first of its kind to be designed specifically for the production of membrane proteins," Hanson said.

The kit has the capability to produce large quantities of protein because it uses Rhodobacter, a type of bacteria that naturally produces many internal membranes. In the kit, membrane proteins are synthesized at the same time as the membranes that house them. This breakthrough shortens the proteins' exposure to inhospitable environments, preventing them from degrading.

This research was supported by the National Institutes of Health.

LICENSE ME! www.anl.gov/technology

IN MEMORIAM: THE REMARKABLE CAREER OF MARGARET BUTLER | by Else Tennessen

Argonne scientist Margaret Butler helps assemble the ORACLE computer with Oak Ridge National Laboratory Engineer Rudolph Klein. In 1953, ORACLE was the world's fastest computer, multiplying 12-digit numbers in .0005 seconds.

Margaret Butler, 89, the first female fellow at the American Nuclear Society and director of the National Energy Software Center at Argonne National Laboratory from 1972-91, passed away last year of natural causes.

Born Margaret Kampschaefer, she attended Indiana University on a scholarship, finding her calling in mathematical statistics and differential calculus. She received her bachelor's degree in mathematics and statistics in 1944 and went to work for the Federal Bureau of Labor Statistics. >>>

After a stint in post-war Germany with the U.S. Army Air Forces, she returned to the United States and was hired at Argonne as a mathematician in the Naval Reactors division. Her job involved using a slide rule to perform calculations for the physicists designing the first prototype submarine reactor.

Later she joined the Reactor Engineering division and began to specialize in the rapidly emerging field of computers, writing mathematical subroutines, systems software, and reactor applications for Argonne-built computers ORACLE and GEORGE and for the first commercially available machine, the UNIVAC, in the mid-1950s. She was named leader of the Reactor Computing Group in 1957.

From 1959 to 1965, Margaret led the Applications Programming section in the laboratory's Applied Mathematics division, where she developed programming teams for reactor, physics, chemistry, biology, and high-energy physics problems. In 1960 she also organized the Argonne Code Center, which would later expand into the National Energy Software Center: the software exchange and information center for the entire U.S. Department of Energy and the Nuclear Regulatory Commission. Butler was the director of NESC from 1972 until 1991. She continued to work at Argonne well after retirement, until 2006.

ARGONNE METEOROLOGIST SCOTT COLLIS NAMED ONE OF POPULAR SCIENCE'S 'BRILLIANT 10' | by Brian Grabowski

Argonne radar meteorologist Scott Collis is one of Popular Science's "Brilliant 10" for his climate and meteorology-focused research. The Brilliant 10 is a group of 10 researchers under 40 who have made revolutionary contributions to their fields.

"This is a well-deserved honor for Scott Collis, who is a leader in Argonne's climate research initiatives," said Argonne division director John Krummel. "Dr. Collis's great work is helping us to better understand how clouds form and move and how changes in clouds can affect the weather across vast distances. His research is vital to Argonne's ongoing efforts to create reliable, useful climate models that will enable us to understand the impacts of changing climate around the globe."

Argonne meteorologist Scott Collis uses instruments to remotely sense cloud and precipitation data. He's also an avid biker.

Much of Collis's work focuses on the areas of climate and meteorology, and he is an expert in the remote sensing of precipitating cloud systems. He currently leads the Atmospheric Radiation Measurement centimeter radar products team at Argonne and is the science lead on the Python-ARM Radar Toolkit (Py-ART), which he invented. This community-based, open-source software project serves as an architecture to allow the scientific community to easily interact with complex remotely sensed data and to contribute back to the project.

Collis's work is funded and supported by the U.S. Department of Energy's Office of Biological and Environmental Research.

NEWS

WARHEADS TO PLOWSHARES | by Louise Lerner

Dismantled Russian warheads are powering lights in America at this very moment.

From right to left: Greg Martin (SAIC, Inc.) reads and Robert Elwood (Nuclear Consultants and Engineers, Inc.) records the serial number of a vessel containing low-enriched uranium hexafluoride. Martin and Elwood are part of a program that has converted the equivalent of about 20,000 nuclear warheads into fuel that provides electricity in America.

There's a decent chance you're reading this by lights that are powered by the remains of Soviet-era nuclear weapons. In fact, today 10% of American electricity comes from dismantled Russian warheads.

When the Soviet Union collapsed, the United States—concerned about the fate of the former Soviet stockpile—struck a deal with the Russian Federation. Under the terms of the 1993 U.S.-Russia HEU Agreement, U.S. nuclear experts monitor Russian plants as they "downblend" the uranium to a lower enrichment that can be burned in reactors in the U.S. and turned into electricity.

At the end of 2013, researchers at Argonne wrapped up their 15-year involvement in the 20-year agreement. Uranium from Russian warheads is currently the source of approximately half the nuclear fuel used annually in the United States.

Natural uranium straight from the mine contains less than 1% of an isotope called Uranium-235. You can "enrich" this natural uranium by adding more U-235 isotopes.

Nuclear warheads need it to be highly enriched (close to 90%), but commercial reactors like the ones in the U.S. run on low-enriched uranium (LEU, less than 5%). In order to get former warheads ready for commercial power reactors, then, scientists have to reduce the amount of U-235.

This process begins deep in the Russian countryside, where Russian technical specialists carefully dismantle the warheads and extract the HEU. Engineers from Argonne and other national laboratories watch as this uranium metal is carefully burned to convert it into an oxide form. After it has cooled, the material is chemically cleaned and converted into uranium hexafluoride gas.

In gas form, the HEU is blended with very low LEU gas, resulting in a product that is less than 5% U-235. Next, the uranium goes into shipping containers; as it cools, it changes into a liquid and then into a solid. After it arrives at the Paducah Gaseous Diffusion Plant in Paducah, Kentucky, it is shipped onward to American companies that fabricate nuclear fuel for U.S. nuclear power plants—like the 11 Illinois nuclear reactors that generate most of Chicago's electricity.

All the while, experts from Argonne, other national labs, and the National Nuclear Security Administration monitor the activities in Russia to make sure all the processes took place as agreed upon.

Argonne engineer Cynthia Boggs managed DOE's Permanent Presence Office at one Russian facility. "We witness the processing of the uranium and conduct nondestructive assays to make sure the uranium is accounted for and all the steps went as planned," she said. She and other DOE teams rotated in and out of Russia on one- or two-month shifts.

The program has been a resounding success. "When the program ends, we will have converted 500 metric tons of uranium," Boggs said. 500 metric tons of HEU is equivalent to about 20,000 nuclear warheads.

> Nuclear energy provides about 20% of U.S. electricity—even more if you're in a state like Illinois, which has 11 reactors.

Funding for this program is provided by the Department of Energy's National Nuclear Security Administration.

www.ne.anl.gov

BUGS FOR A BETTER WORLD | by Meghan Cetera

X-ray science taps bug biology to design better materials and reduce pollution

Bug spray, citronella candles, mosquito netting—most people will do anything they can to stay away from insects during the warmer months. But those creepy crawlers we try so hard to avoid may offer substantial solutions to some of life's problems.

Researchers using the advanced X-ray technology at the Advanced Photon Source were able to take an inside look at several insects, gathering results that go beyond learning about insect physiology and biology. What they found could provide a blueprint for a material used for artificial ligaments, a chemical-free way to protect crops from insects, and a new insight on how human muscles function.

Caddisflies

Most people know the caddisfly as the artificial bug on fly fishing lures. But few know that real caddisflies spin an adhesive silk underwater to build nets to capture food and provide protective shelter. The chemical structure of the silk allows it to adhere to most substances underwater.

"It is really not much stronger than super glue, but try to put super glue in your bathtub without it ever getting a chance to dry," says Jeff Yarger, professor of chemistry, biochemistry, and physics at Arizona State University and author of a study that examined caddisfly silk.

Designing a synthetic version of the silk could create an adhesive used for liquid stitches. But even more valuable is its potential use as the first artificial human tendons and ligaments. The fly silk's long fibers make it behave a lot like collagen material used in connective tissues, and its ability to adhere in wet conditions make it viable as an internal implant.

To understand what makes this material both waterproof and collagen-like, Yarger and his team had to examine the biopolymers, tiny molecular structures that serve as the building blocks for the silk, using the APS.

The crystalline structures in the silk are so small that Yarger says it is impossible to look at the molecular makeup of the silk with conventional X-rays. "But the synchrotron analysis at the APS allows us to do this," Yarger said.

They found that at the molecular level, caddisfly silk differs greatly from other terrestrial spun silks such as those from spiders or silkworms. Caddisfly silk is phosphorylated, meaning that after the amino acid chain that makes up the silk is created, phosphate molecules bond to the chain. Phosphates can act as bonding agents and are already used to make some water resistant paints.

"The next step is to see how we might be able to mimic nature with this new motif we discovered," Yarger said.

Grasshoppers

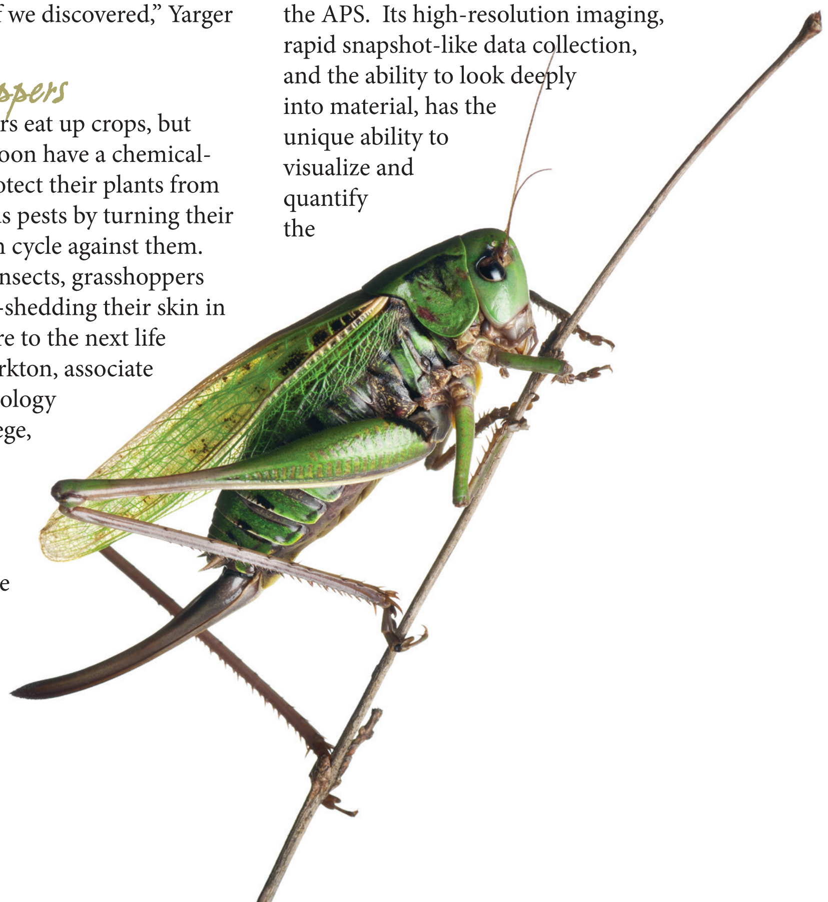
Grasshoppers eat up crops, but farmers may soon have a chemical-free way to protect their plants from these voracious pests by turning their natural growth cycle against them.

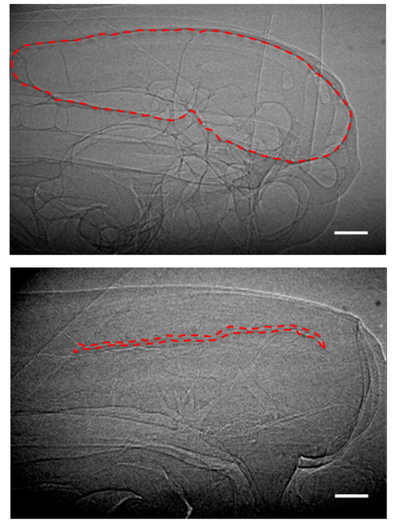
Like many insects, grasshoppers have to molt—shedding their skin in order to mature to the next life stage. Scott Kirkton, associate professor of biology at Union College, observed that just before molting, a grasshopper's insides become essentially too large for its outer shell. This compresses the grasshopper's tracheal system and makes it difficult for it to breathe. As a result, the team saw a reduction in the number of jumps per minute for the grasshoppers about to molt versus those that were not, suggesting that a compressed respiratory system reduces mobility.

From this, Kirkton hypothesized that a lack of oxygen delivery to the grasshopper's body is a trigger for molting. Storing grains or crops at low oxygen levels would limit the oxygen the insects get and trigger molting. The resulting stunted growth cycle would create petite pests with petite appetites, leaving more crops to make their way to supermarket shelves.

"A faster development time would produce smaller adults with reduced appetites and reduce the overall lifespan of the insect," Kirkton said.

The key to discovering the connection between oxygen and the molting cycle came from Kirkton's use of the phase-contrast beamline at the APS. Its high-resolution imaging, rapid snapshot-like data collection, and the ability to look deeply into material, has the unique ability to visualize and quantify the functioning respiratory system of a live insect in real time.





These two images compare the air sacs of early and late-stage grasshoppers. The dotted lines outline the air sacs, which researchers found shrink significantly just before molting. Researchers hypothesize that less oxygen triggers molting—so one possible insect control method would be to store grain at low oxygen levels to stunt grasshopper growth cycles. Image: Scott Kirkton.

Kirkton recently published his look at the respiratory system of the American grasshopper during the period right before molting. While Kirkton said that more research needs to be done, he thinks that this finding is applicable to a wide range of insects, showing promise for a universal and chemical-free pest control method.

Scientists are using X-rays to steal insects' secret formulas to design our own materials.

Moths

Although few gym rats want to admit it, whispery moth wings and bulging human biceps aren't that different. What we learn from them can teach us more about human muscle mechanics, which could potentially improve physical therapy treatments and help us further understand diseases that attack the muscular system.

Logistically, looking at the protein structures within a moth's muscle cells is no easy task. To conduct this research, Tom Daniel, professor of biology at the University of Washington, had to seek out Thomas Irving, who is director of the Biophysics Collaborative Access Team at the APS. Daniel said it was Irving's wizardry—his expertise in biophysics and experience "hooking up insects to gizmos"—that helped Daniel pull together the experiment.

The team glued a moth by its thorax to a support structure, attached a series of electrodes to its flight muscles to trigger its wings to beat at a rapid pace, and then used the APS to examine the molecular structure of its muscle movement in real time. The results shed light on more than the mechanics of moth flight; they may redefine our understanding of how our own muscles function.

When a moth flaps its wings, a tug-o-war is happening at a molecular level. Filaments of thick proteins called myosin tug on thinner filaments of actin to contract a muscle strand, then detach to lengthen the strand. When connected and contracting, the filaments form a rubbery lattice-type structure that stores elastic energy. It's like a microscopic trampoline, waiting for something to bounce on it. So when a muscle is contracting, it is acting more like a spring waiting to release its energy than a motor.

Using the APS, Daniel and his team observed that the top of the moth's thorax, which is the muscle that makes the wings move, was cooler on top than on the bottom. Interestingly, the filaments stayed connected for longer and maintained the rubbery structure for longer in the cooler regions. The elastic energy stored in these cooler regions is released at the end of the lengthening or shortening phases of the muscle. This allows the moth to fly without expending a large amount of energy.

Daniel said that the presence of elastic energy was not a surprise. The energy cost of rapidly accelerating and decelerating wings during flight is enormous and no insect would be able to maintain that kind of energy output.

What was surprising, though, was the implication that this feat could be based on temperature differences. Because moth muscle is molecularly similar to a human's, this may mean that elastic energy serves a much larger role in our muscle function than previously believed—and helps us gain a deeper understanding of how muscle works.

Use of the APS by all of the research groups was supported by the U.S. Department of Energy's Office of Science. The caddisfly research was supported by the Department of Defense's Air Force Office of Scientific Research, the National Science Foundation, and the National Institutes of Health. The grasshopper research was supported by the Union College Faculty Research Fund, the National Science Foundation, and the National Institutes of Health. The moth research was supported by the National Science Foundation, the National Institutes of Health, and the University of Washington.

www.aps.anl.gov

A PLUG FIT FOR EVERY CAR | by Carolyn Steele

Engineers Jason Harper (left) and Daniel Dobrzynski at work in Argonne's Electric Vehicle Interoperability Center, which seeks to create worldwide standards for electric car plugs and charging stations.

If you can't find a charging cable for your cell phone, it's an inconvenience. But what if you're away from home and can't find a charging station compatible with your electric vehicle?

Over the last few years, many cell phone ports have been standardized so a large portion of chargers are interchangeable, but right now, there aren't any equivalent standards for electric vehicle charging stations. Last May, Argonne National Laboratory opened the Electric Vehicle Interoperability Center to help solve this problem. The goal of this state-of-the-art facility, in collaboration with the European Commission's Joint Research Centre, is to help ensure that any electric vehicle can safely charge anywhere, anytime.

Jason Harper, who has been involved in Argonne's research on plug-in electric vehicles for several years, explains that the collaboration benefits everyone. "Argonne has literally written the standard for testing plug-in electric vehicle and charging station interoperability," he said, "and the Joint Research Centre brings to the table an expansive experience with smart grid simulations and demonstration projects."

Since charging rate, the type of current (AC/DC), and the electric vehicle's plug size and shape vary from station to station—and charging requirements vary from car to car—it's currently hard for electric vehicle owners to know which station can safely charge which vehicle. The EV Interoperability Center staff has already been actively involved in developing new charging technologies, establishing and standardizing testing procedures for these technologies, and identifying gaps in charging technology.

Right now, the EV Interoperability Center is working with the Joint Research Centre to make sure even cars from different countries can charge their batteries at the same stations. "Global standardization allows seamless operation of plug-in vehicles across international borders. It also allows multinational corporations to manufacture one component that can be used anywhere in the world," says Harper.

All of this means that if you drive an electric car, you're a lot less likely to get stranded somewhere far from home when the battery runs out.

Another benefit of this research involves the smart grid—the network of electricity providers and physical components that gather and process information, keep electric plants running, and bring your electricity to you. Electric utility companies and network operators need to be able to "future-proof" their systems in order to keep things running smoothly. To do this, they need to be able to predict the future demand for electricity.

In the future, Harper explains, "with the rollout of smart grid technologies, such as smart meters and sensors that allow two-way communication, you can mitigate the impact of electric vehicles on the grid while still using the existing infrastructure—transmission lines, transformers, etc."

Someday, EVs could serve as parts of the grid: communicating with the smart grid to charge in off-peak hours or sending energy back to the grid, which helps offset heavy loads on the grid. Making the grid more stable is good for everyone, because it allows us all to have the electricity we want—when and where we need it.

This work was supported by the Department of Energy.

Harper won a 2014 Federal Lab Consortium Award for Excellence in Technology Transfer for commercializing an Argonne-designed charger that lets owners charge vehicles via direct current (DC), which can charge a car in under 15 minutes (compared with six to eight hours for alternating current, AC).

NEWS

THE FUTURE OF BATTERIES: Q & A WITH THE DIRECTOR OF THE NATIONAL LABORATORY BATTERY HUB

by Ben Schiltz

A scientist at Johnson Controls performs battery research at the company's Meadowbrook advanced battery center in Holland, Michigan. Johnson Controls is one of several major U.S. battery manufacturers that form the Joint Center for Energy Storage Research. Image by Johnson Controls.

Everywhere you look, you see lithium-ion batteries. They're in your laptop, your cell phone, your power tools, maybe even your car. Lithium-ion battery research accounts for about 95% of all battery research and development, which has resulted in countless improvements to the technology. But lithium-ion batteries can only go so far.

The Joint Center for Energy Storage Research, or JCESR, based at Argonne, is a partnership of five national laboratories, five universities, and four private-sector partners. The goal is to develop technologies that take batteries beyond lithium-ion—to create storage systems with five times the energy density at one-fifth the cost within five years.

Currently a year into JCESR's five-year charter, George Crabtree, director of JCESR, talks about the vision, goals, and challenges on the leading edge of battery research.

Q: What is your vision for JCESR?

George Crabtree: Our vision is to transform two of the biggest energy sectors in the U.S., and those are transportation and the grid. We want to transform transportation by electrifying it. With better batteries, we can power more cars and trucks with domestic electricity rather than foreign oil. For the grid we want to increase the amount of wind and solar energy to at least 20% of the overall electricity supply. In order to do that we will need to more efficiently store the energy that is generated by these variable energy sources. JCESR is working on the breakthrough technologies that will make these two transformations happen.

Q: What are JCESR's goals?

Crabtree: We want to achieve three legacies that will change the battery R&D landscape. The first one is to create a library of fundamental knowledge about how the materials and phenomena of energy storage work at the atomic and molecular level. We understand many of the phenomena related to lithium-ion batteries. But beyond lithium-ion is a wide horizon of virtually untapped potential, where we will achieve the breakthroughs and transformational goals we are pursuing. We need discovery science to explore this horizon, building the knowledge base that will enable the transformational batteries that we seek.

The second legacy is using this fundamental knowledge to deliver two rechargeable energy storage prototypes: a compact high-performance battery for the car and a large-scale battery for the grid. Our third legacy is embedded in the other two: we will introduce a new paradigm that, for the first time, combines discovery science, battery design, research prototyping, and manufacturing consulting into one highly interactive organization. This strong interaction across the entire R&D spectrum from discovery to prototyping to commercial manufacturing will accelerate the pace of discovery and innovation and shorten the time for commercialization of new ideas. It is exactly what the U.S. needs to develop a commanding competitive edge in battery science and technology.

Q: What's one of the ways you are accelerating discovery?

Crabtree: In the science community, we typically share information by publishing papers. So, after the information is created, it takes about a year for the paper to be peer-reviewed, for it to appear in the literature, and for someone else to read and appreciate it. Then the recipient will think about it for a while before starting to act on it. By the time he or she starts a program to move

the science to the next level or to apply the information to new technology, there could be a two-year delay.

In JCESR there is no delay. Results are communicated and adopted by other groups within the JCESR team instantaneously, well before the cycle of publication and incubation has time to act. This is one of the primary ways we increase the pace of discovery and innovation.

Q: How is JCESR research different from other battery research?

Crabtree: Typical battery R&D produces only incremental advances. Lithium-ion batteries, for example, will be improved by only a few percent per year by getting better performance from a particular battery component, often the cathode. In JCESR, we are doing something that is totally different. We're not incrementally improving an existing technology: we are inventing a whole new technology. So we are putting together the three components of the battery, the anode, the electrolyte, and the cathode, in ways that have never been done before.

In some cases, there may be a new idea or a certain component that shows promise. But in order for the new idea to work, it has to be used in a battery system where all the components within that system work together properly. So it's very important to take a systems approach and invent the battery from the bottom up: make it work as a system rather than simply improving one component of a system that already exists. So this is a different animal completely, and you need a different approach.

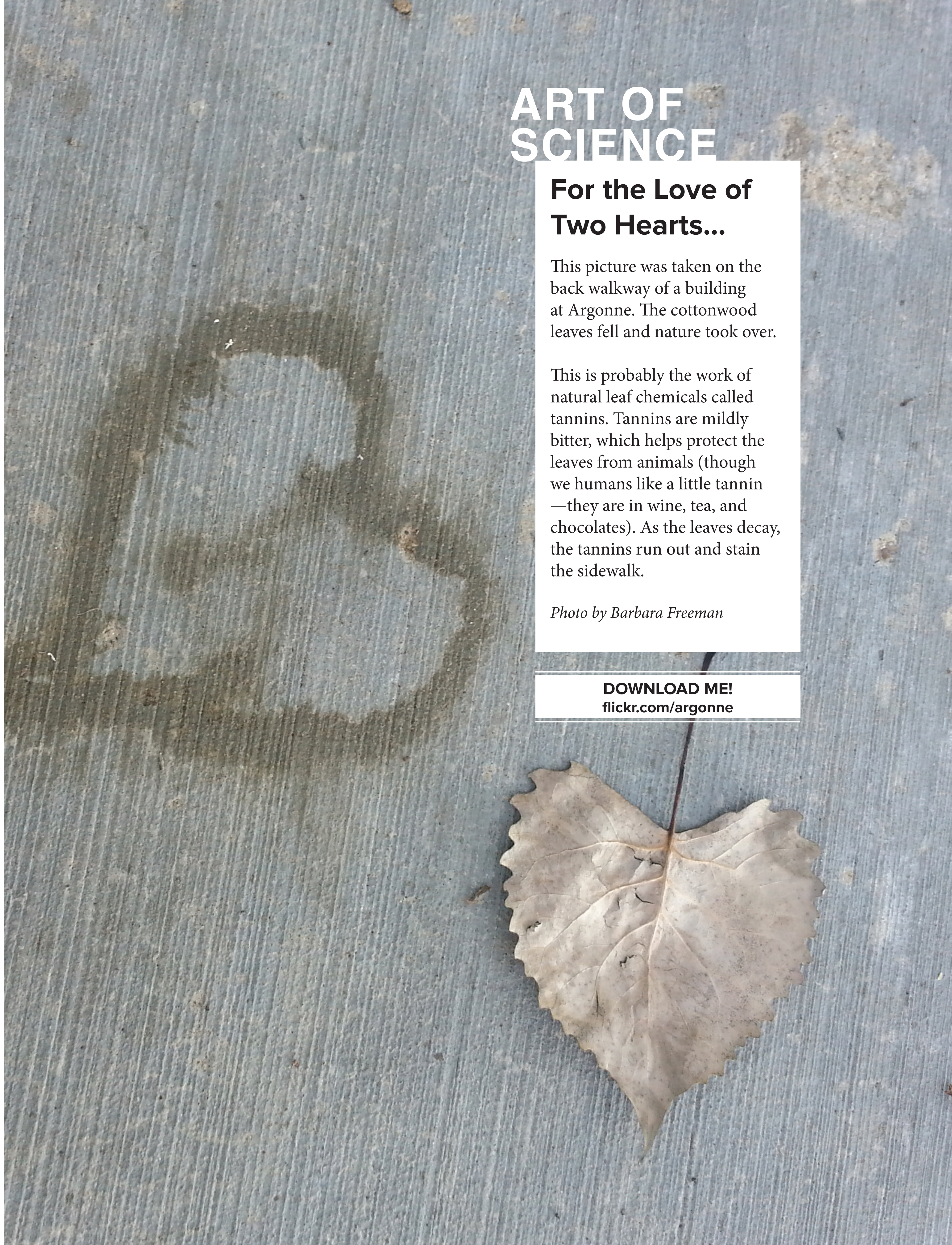
Q: What scientific challenges has JCESR faced?

Crabtree: One challenge is the complexity of the beyond lithium-ion space. First, we have three battery components; an anode, an electrolyte, and a cathode. Then, for the anode there are three or more types; there are two kinds of electrolytes, liquid and solid; and there are at least three kinds of cathodes. If you start trying to mix and match these, you quickly realize the number of possibilities is huge, and it's quite impossible to build and compare all of them.

That's one of the reasons technological modeling, building the battery on the computer, is so valuable. Computer modeling enables us to simulate a host of materials for the different battery components, many more than we can reasonably test. The range of things you can do on the computer without having to do it in the lab has increased dramatically.

In addition, at JCESR our scientists use their expert judgment to determine where the best research opportunities are for breakthrough discoveries. And they don't do that in a vacuum. JCESR scientists are informed by all of the fundamental science that JCESR is creating for our first legacy. Then they apply that knowledge to determine how a battery composed of these new components would work. At the moment, we are facing many, many conceptual options for putting a battery together. We need to filter that space both in the computer and in the laboratory, and after a couple of years we will have a much broader base of fundamental knowledge to work with and we can start to visualize the kind of a battery that will meet our goals.

Lawrence Berkeley National Laboratory scientist Anna Javier prepares a sample. Berkeley Lab is one of several major U.S. research institutions that form the Joint Center for Energy Storage Research. Image: Lawrence Berkeley National Laboratory.



ART OF SCIENCE

For the Love of Two Hearts…

This picture was taken on the back walkway of a building at Argonne. The cottonwood leaves fell and nature took over.

This is probably the work of natural leaf chemicals called tannins. Tannins are mildly bitter, which helps protect the leaves from animals (though we humans like a little tannin —they are in wine, tea, and chocolates). As the leaves decay, the tannins run out and stain the sidewalk.

Photo by Barbara Freeman

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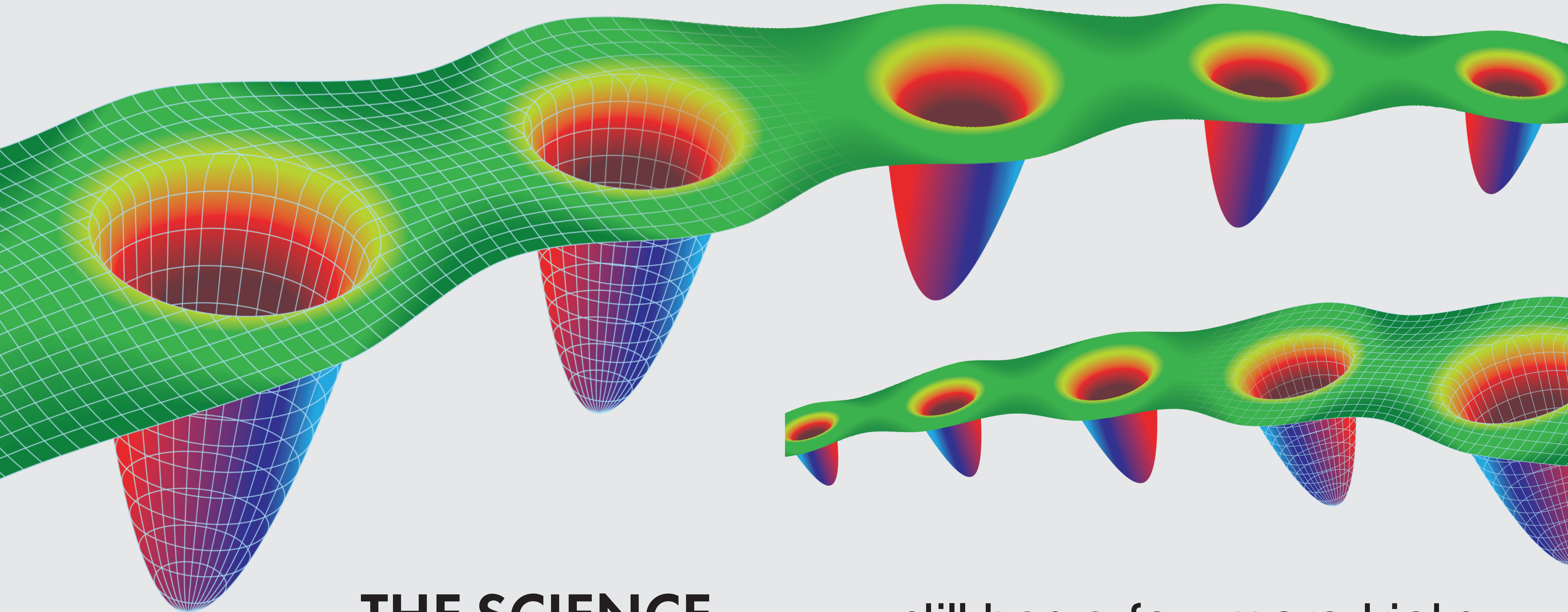


THE SCIENCE THAT STUMPED EINSTEIN...

by Louise Lerner

...still has a few more tricks

In 1908, the physics world woke up to a puzzle whose layers have continued to stump the greatest scientists of the century ever since.

That year, Dutch physicist Kamerlingh Onnes cooled mercury down to -450° Fahrenheit and discovered—to his astonishment—that it could conduct electricity perfectly. And then for the next 50 years, no one could explain why.

Ordinary wires, even really good ones like copper, lose up to a third of the electricity they carry over long distances. But these materials, called superconductors, don't lose any energy. Ever. You could start a current in a loop of superconducting wire and it would circle around, theoretically, forever.

This phenomenon confounded the greatest minds in physics. From papers, lectures, and the reports of former students, we know that Einstein spent a lot of time thinking about it. Everyone did; it was one of the great unanswered questions, even as scientists unraveled other mysteries like the structure of atoms and the age of the universe.

But Einstein never came up with an answer. Neither did the great quantum physicist Richard Feynman, or any of the other luminaries: Niels Bohr, Lev Landau, Werner Heisenberg, Maria Goeppert Mayer. Physicist Felix Bloch crankily suggested a new theory: "Superconductivity is impossible."

SUPERCONDUCTORS & SUSTAINABILITY

Scientists are particularly interested in using superconductors in wind turbines. A wind turbine's capacity is limited by size, which in turn is limited by how heavy the engine is. An engine based on superconductors could significantly reduce that weight and boost wind power capacity.

In their labs, scientists continued to discover more and more superconductors, but the new materials didn't seem to follow a pattern. Some were pure elements; some were alloys. Even more oddly, it turned out that normally good conductors, like copper, were worthless as superconductors. And why did they all have to be cooled down to near absolute zero to work?

"All of the great minds had a go at figuring out the theory behind superconductors," said Argonne Distinguished Fellow and materials scientist Mike Norman. "But no one had anything good until 1957."

That year, a trio of University of Illinois physicists published an explanation called BCS theory (for Bardeen, Cooper, and Schrieffer) that explained the odd behaviors. Satisfied, scientists shelved it away under "solved mysteries."

That's why no one was prepared when, in 1986, a team from a Swiss laboratory announced it had found a superconductor that worked at much warmer temperatures—up to -280°F. Although to most of us that number sounds positively frigid, for scientists studying superconductors it was a thunderclap.

BCS theory did not explain this phenomenon. Physicists were stunned. They went back to the drawing board, and that's where they still are today, a quarter-century later. In the meantime, we've explained why the universe is expanding, documented what we're made up of down to the tiniest subatomic particles, and landed a robot on Mars; but we can't explain why these new superconductors work.

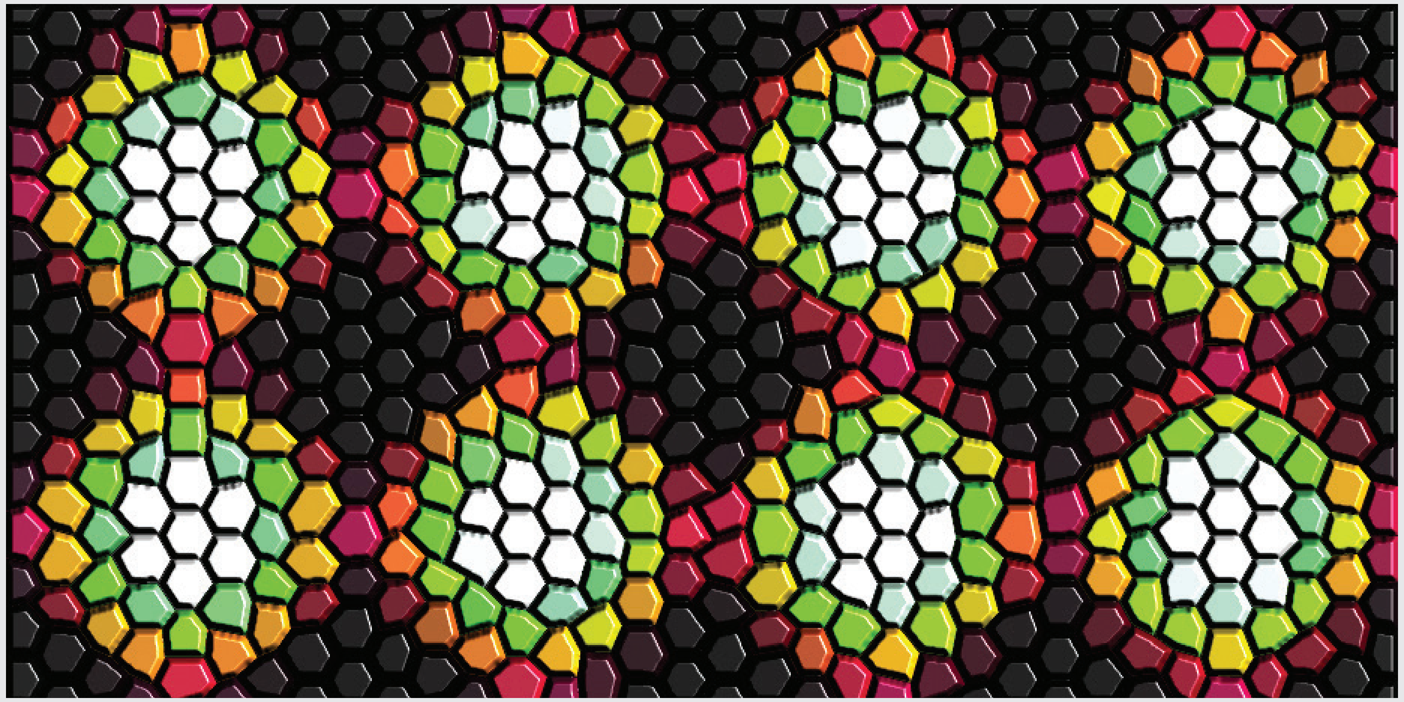
This hasn't been for lack of trying—after all, superconductors are enormously useful. Their unique properties let scientists invent technologies we'd never have otherwise. So far, they've given us cell phone tower signals, Maglev trains, and an unprecedented window into how our bodies work: they are an integral part of MRI scans to diagnose and study everything from cancer and multiple sclerosis to depression and schizophrenia.

As useful as superconductors are, they have a lot of limitations, which is why it remains important to figure out how they work. The biggest problem is that superconductors still have to be extremely cold to work. That means that if you want to put one in, say, an MRI machine or an engine, you also have to build in complex, expensive ways to cool it down. The -280° F superconductors were a big deal because you can cool them down to that temperature with liquid air, which is much less expensive than liquid helium.

But if we could craft a material that would superconduct at close to room temperature, the possibilities strain the imaginations of a roomful of engineers. Room-temperature superconductors would represent an unbelievable advance for energy: imagine wires stretching across America without ever losing any electricity, or engines that are close to 100% efficient because they lose much less energy as heat. (Ordinary engines are at best about 50% efficient—that's why they get so hot.) Superconductors could make windmills cheaper by reducing the turbines' weight. They could form the basis of ultrafast computer processors.

A RAY OF LIGHT ON AIRPORT SCREENINGS

In 2007, Argonne scientists discovered that applying voltage to high-temperature superconductors yields a kind of light called Terahertz radiation, or T-rays. (T-rays lie in between infrared and microwaves on the light spectrum). They are useful in a number of applications—in cancer detection and in a non-harmful way to screen for explosives at airports, notably—but the current equipment to generate T-rays is bulky and expensive. Argonne scientists are studying whether superconductors could work as an alternate solution to generate T-rays.



This mosaic represents the distribution of superconductivity around holes (white) in a thin sheet of superconducting film. Green indicates strong superconductivity. Further away from the holes, the superconductivity decreases (yellow, red, and finally black, where the material is densely populated with vortices that interfere with superconductivity.) Image by Vinokour et al.

All this is a small taste of what superconductivity could promise us, if we could master it.

While BCS theory explains the behavior of the original low-temperature superconductors, the theory behind the so-called "high-temperature superconductors" remains stubbornly elusive, and developing one is still one of the Holy Grails of physics.

"I've met people from all kinds of specialties, from string theorists to metallurgists, who all have their own pet theories about what will really prove to be the key," Norman said.

Superconductivity has such high practical potential that the U.S. Department of Energy established a special institute to study it called the Center for Emergent Superconductivity, an Energy Frontier Research Center headed by Brookhaven National Laboratory with Argonne and the University of Illinois at Urbana-Champaign as partners. The program studies superconductivity with the triple goal of studying superconductor theory, making new superconductors, and improving current superconductor technology.

DID YOU KNOW?

Argonne physicist Alexei Abrikosov won the 2003 Nobel Prize in Physics for his theory of vortices in superconductors.

The reason the field is so obsessed with theory is that it's difficult to make breakthroughs without a fundamental understanding of how the electrons in a superconductor behave. "A lot of it is still serendipity," Norman said, "which is not where we want to be."

"It's become clear that superconductors involve a highly correlated electron system," said Argonne physicist Wai Kwok. "It's what we call a many-body problem, which makes it hard to model. We don't have the math to do this yet."

We do have the theory more or less worked out for the first wave of superconductors, called conventional superconductors. Electricity is really just electrons moving around, so scientists had to figure out why they got around so easily in these particular materials.

The next few paragraphs contain more than Einstein ever knew about superconductors.

You probably know that as the temperature rises, atoms get more and more excited and bounce around all over the place. But at close to absolute zero, atoms get very, very still. At these very cold temperatures, the atoms in the superconductor form a stiff lattice. An electric current sends electrons running through the lattice. As they sail through, the positive protons in the lattice are a tiny bit attracted to the negative electrons, so they move slightly toward the electron. The resulting increased positive charge pulls the next electron forward a little faster. Imagine dolphins riding the wave created by the wake of a ship. In ordinary materials, electrons bounce off the lattice and are lost as heat. But the wake effect helps the electrons move along in an orderly fashion.

Unfortunately, this fragile effect breaks down very easily as the material gets warmer. So we know this phenomenon can't explain unconventional superconductors, the kind that work at much higher temperatures and thus are used for most practical superconductor applications.

Besides needing to be very cold, two other properties make superconductors hard to work with. First, if you bend them too much, the internal grains and crystals become so misaligned that they won't superconduct anymore.

Scientists hope to find a superconducting material that is isotropic—which means that it will continue to superconduct even when it's twisted into a coil, a necessary condition for use in engines and other tight spaces. "All kinds of cables and electromagnets are made by twisting," Norman said.

The problem is that magnetic fields affect the performance of a superconductor. If a scientist tries to apply a magnetic field, the superconductor will repel it by creating its own field that runs exactly counter to it. If the magnetic field is too strong, the superconductor will throw up its hands and stop being a superconductor altogether.

Furthermore, the superconductor's capacity changes depending on whether the magnetic field is parallel or perpendicular to it. This is particularly problematic when trying to use superconductors in engines, since the magnetic field orientation can change with each turn of the motor. So researchers want to figure out a way to keep a superconductor working smoothly even while there's a magnetic field in the vicinity.

One of Argonne's principal superconductivity studies focuses on the reason why magnetic fields impair the functioning of superconductors. "When you apply a magnetic field to a high-temperature superconductor, these little pockets of nonsuperconductivity called vortices form," said Kwok. "They start out as just a few nanometers across, but get bigger as the temperature increases. Eventually, these vortices overlap and eliminate superconductivity altogether."

Likewise, when you increase the magnetic field, the number of vortices increases. When you apply an electric current to such a superconductor, it pushes the vortices around.

The moving vortices create a voltage across the superconductor, causing electrical resistance and energy loss. The more the vortices move, the worse the problem gets. So Argonne scientists want to pin them down.

Kwok and his team knew that vortices like to sit at defects in the material. So they created artificial defects by bombarding the superconductor with lead ions. "The lead ions act like cannonballs, punching through the superconductor and leaving column-shaped defects behind," Kwok said. "These attract the vortices and help make them stay put, which significantly improves the superconductor's current capacity."

Elsewhere at Argonne, Distinguished Fellow Valerii Vinokour took a different approach. He and his colleagues worked with extremely thin superconducting wires that are just 50 nanometers across. (For scale, your fingernails grow at the rate of one nanometer per second.) They are so thin that only one row of vortices can fit on them.

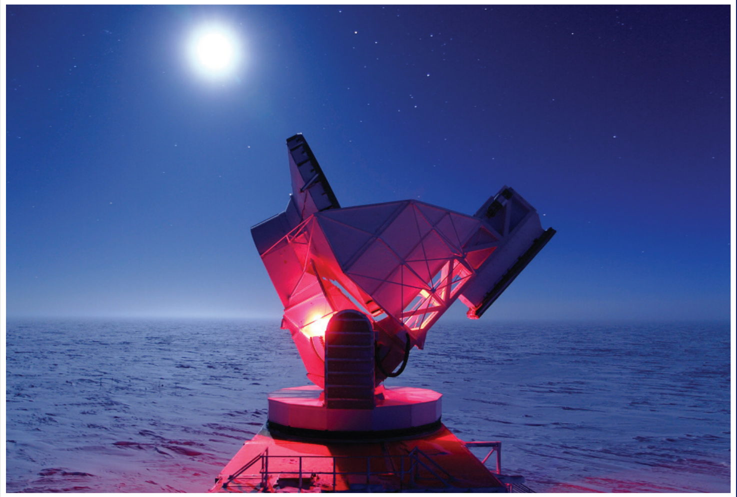
Then they applied an external magnetic field—and found that the material stayed superconducting at temperatures and field strengths where no one had been able to pin vortices before.

These advances are useful for several industry applications—for instance, Kwok and his team work directly with industrial partners to improve their superconductivity-based products, such as superconducting wire.

Kwok and others at Argonne, along with their industrial partners, are continuing to explore a variety of approaches. One interesting angle involves exploring nanoparticles as a way of creating customizable defects. Nanoparticles are good at self-assembling, so one idea is to have them assemble into columns that would serve as defects to pin the vortices.

> Handy things like MRIs, the web, and GPS satellites all owe their gears and genes to physicists and other scientists studying fundamental properties of matter.

The science that stumped Einstein is now 112 years old and counting, and the Holy Grail is still waiting for someone to claim it. But the physics world thrives on challenges, and our modern world relies on the technology that physics creates to solve those challenges; handy things like MRIs, the web, and GPS satellites all owe their gears and genes to physicists and other scientists studying fundamental properties. Superconductors no doubt have a lot more to give the world—if we can tease out their secrets.



At the South Pole Telescope, scientists measure cosmic radiation still traveling across space from the early days of the universe—using superconductors. Image by Daniel Luong-Van, National Science Foundation.

Research described in this article has been funded by the Center for Emergent Superconductivity, an Energy Frontier Research Center funded by the U.S. Department of Energy.

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SEEING BACK IN TIME WITH SUPERCONDUCTORS

For Argonne physicist Clarence Chang, looking backward in time to the earliest ages of the universe is all in a day's work.

Chang helped design and operate part of the South Pole Telescope, a project that aims a giant telescope at the night sky to track tiny bits of radiation that are still traveling across the universe from the period just after it was born.

"Basically, what we're looking at is the afterglow light of the Big Bang," Chang said.

In the wake of the Big Bang, all the matter in the universe was just hot, dense particles and light. As the universe got older, it began to spread out and cool down over time, and the intense light from that period traveled across space. It's still traveling, hitting us all the time, and it has a very distinct radiation signature. "We call this the Cosmic Microwave Background, and it is essentially a snapshot of the universe as it looked about 400,000 years after the Big Bang," Chang said.

There's still a lot we don't know about the makeup of the early universe. Particularly mysterious are the dark matter and dark energy that appear to make up 95% of the universe, but about which we know very little. Mapping the Cosmic Microwave Background can shed some light on these dark forms.

The Cosmic Microwave Background photons are absorbed by water, so in order to catch them, you need a very dry, flat and preferably cold space, which narrows it down to just two locations on Earth. One is the Chilean mountains, where we have a different sky mapping project underway, and the other is the South Pole.

The South Pole telescope is more than 30 feet across; Chang and colleagues at Argonne helped build its camera. At the core of the detector technology is an extremely thin superconducting film. Although superconductors can carry an electrical charge perfectly, they are extremely sensitive to changes in temperature. When thermal radiation from the Cosmic Microwave Background hits the camera, it heats the material up slightly, which changes the conductivity of the film. This lets physicists record the energy coming from that particular part of the sky.

"So far we've mapped about 2,500 square degrees of the sky," he said, "so there's just 37,500 to go."

by Jared Sagoff

CITY OF THE BIG DATA

Chicago turns to technology to address urban challenges.

Major cities have major problems, like overcrowding on public transit, blighted neighborhoods, and limited resources at public hospitals. To solve these problems and others, public agencies have begun to take a new approach: using extensive data analysis for solutions to some of the hardest community challenges.

As part of a collaboration between Argonne and the University of Chicago, a group of young researchers—most either still in or just out of college or graduate school—began this past summer to explore the use of data analytics to address thorny social and economic issues.

Held for 12 weeks last summer in an immense lofted office on the 23rd floor of a downtown high-rise, the Eric and Wendy Schmidt Data Science for Social Good (DSSG) summer fellowship was initially conceived by Rayid Ghani, who had spent the previous 18 months as the chief data scientist for President Obama's re-election campaign. With institutional backing from the University of Chicago and funding from the MacArthur Foundation and Google executive chairman Eric Schmidt, DSSG quickly assembled a crack team of young computational scientists and statisticians.

"For years, people have associated the term 'data analysis' with the hard sciences, like astrophysics or genomics," Ghani said. "Given the recent advances that have been made on the technological side, we noticed that there was a big opportunity for us to extend similar datasets and analytics into the social space as well."

At DSSG, 40 fellows teamed up into a dozen groups of three or four and partnered with a public agency or nonprofit group in the city.

The patterns and trends that DSSG researchers extract from their enormous datasets will soon give policymakers the ability to proactively tackle complex sociological and economic problems.

These partner organizations ran the gamut from social service providers to the Chicago Transit Authority. Even though these organizations have different missions and provide unrelated services, DSSG fellows believe they can use data mining to identify creative solutions to systemic problems.

"Our goal involves applying these computational tools to make policymaking, investments, and interventions all more proactive," said Argonne computational scientist Charlie Catlett, who led Argonne's involvement with the project. "The more we begin to understand these kinds of systems by doing this research, the more easily cities can get ahead of problems."

The transformation of Chicago from its current self to the kind of Windy City envisioned by DSSG faces several immediate obstacles, especially when it comes to introducing the project to industries unfamiliar with data analytics. "Although the groups we're working with are very interested, they often don't know what's possible with the data they're generating," said Juan-Pablo Velez, director of communications for DSSG and a former data journalist with the Chicago News Cooperative.

"The process starts even before you look at the data for the first time," he said. "If you don't understand the context in which the data is produced, you can't communicate with the people who will hopefully be implementing the kinds of policies and changes you will eventually recommend."

"It's a human challenge as much as—if not more than—a mathematical one," he said.

Slicker Cities

One group of DSSG fellows partnered with the Chicago Transit Authority to study the effect of bus scheduling on ridership. Many residents who depend on buses are familiar with what is popularly referred to as "bus bunching," in which two or three buses arrive at a stop in rapid succession after what feels like a nearly interminable wait. By analyzing ridership data collected from tens of thousands of different bus trips all around the city, one of the DSSG teams hopes to more efficiently schedule and route buses to improve service and overall rider satisfaction.

By analyzing ridership data collected from tens of thousands of different CTA bus trips all around the city, teams of data analysts hope to more efficiently schedule and route buses to avoid "bus bunching."

Discoveries with bus transit might also have implications for other types of urban transportation. Last June, the City of Chicago unveiled a new bike sharing program called Divvy, in which riders can rent bikes and dock them at hundreds of different locations around the city. One DSSG team used the data from bike sharing programs in other U.S. cities to anticipate and hopefully avoid situations in which stations are either completely full (leaving no available docks) or completely empty.

In one of the most complex and intriguing projects, several DSSG fellows spent the summer working with representatives from the Cook County Land Bank Authority. Established in the aftermath of the housing crisis, the Land Bank reacquires foreclosed or vacant homes in and around Chicago and then either demolishes, rents them at below-market prices, or repurposes them.

But because some blighted neighborhoods contain many more foreclosures than the city could afford to buy, the Land Bank turned to DSSG for help developing a tool to identify the most attractive or vulnerable properties based on neighborhood statistics like the acreage of nearby parks and crime rates.

The patterns and trends that the researchers at DSSG extract from their enormous datasets will soon give policymakers the ability to proactively tackle complex sociological and economic problems. "We're going to start seeing a real impact in the public domain," Catlett said. "There's going to be an explosion of applications for 'friendlier' cities."

DSSG has attracted the attention of Chicago Mayor Rahm Emanuel and his staff. Last August, Catlett hosted a meeting at DSSG's offices with former City of Chicago Chief Technology Officer John Tolva and a dozen policy officials from the Mayor's office. "When I heard what Rayid and Charlie were doing here, I knew that we were really just touching the tip of the iceberg," Tolva said. "There's so much potential, and I think we as a city are really waking up to the possibilities."

"The more we begin to understand the underlying systems at work by doing this research, the more easily cities can get ahead of problems."
– Charlie Catlett, Argonne computational scientist

Chicago, however, is not the only proving ground for DSSG's research. A number of the student teams spent the summer working on international projects. One team partnered with the Qatar Computing Research Institute to collect and categorize social media reports relating to natural disasters in order to organize the efforts of first responders and volunteers. Another tracked election fraud and political turmoil for Ushahidi, a technology nonprofit that helps international watchdog groups follow incidents related to political unrest around the world.

The massive nature of the datasets also gives data scientists more confidence in projections. "Having this much data allows us to adopt what's called an ensemble approach, which is similar to what forecasters use to track hurricanes in the Gulf of Mexico," Catlett said. "In each case, there are many models and lots and lots of data that we have to look at in concert in order to draw conclusions. But at the same time, if our data demonstrates a general consensus, it makes it much easier for us to manage risk."

By providing students and young professionals with the opportunities to work closely with organizations that are searching for ideas to improve urban communities, Ghani and the other organizers of the DSSG fellowship program hope to entice the fellows to continue applying their talents to social issues even after the end of the summer.

"We want to show them that there's a place where they can use their talents to work on the problems that matter," added Velez.

Catlett said that the program had no trouble recruiting. "We relied exclusively on social media and word of mouth to get the word out over a two-week period, and we still had more than 500 applicants," he said. "These are some of the brightest young minds on the planet, working on some of the biggest challenges we face today."

Argonne researchers Leah Guzowski and Charlie Catlett are developing computational models to help cities improve their citizens' lives.

A SECOND CITY IN THE **SECOND CITY**

City planners in Chicago have created a space to make the prospect of high-tech urban planning into reality. In 2010, the Chicago City Council granted initial approval for the Chicago Lakeside Development, a revitalization of a 600-acre site ten miles south of downtown that was formerly occupied by a U.S. steel plant. Vacant since the late 1970s, the Chicago Lakeside site is planned to eventually contain housing for 50,000 people, 17.5 million square feet of commercial and retail space, a new high school, a marina, 125 acres of public land, and new public transit service. The development will be financed with a roughly $4 billion combination of public and private funds.

Transforming the Lakeside site from an antiquated industrial plant to a modern, diverse urban neighborhood will rely heavily on data-driven approaches. "The unique opportunity and challenge of Chicago Lakeside is that it involves building a community more or less from scratch," said Argonne computational scientist Charlie Catlett, who co-leads the Urban Center for Computation and Data, or UrbanCCD, one of the major partners in the development.

Argonne's role in the initial planning of the Lakeside community involves studying and supporting what urban planners call "interdependencies" between the different parts of city infrastructure. "We want to improve our ability to understand, for instance, how traffic flow might be affected if we were to build a new high-rise office building on a particular street," said Argonne energy policy scientist Leah Guzowski, who with Catlett has developed a new computational platform called LakeSim, which is expressly devoted to planning the community. "This requires us both to explore how we integrate existing tools into a common engine that would allow cross-communication as well as to identify new tools to fill critical gaps."

By using big data to plan a new and ever-evolving community, UrbanCCD hopes to build a livable, sustainable, and efficient urban environment from scratch. "LakeSim is a new approach with strong potential to improve the way we design cities, and in turn the way we all live in and interact with cities," Guzowski said. "This is a unique way of allowing us to think critically about how the city will look and function 30, 40, or 50 years from now. We know the decisions we make now will have a significant impact on the quality of future urban life."

While Guzowski described the

majority of Argonne's work on the Lakeside development as still in its "proof of concept" stage, she explained that a data-driven approach to urban planning provides the analytics and science behind a more sustainable and livable city. "The world is currently experiencing a rapid shift toward urbanization, and we have to innovate and engineer our way to new ideas that will help us prepare for a whole host of new demands and consequences in the next few decades, especially for energy," she said.

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THE VOLCANO OF A HUNDRED THOUSAND MOUTHS

Tiny carbon particles could play a larger role in climate change than we thought.

by Louise Lerner

When the 1893 World's Fair opened in Chicago, fairgoers aboard the world's first Ferris wheel soared high enough to compare two cities: the White City—gleaming whitewashed architecture built for the massive fair—and its dark twin, the blackened, soot-stained buildings of the Loop just a few miles to the north.

Chicago, like many industrialized cities in the 19th century, lay under a thick layer of soot of its own making. Dirt from trains and factories soiled linen shirts and blew into homes past tightly shut windows. Across the Atlantic in London, residents lit lamps at midday to wade through pea-soup fogs, yellow with sulfur, that lingered over the city for days.

Nineteenth-century meteorologist Luke Howard called London "the volcano of a hundred thousand mouths," referring to the city's factories and engines that constantly exhaled soot, which is mostly made up of tiny particles of black carbon. Black carbon is released when things burn: coal and other fuels, bush fires, and the combustion that powers diesel engines and generators.

In the 20th century, scientists began to learn exactly how bad soot is for human health—it accelerates heart failure and burrows into lung tissue, aggravating asthma and respiratory conditions. More recently, scientists have started to realize that carbon particulates play a second unwelcome role: the second largest contributor to climate change.

Environmental regulations have helped to clear the skies over many cities. Yet the U.S., along with other countries around the world, still releases particles of carbon from trucks and generators, and we still don't really understand what happens to it once it leaves the exhaust pipe.

But there is one bright spot in the study of soot. Unlike carbon dioxide, which will remain for hundreds of years, it can cycle out of the atmosphere within weeks. Whatever harm carbon particulates do to the atmosphere is temporary, at least theoretically. That is, if we could only stop.

> "Changing habits is perhaps the most difficult challenge of all," said Argonne scientist Rao Kotamarthi.

Carbon dioxide has long been established as the most notorious contributor to climate change. But aerosolized carbon particles floating around in the atmosphere also influence climate, although their combined effect is substantially more complex. For example, aerosols can scatter incoming solar radiation away from Earth—fling it back into space—which cools the Earth. Or they can absorb solar radiation, which contributes to global warming.

Though they by and large tend to absorb heat, carbon particles are big enough to serve as nuclei for cloud formation. And clouds reflect more sunlight, which cools the Earth. However, there's some evidence that clouds formed around black carbon don't last as long; the dark nucleus absorbs heat and evaporates the cloud.

Researchers try to understand this massive puzzle by building extremely detailed virtual models of the atmosphere. At Argonne, climate scientists like Yan Feng pack all the data they can get their hands on into an elaborate working picture of the atmosphere and how it behaves.

To make sure that the model's analyses line up with the real world, scientists go through a process called "ground-truthing." "We compare our model's results to measurements taken at actual sites and see how they compare," Feng said. > > >

Once they know the model is reliable, Feng and her colleagues can run models forward in time to see what might happen in 10, 25, 100 years, depending on whether we cut aerosol emissions or let them run wild.

"It's an extremely complex puzzle, but we can address it by looking carefully at problems one by one," said Rao Kotamarthi, who manages a climate modeling program at Argonne.

Carbon aerosols are in some ways more difficult to model than carbon dioxide. Whereas carbon dioxide spreads fairly evenly around the world, black carbon tends to affect weather more locally. Carbon particulates often linger in the same region where they are emitted because the particles are too heavy to mix into the atmosphere but not as easily washed out in raindrops as other aerosols. A lot of carbon aerosol modeling, therefore, relies heavily on meteorology: charting the local ebb and flow of wind and water and temperature to map how the particles travel. "For example, large-scale meteorology, like a big cold front, can wipe out some of the carbon's effects—but not all," Feng said.

In the past few years, Feng has turned her attention to a second type of carbon in the atmosphere, called brown carbon. These are organic particles with different chemical compositions; they can be tar balls or fats. Long, smoldering fires give off brown carbon; hot fires release black carbon.

There's a lot more brown carbon in the atmosphere by mass, but it can't trap as much heat by mass as black carbon—"Think of wearing a black shirt in the sun," Kotamarthi said—so it's largely been overlooked.

Only recently have researchers at Argonne and elsewhere begun to explore brown carbon's effects and habits more closely. "We have a little idea of how black carbon behaves," Feng said. "But brown carbon was only identified as a potentially significant factor in the past several years."

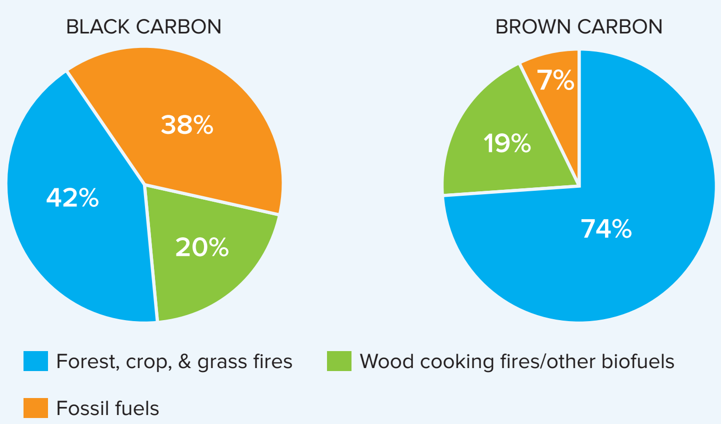
Feng, along with Kotamarthi and Professor V. Ramanathan at the Scripps Institution of Oceanography, recently published the first global model study to estimate how much heat brown carbon traps in the atmosphere. "Our model shows how carbon is distributed across the atmosphere," she said. "We can use that to predict how much solar radiation is being trapped in the atmosphere, and from that we can estimate how much the global temperature may rise." Feng thinks that brown carbon could turn out to be a significant factor in how aerosols affect Earth's climate.

There are still a lot of uncertainties in the model, though. "Getting more data is the biggest problem," Kotamarthi said.

That's where Argonne environmental scientist David Streets comes in. Streets specializes in collecting data on emissions; he modeled Beijing's air quality before it hosted the 2008 Summer Olympics. In 2005, along with Professor Tami Bond of the University of Illinois, he published the gold standard figures for soot sources now used by modelers around the world.

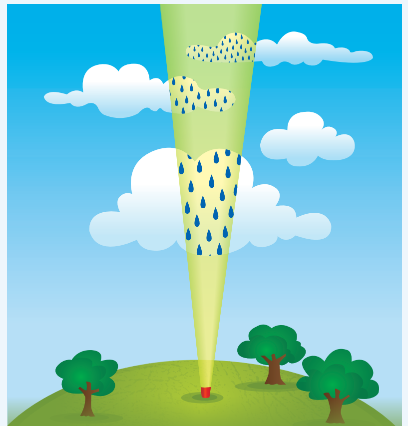
"We tell them what's being emitted into the air," Streets said. "They use meteorology to get where it winds up and how it affects weather and climate."

WHAT DOES CARBON COME FROM?



BROWN CARBON
Organic molecules like tar balls or fats, given off by long-smoldering fires

BLACK CARBON
Carbon particles given off by hot fires, like coal plants, forest fires, and combustion from cars



According to Argonne scientist Yan Feng, clouds are one of the largest uncertainties in today's climate predictions.

"Water is an extremely important parameter in climate change, because when water changes phase—condensing from vapor into water droplets, or changing to ice—it releases energy as heat," said Argonne meteorologist Richard Coulter.

To get data, many older models use satellite images to determine cloud cover. But that's a 2-D view; when you look down from space you can see the top layer in the atmosphere, but not the ones underneath. It's as if you were asked to judge what kind of cake lay underneath the frosting from looking at the top. We need 3-D.

By using science fiction's favorite solution—lasers—scientists can acquire a more comprehensive picture of cloud dynamics. By directing a laser up into the atmosphere—up to nine miles high—and measuring what's reflected back down, researchers can take cross-slices of the atmosphere.

The laser light scatters differently when it hits something other than water droplets, like flat ice crystals or irregularly-shaped soot particles. "It's a bit like when they turn on the fog machine at a laser light show," Coulter said. They can even measure how big the aerosol particles are.

The instruments take data around the clock, from ground installations or strapped aboard portable weather instrument arrays. One such mobile climate array is the AMF2, currently headed to Finland after a run in the Pacific Ocean, and which is run by Argonne as part of the Atmospheric Radiation Measurement program.
Read more: arm.gov/sites/amf/amf2

To ensure the accuracy of his data, Streets works with collaborators all over the world, including rapidly industrializing countries like China and India.

Climate modelers also keep an eye on a number of different global economic indicators, because the health of the world's economies significantly affects emissions. In 2008, scientists saw the economic crash written out in the sky. Aerosols dropped noticeably. The skies cleared over Greece in 2010 as the debt crisis squeezed its citizens below.

This is a central reason why aerosol emissions control is so hard. Carbon, like carbon dioxide, tends to ride piggyback on economic development. In particular, developing countries—where the electricity sometimes goes out because the power infrastructure hasn't quite kept up with demand—tend to rely heavily on diesel generators. They produce a lot of black carbon.

And aerosols are a major human health problem in developing countries. The World Health Organization puts smoke from solid fuels as the 10th major mortality risk factor globally; it estimates that smoke contributes to approximately two million deaths annually, particularly affecting women and children. Urban air pollution ranks among the top 10 risk factors in middle and developed countries too.

We've succeeded in reducing emissions from factories and other sources in developed countries like the U.S. and Europe; in many places, black carbon emission levels are lower than they've been in decades, if not centuries. In Chicago, cleaners scrubbed a century's worth of soot off several buildings in the Loop to discover stone and brick underneath in shades of delicate pastels that probably hadn't been seen since the last tourists left the World's Fair more than 100 years ago.

"Purely from a technical standpoint, we could do this," Streets said. "We have the technology." ⚛

Funding for this work comes from the DOE Office of Science, Atmospheric System Research program and Atmospheric Radiation Measurements program, and NASA's Modeling, Analysis and Predictability Program.

WHAT DO WE NEED TO IMPROVE OUR CLIMATE MODELS?

MORE DATA

There's a lot we still don't know about our own atmosphere. The Department of Energy runs several stations of instruments that take climate data to add to this library—two of them mobile, so they can take measurements in hard-to-reach places like the middle of the Pacific Ocean (via boat) or even in Antarctica. Turn to page 5 to read about the next journey for one of these mobile climate stations.

HIGHER RESOLUTION

Even the best climate models today don't have very good resolution—they often use just a few data points to represent hundreds of square miles. To get models that more accurately reflect real conditions, we'll need programs that can incorporate more data, ways to interpret and store it, and a computer that can handle it.

FASTER SUPERCOMPUTERS

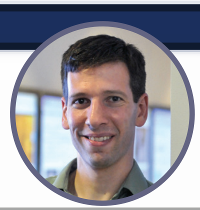
Argonne uses supercomputer Mira to run scientific simulations with 10 petaflops of computing power—10 quadrillion operations per second. But if we add more data and higher resolution, we'll need still more powerful supercomputers. Argonne researchers are already working on designing computer architecture for the next generation of supercomputers at exascale—that is, quintillions of operations per second.

CROWDSOURCE

HOW DO WE START TACKLING CLIMATE CHANGE?

WINTER 2014 | ARGONNE NATIONAL LABORATORY



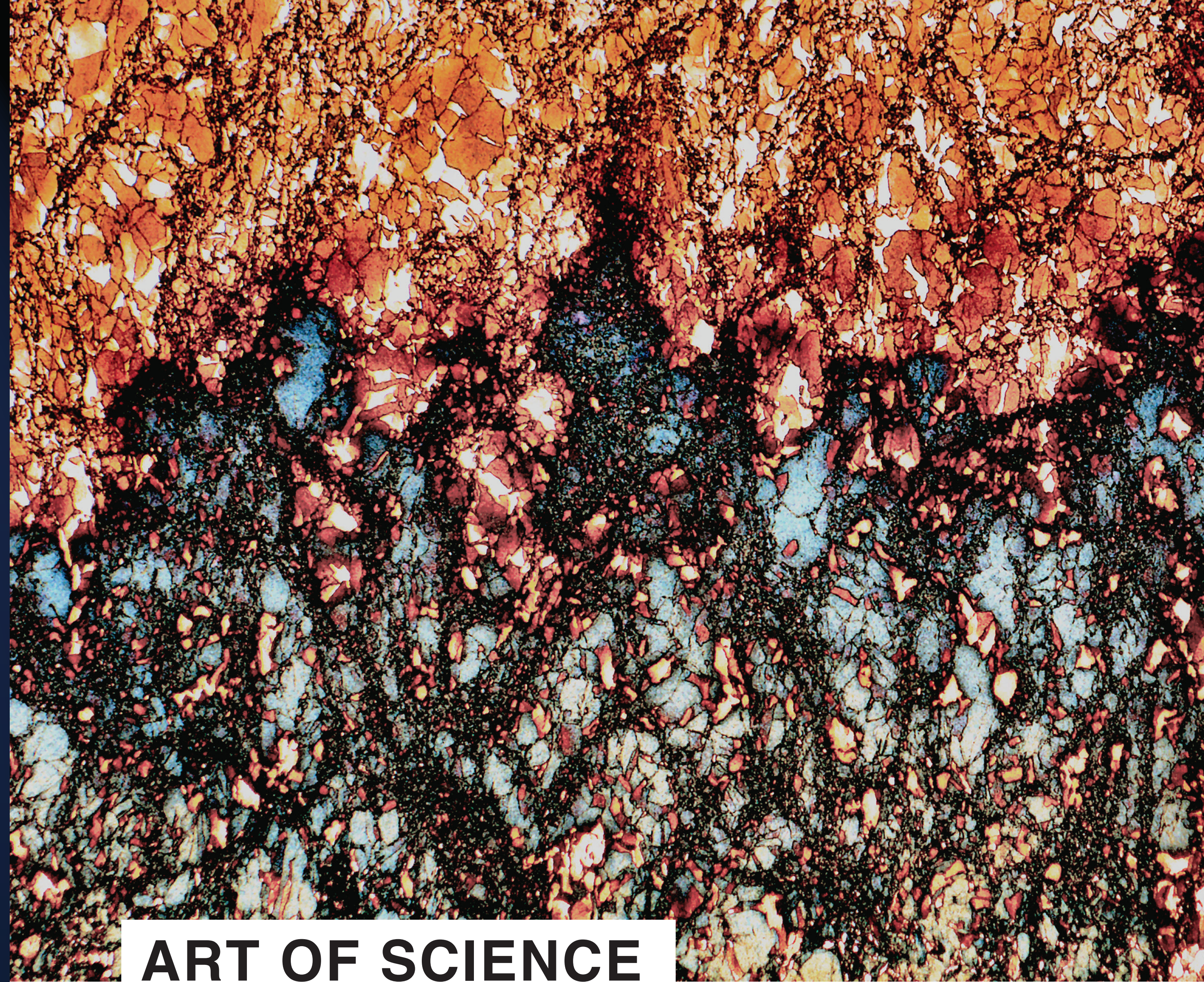



RAO KOTAMARTHI

YOON CHANG

SETH DARLING

AMGAD ELGOWAINY



ART OF SCIENCE

Blue Flame, Stained Glass

By Gary Navrotski, Mike Bosek, Jeff Collins, Jeremy Nudell, Ali Khounsary, Bran Brajuskovic, Patric Den Hartog, and John Quintana

This isn't actually a stained glass mosaic, but individual grains of strengthened copper. The largest orange blobs are about the size of a fine human hair. The dappled pattern came from applying ferric acid, which ate through the metal but left some copper crystallites behind. Argonne's Advanced Photon Source—which provides ultra-intense X-ray beams to more than 5,000 scientists from around the world each year—relies on such exotic materials in its instrumentation.

DOWNLOAD ME!
flickr.com/argonne

7 THINGS you may NOT KNOW about DIESEL

| by Louise Lerner

1 Diesel engines are more efficient than gasoline engines. A gas engine is only about 20% efficient. That means only 20% of the fuel actually moves the car, and the rest is lost to friction, noise, engine functions, or goes out as heat in the exhaust. But diesel engines can reach 40% efficiency and higher. That's why they are so popular for moving heavy vehicles like trucks, where extra fuel really starts to get expensive.

2 If you toss a lit match into a puddle of diesel fuel, it'll go out. That's because diesel is much less flammable than gasoline. In a car, it takes intense pressure or sustained flame to ignite diesel. On the other hand, if you toss a match into a pool of gasoline, it won't even touch the surface—it ignites the vapors above the surface. (Please don't do this at home!)

3 We now produce about 100 times more biodiesel than we did 10 years ago. In 2002, the U.S. produced about 10 million gallons of biodiesel. In 2012, that number was 969 million.

4 At high altitudes, diesel engines get better power than gasoline. Gasoline engines operate at a very specific ratio of fuel and air. At high altitudes, the air is thinner—literally: there are fewer molecules of air per cubic foot. That means that in the mountains, gasoline engines have to add less fuel to keep the ratio perfect, which affects performance. Diesel engines have turbochargers, which pump more air into the combustion chambers at high altitudes, which helps them perform better.

5 Diesel's not dirty anymore. The U.S. EPA now requires diesel engines to meet the same pollution criteria as gasoline engines. Carmakers added a device called a diesel particulate filter, which removes visible smoke. "If you're buying a diesel car from 2007 or later, it's no dirtier than a gasoline-powered vehicle," says Argonne mechanical engineer Steve Ciatti.

6 Diesel engines get best performance below 65 miles per hour. They get peak power when the engine revolutions per minute (RPM) are low, generally at speeds below 65 miles per hour. Gasoline engines, in contrast, get to peak power by running the engine fast and high and the RPM at 5,000—i.e., with the pedal to the metal.

7 Diesel's an interesting option for the environmentally-minded. Since they produce less carbon dioxide, run more efficiently, get high mileage to the gallon, and have their emissions cleaned, diesel-powered cars are an alternative for those who wish to reduce their carbon footprints. Since the technology is already well-developed, they tend to be relatively cheap, too.

What if you could combine the best parts about gasoline and diesel engines? Argonne engineer Steve Ciatti is doing just that. Find out more at http://1.usa.gov/1dnk3kn.

RIVER LIFE: MAPPING THE CHICAGO RIVER MICROBE POPULATION

Scientists from Argonne are partnering with the Metropolitan Water Reclamation District of Greater Chicago to find out the typical sources and distribution of microbes in Chicago-area waterways.

Argonne scientists will analyze samples taken monthly from the Chicago River during the recreational season—between March and November—and run them through a DNA sequencer to identify and count the microbes in the river. The entire study will take seven years and will record the changes that happen as the MWRD takes steps to begin disinfecting its outflow.

"Repeating the sampling is critical because the river's inhabitants change with the season, after rainfall, during temperature swings, after large discharges, or after sewer overflows," said Argonne environmental scientist Cristina Negri. "Even boats churn up the sediments as they pass and redistribute the microbes."

"The river has become substantially cleaner over the past several decades, thanks to many interventions, but we still don't have a very thorough understanding of what lives there," said Jack Gilbert, an Argonne environmental microbiologist. "The EPA currently just looks for *E. coli* or a few other known pathogens. We look at all bacteria and viruses, pathogenic or not, by sequencing the genomes of the whole community and using our computational might to sort through who is there and what they are doing.

"This is important because all these species interact with one another in the water—perhaps there's another microbe or condition that triggers blooms of bad bacteria."

Stay tuned for more studies on water in the next issue.

the Secret lives OF SCIENTISTS

Meet researchers from Argonne with unusual hobbies and interests.

Bill Gasper

Environmental Safety & Health Coordinator and Beekeeper

AN: What do you do at Argonne?

GASPER: For the last 14 years I've been an environmental safety & heath coordinator for my division, Environmental Sciences. We do a lot of fieldwork, often in places where we are studying contaminated areas, so it's important to make sure we provide a safe environment for the researchers.

AN: How did you get started with your hobby?

GASPER: My dad used to keep bees when I was a kid. We always had bees on the property. So I've been interested in bees for probably close to fifty years.

AN: So you keep them in your backyard?

GASPER: Right now I have six hives.

AN: How many bees is that?

GASPER: It fluctuates. Probably up to 60,000 bees per hive during the summer. Then in the winter it dwindles down and they get through with maybe 15,000 bees.

AN: What's involved in taking care of them?

GASPER: The biggest task is to make sure the hive has enough room as it grows. Otherwise as it gets bigger, the hive will split in two, and half the bees will leave and start a new colony someplace else. That's called swarming. There are also viruses, parasites, bacteria, which can all contribute to illness in the hives, and pesticides, herbicides, and insecticides weaken them. So occasionally you check on them: partially disassemble the hive, see if the queen is healthy and laying eggs, see what their stores of pollen and honey look like. If a hive is diseased, there are medications and treatments.

AN: So you can just open up the hive?

GASPER: Whenever you work the bees, you use a smoker. It's a can with a bellows on it and you get a fire going in there with some fuel that will smolder, and you use smoke to calm the bees. They get sort of dazed. It makes it easier to manipulate them.

AN: What do you wear?

GASPER: I always wear a veil that covers the head and face, because they will go for your face. That's their primary instinct. They go for your eyes. That's programmed into them. I also usually wear light-colored clothing. One of their biggest natural enemies are bears, so they go for dark objects. And I generally wear leather beekeeping gloves.

AN: I have to ask. Do you ever get stung?

GASPER: Yeah, once in a while, but not very often. Because honeybees are really pretty docile. They're not aggressive. They're not meat-eaters like wasps and hornets. Also if you get stung enough, you do work up a resistance to the bee venom. You feel the prick, but it doesn't burn and sting.

AN: How do you get the honey out?

GASPER: I set up a "honey house" in my garage. It's a messy business because there's wax and honey everywhere. To give you a picture: a hive is a series of boxes that stack on top of each other and within those boxes are wooden frames, each with a sheet of wax. The bees build on that with their own wax, and that's where they put their young and their reserves of honey and pollen. On each cell, when the honey is ripe, they put a little wax cap that seals it off. When it's harvest time, you take those boxes off the hive, bring them into the honey house, take a hot knife and cut the wax caps off. Then you basically put the frames in a giant centrifuge and spin the honey out. I strain it to get rid of any stray bits—wax, little pieces of legs or wings or whatever might be in there—and then it goes right into jars, no other processing.

AN: How much honey do you get?

GASPER: Last year I got about 175 pounds of honey. I had four hives back then, and it was dry that summer so it was a down year. You can probably average 60 pounds of honey per hive, but it's not unheard of to get 120 pounds or more from one hive in a banner year.

AN: What do you do with it all?

GASPER: Mostly eat it—put it on a piece of toast—or give it away. People love to get honey.

AN: What does the honey taste like?

GASPER: Depending on where the bees forage, you can get very unique flavors. I'm in an urban setting, so they're going to flower gardens, vegetable gardens, trees. Some beekeepers will target certain "honey flows" to get honey from a particular flower. So when, say, the clover is in flower they'll watch really closely and take that honey off. Mine, I just let it all come together. It always tastes great.

AN: How do your neighbors feel about all this?

GASPER: The neighbors on both sides are really excited about the bees, actually. They understand their contributions to wildlife and flowers. I have one neighbor who moved in and had never lived near bees, but his new plantings are all doing great, and he says it's because of my bees. And, you know, a jar of honey or two goes a long way to improve the bee's image. Especially when it's from someone's backyard.

AN: What's the reward you get from beekeeping?

GASPER: It's a fascinating hobby. It's really interesting to see how they work together for this common good of sustaining the hive—they sacrifice their lives. It's nice to provide pollination for everything around. And it doesn't hurt that you get a little sweet reward at the end.

cheat sheet:

CONTENDERS FOR THE **NEXT GENERATION OF BATTERIES**

To make electric cars really take off, we need a battery that's powerful enough to take a car 350-400 miles and cheap enough to be widely affordable—and also light, long-lived, and safe. Of course, we also want laptops that last 100 hours and big battery farms to store electricity generated by fickle solar and wind, and each problem might need a different solution. Nobody yet knows for sure, but here are the primary contenders for the next generation.

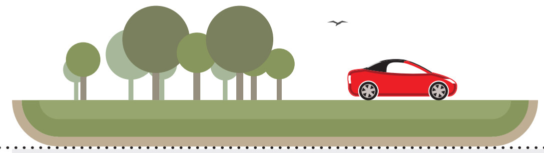
TERMINOLOGY

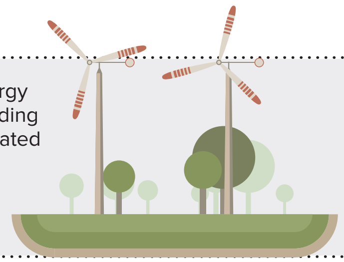
CATHODE – The positively charged side of the battery

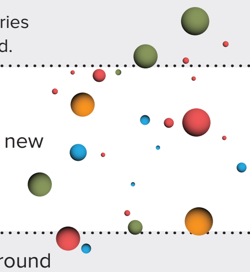
ANODE – The negatively charged side

ELECTROLYTE – The medium (usually liquid) that lets the ions flow back and forth between cathode and anode

	HOW THEY WORK	WHAT THEY'RE FOR	ADVANTAGES	DISADVANTAGES	READY FOR PRIMETIME YET?
LITHIUM-ION	When you charge it, you use energy to force lithium ions into the anode. When it discharges, the ions flow to the cathode through a thin membrane and generate a current.	Cell phones, laptops, cars (currently in Tesla, Nissan Leaf, BMW i3, Ford Fusion Energi, & Chevy Volt)	+ Currently pack the biggest punch per ounce of any battery on the market + Safe, well-understood + Easily recharged + Can scale to any size + Already in wide commercial production	– We need to store more energy in less space – Not very cheap – Could last longer – Needs very precise manufacturing to avoid malfunctions	Yes—has been on the market for decades. Argonne and JCESR researchers are studying new chemistries. The next generation will double or triple performance and cut the cost by half.
SODIUM-ION	Similar to lithium-ion, but use sodium ions instead of lithium to carry charge back and forth	Large-scale energy storage (like holding electricity generated from wind)	+ Sodium is more abundant than lithium, could make batteries cheaper + Can work at room temperature + Relatively unexplored—new material discoveries are possible	– They hold less energy than lithium, so the battery might be too heavy for a car – Current cell lifetimes are not very long	Not yet Scientists at Argonne are studying cell chemistries to increase the cell's energy and improve cell life.
MAGNESIUM-ION OR ALUMINUM-ION	Similar to lithium-ion, but magnesium (or aluminum) ions do the work	Cars, cell phones, laptops	+ Magnesium and aluminum are both more plentiful than lithium + Magnesium provides two electrons and aluminum has three (vs. lithium's one) so it could be more energy-dense	– Chemistry not well understood yet – Needs a new electrolyte that won't gum up the works – Cells have short lives	Not yet Scientists at JCESR are designing new materials to make batteries last longer.
FLOW BATTERIES	Two tanks of liquid, one positively charged and one negative, are separated by a membrane. Where they meet, the ions exchange and generate power.	Cars, grid, backup power	+ You can separate the two parts of the battery, which makes it easier to design around + Can be designed for maximum power or lighter weight	– Currently can't hold as much energy as lithium-ion – Engineering challenges remain, like pumps & leaks	Pre-commercial IIT and Argonne scientists just received a $3.4 million ARPA-E award to study using nanoparticles to improve performance. JCESR scientists are studying flow batteries for large-scale storage in the electric grid.
LITHIUM-SULFUR	Lithium ions from the anode react with sulfur held in the cathode to produce energy.	Cars, cell phones, laptops	+ Could pack more capacity into a lighter package + Sulfur is a cheap component + Very light	– Current versions have short lifetimes – The electrolyte needs work—it tends to dissolve the cathode and react with the anode.	Not yet Scientists at JCESR are working on new electrolytes to improve cell life.
SODIUM-SULFUR	A molten sodium core exchanges ions with sulfur through a solid electrolyte barrier.	Large-scale energy storage (like holding electricity generated from wind or solar)	+ Materials are cheap and abundant + Fairly long lifetime	– Have to operate at high temperatures, so can't use in a car	Large scale demonstrations exist around the world for grid storage applications.
LITHIUM-AIR	Uses molecules of oxygen from the air to react with lithium ions in the anode, which releases energy. Recharging forces out the oxygen atoms, and the lithium is ready to start again.	Cars	+ Could make a very light battery	– Finding electrolytes that don't react with the other components is a challenge–cells have very short life – May need extra safety engineering	Not yet Scientists at JCESR, the battery hub led by Argonne, are working on the basic science behind these.

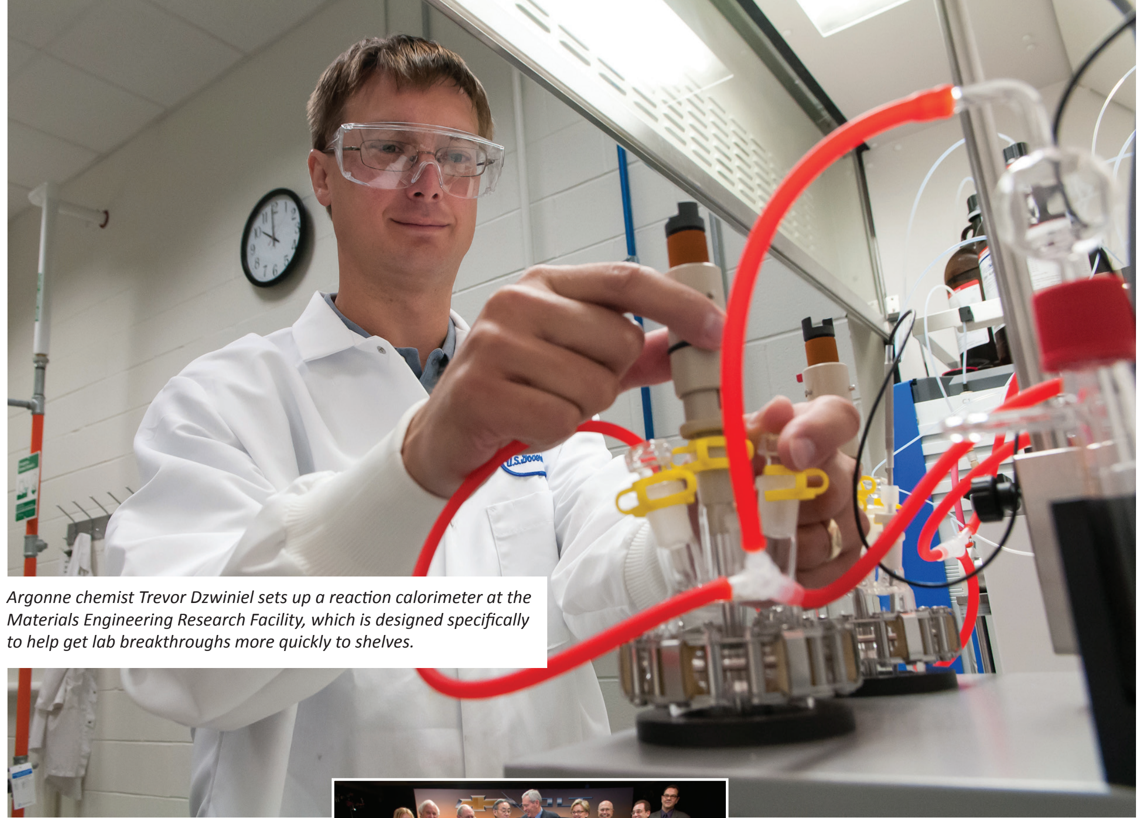






by Angela Y. Hardin

ARGONNE'S NEW AND IMPROVED INDUSTRY AND BUSINESS OUTREACH



Argonne chemist Trevor Dzwiniel sets up a reaction calorimeter at the Materials Engineering Research Facility, which is designed specifically to help get lab breakthroughs more quickly to shelves.

During the last two and a half years, Argonne Technology Development & Commercialization, or Argonne TDC—the business outreach arm of Argonne National Laboratory—underwent an extensive makeover that has put it in the best possible position to help the U.S. Department of Energy achieve its mission to ensure the nation's security and economic prosperity by addressing its energy, environmental, and nuclear-related challenges.

"The way a national lab accomplishes that is through the research and development of advanced technologies," said Greg Morin, interim director of Argonne TDC and director of strategy and innovation at Argonne. "But that R&D means very little if the invention simply sits on a shelf gathering dust, doing nothing to improve how Americans—and the world—use energy, or to help U.S. industry develop and commercialize new and advanced technologies."

Much like a sports team that's rebuilt its roster of players, Argonne TDC has invigorated its staff with the addition of several talented business development and contracted-research administration professionals, who have had successful private and public sector and startup experience.

Argonne, like its other sister laboratories, doesn't compete with private industry. Rather, it supports the aims of industry, as long as it harmonizes with the Department of Energy mission. The lab has a long history of licensing its patented technologies, working with private sector concerns to develop marketable technologies that allow U.S.-based business to compete in the global marketplace with unique, state-of-the art technologies.

As the lab moves forward, its aim is to significantly boost the number of projects with private companies.

In recent few years, Argonne has been forging working relationships with the City of Chicago, Chicago's research universities, and other non-governmental agencies. This varied collection of entities is working together to bolster the region's and the state's entrepreneurial ecosystems.

Past commercialization successes include battery technology for the Chevy Volt.

The goal is to grow and diversify Illinois' business base by developing nascent industries and aiding entrepreneurs and existing businesses that are seeking to commercialize new products or improve existing products and processes.

So the research and technology development that takes place at Argonne has the potential over time to have a positive economic development impact, Morin said. Indeed, the technological results of scientific research have driven the world's economy for more than 100 years. "Just look at impact of the transistor on the global economy in the last six decades. Silicon Valley would not exist without it; neither would the laptop, cell phones, or MP3 players, to name just a very few," he said.

"And if you're a business owner, imagine working with some of the brightest scientific and engineering minds in the world," Morin said. "They're not intimidating to work with. In fact, they want you to succeed. It reflects positively on them, not to mention the sense of accomplishment that they feel."

Argonne TDC is especially interested in working with more small businesses.

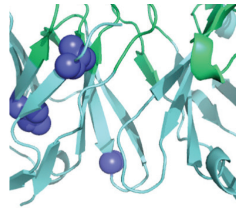
"Small business may not have the financial wherewithal to work on developing or licensing a marketable technology with a national laboratory," Morin said. "But there are ways that Argonne can work with a small business, including through the Department of Energy's Small Business Innovation Research and Small Business Technology Transfer programs."

Argonne is a national laboratory and is the Midwest's only multipurpose national laboratory. So Argonne TDC is also working to open the door wider to work with other states and cities in the Midwest and beyond as they look for ways to strengthen or transform their economies.

"State economic development offices are constantly competing with each other to attract existing businesses from other states to their state," Morin said. "That doesn't necessarily do a lot to help the nation's GDP. We're looking to show those 'econdev' offices how Argonne and other national labs can enable other options—creating new and expanding existing companies though improved products and new technologies through science. These options will take more time and effort to achieve, but the economic return—especially in terms of job creation—is likely to be far greater."

AVAILABLE FOR LICENSING

Argonne has available for licensing a suite of bio-based products for the medical and renewable energy industries. If you are interested in licensing or want to learn more our patented technologies, please contact **partners@anl.gov** or visit **www.anl.gov/technology.**

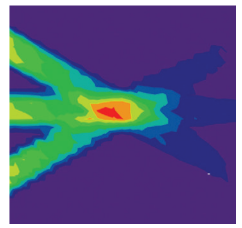


Antibody engineering strategy improves stability
Addressing the global demand for antibody therapeutics, Argonne has developed a cost-effective engineering strategy for improving the stability of antibodies and antibody fragments. The strategy is novel, as it targets a small number of amino acid residues in antibody variable domains.

U.S. Patent Application WO2011/008690 A1

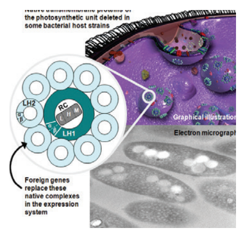
High-tech brain implant predicts, prevents epileptic seizures
Argonne's unique, advanced brain implant system can predict an epileptic seizure before it starts and induce hypothermia to the affected region quickly enough to suppress the seizure. The system consists of miniature brain implants with a small external monitoring unit. One implant predicts epileptic neuron activity by measuring local changes in brain temperature. And an array of probes in the brain rapidly cools the epileptic zone to suppress seizures.

U.S. Patent 8,165,682



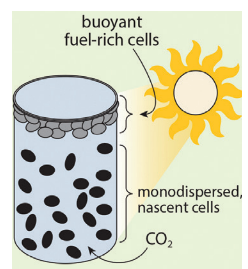
Endoscopic electron beam cancer therapy
Argonne researchers have developed a sub-millimeter size electron beam for cancer treatment. The tiny beam is delivered through a laparoscopic tube inserted in a small incision and positioned directly at the tumor. The beam offers cost-effective treatment in previously inoperable or radiation-sensitive areas of the body.

U.S. Patent 7,312,461



A Rhodobacter system for the expression of membrane proteins
Argonne has created a system using a photosynthetic bacterium called Rhodobacter to express heterologous membrane proteins. Membrane proteins for more than 60% of drug targets. The Rhodobacter system is advantageous for its lower production costs, ease of purification, scalability, and high yields. (See page 7 for more information).

U.S. Patents 6,465,216; US2011/0244524; and 13/619,409



Engineering biofuels from photosynthetic bacteria
Producing fuel from renewable energy sources has numerous obstacles. Argonne has created biofuels from photosynthetic bacteria. The fuels are made from agricultural feedstocks under a method that combines engineered and natural photosynthetic mechanisms.

U.S. Patent Application 2011/0302830

www.anl.gov/technology

SCIENCE IN THE 1000 MOST COMMON WORDS

Last year, webcomic XKCD published a diagram of a rocket using only the 1000 most commonly used words in the English language. (Check it out at xkcd.com/1133). So we asked our scientists to try a hand at explaining their research the same way.

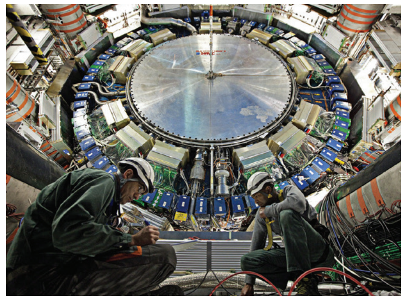
LILY ASQUITH High-energy physicist (Large Hadron Collider)

We make two very small things go very fast towards each other. Nearly as fast as light. These things are very small pieces of matter, which makes up everything in the world. When they hit each other, stuff happens. A bit like when a car hits another car, but these things are not even nearly as big as cars. They are smaller than almost anything.

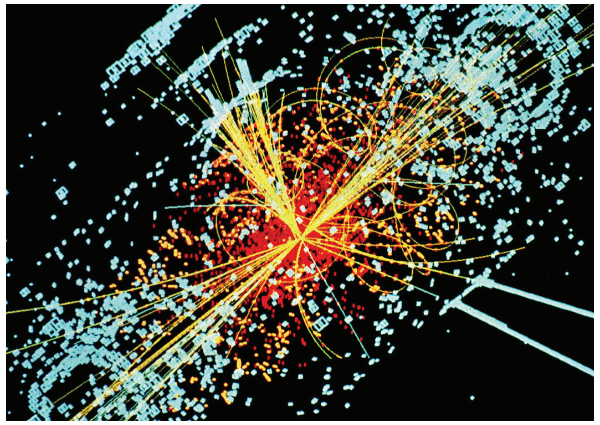
The things are broken into pieces. Sometimes the pieces can be very interesting. Some of them have not been seen since the beginning of time. They weren't seen then, either, because there were no living things here to see them.

Anyway, now we know the things were there at the beginning of time, because some other people built a big, beautiful catching thing to catch the small, interesting pieces.

Most of what we caught was not very exciting, and made us feel tired. But a little of what we caught was the best thing ever and made us feel very good.



We and some other people with big brains across the world built this big beautiful catching thing to study very tiny pieces of the things that make up everything in the world. Picture by CERN.



When pieces of matter hit each other while going very fast, they break into even smaller pieces of matter. That is how we can study what makes up everything in the world. Picture by CERN.

ERIC RASK Research engineer

My group drives cars in order to better understand how much stuff they burn and how to make them better. We look at how the car runs as well as all it eats.

We use this to help people know more about their car or a car they might make or buy. How a car drives when going fast or slow is also important to know because people drive different and sometimes we want one number and sometimes we want many numbers for each car type. Knowing this for each car type also helps write new ways to tell people what their car will do for them and the world.

At Argonne, Henning Lohse-Busch (left) and Eric Rask try to figure out ways to make cars better at going further and burning less.

It's really hard! Try your hand at explaining a hard concept with only the most common 1000 words with the automatic text editor at splasho.com/upgoer5/

ARGONNE HELPS INTRODUCE GIRLS TO ENGINEERING CAREERS

| by Alex Mitchell

As a middle-schooler, Mia Cochrane (at right, in orange) attended a 2007 Argonne workshop that pairs students with women engineers and scientists.

As Mia Cochrane walks among the tall jack pines on the campus of Michigan Tech University, she represents a success story.

First and foremost, of course, it's a story of personal success. Cochrane, an 18-year-old freshman, is attending a major technological institution, where she is pursuing her dream of becoming an environmental engineer.

It is also a story of success in science education and outreach—one that began with a modest roadside sign and continues to be written.

Cochrane's first brush with big science came in 2006, when she was 11 years old and Argonne National Laboratory was holding an open house to celebrate its 60th anniversary.

"I saw a sign (advertising the open house) by Lemont Road on my way to work one day," said Mia's father, Bill. "I knew Mia was interested in her science class, and I thought she might like it."

A few days later, Mia and her father attended the open house, where she was exposed to an array of facilities, demonstrations, and ideas. Among them was a program called "Introduce a Girl to Engineering Day."

"There was a vendor's table for 'Introduce a Girl,' and it looked really interesting," Mia said.

Why a program specifically aimed at exposing girls to engineering?

It's no secret there is a gender gap in the sciences. According to a 2011 report by the U.S. Department of Commerce, women are vastly underrepresented among STEM (science, technology, engineering and mathematics) degree holders and in STEM jobs. In recent years, the number of girls and women studying STEM has steadily increased, but a significant—and confounding—gap remains.

With this gap in mind, each year Argonne invites roughly 80 eighth-grade girls to the lab, where they meet women engineers, learn about engineering careers, and do hands-on activities and experiments.

At the 2006 open house, Cochrane signed up, and a few months later, she was back at Argonne for Introduce a Girl to Engineering Day 2007.

"It was a very exciting day," Cochrane said. "When I got there, I met the mentors, we visited a few of the buildings, and we got to see some demonstrations.

"I fell in love with it; it was amazing. I have been interested in engineering ever since."

According to Bill Cochrane, it was immediately apparent to him and to Mia's mother, Kim, that the event had made an impression on their daughter.

"When she got back that day, she couldn't stop talking about how much fun it was," Bill said. "Mia told me about a pie chart they showed that showed the percentage of women and men in engineering, and she said, 'I want to be in that small percent!'"

Having caught the science bug at a 2007 Argonne workshop, Mia Cochrane is now in her first year at Michigan Tech and studying to be an environmental engineer. Photo courtesy Michigan Tech.

For the rest of her eighth-grade year and throughout high school, Mia continued to explore the sciences.

"In eighth grade, we really got into biology," she said. "We brought in water samples, and we got to look at microscopic organisms. I think it would be really cool to figure out what you can use those organisms for. How you can treat the water. Environmental stuff in general interests me."

It's of course gratifying for those involved with Introduce a Girl to Engineering Day to see one of the girls they've met and worked with go on to pursue an engineering degree.

"I think it speaks volumes to the importance of engaging kids early in their schooling," said Tina Henne, who coordinates Argonne's postdoctoral program and has helped mentor Cochrane. "We bring them in and show them what they can be and how science and engineering impact our world. To make a lasting impression on a kid is huge."

"I'd like to see the mindset shift from thinking of a linear STEM pipeline to one that is more circular. Encourage everyone to mentor back to the generation behind them. Keep engaged with students and professionals at all levels. This is how you build strong communities. Through programs like Introduce a Girl to Engineering Day and Science Careers in Search of Women, we've been pretty successful at that."

During her final weeks of high school, Cochrane visited Argonne for a career shadowing day. As she sat in a nondescript conference room answering questions about her path to engineering school and her plans for the future, her enthusiasm for her studies and for what lies ahead was palpable.

"I've always been interested in science," she said. "I've also always had people who are encouraging me to go for it—whatever it is I want to learn or do."

To learn more about Argonne's education programs, visit www.dep.anl.gov.

EDUCATIONAL PROGRAMS AT ARGONNE

Argonne offers a variety of educational programs and resources for both students K-12 and their teachers, as well as internships for undergraduates and grad students and postdoctoral fellowships.

Introduce a Girl to Engineering Day
8th grade girls meet women engineers, visit the labs, and perform hands-on activities and experiments.

Rube Goldberg Machine Competition
Chicago-area high schools build a machine to do a simple task (like watering a plant) by a sequence of at least 20 steps, à la the cartoons of Rube Goldberg.

Science Bowl Car Competition
Middle school teams compete to build a working model electric car.

Science Careers in Search of Women
High school women meet Argonne women scientists and engineers for a day of activities and tours at the lab.

Find out more at www.dep.anl.gov

ASK A SCIENTIST

KATIE CARRADO GREGAR,
NANOSCIENTIST & USER/OUTREACH PROGRAMS MANAGER AT THE CENTER FOR NANOSCALE MATERIALS

IS THERE NANOTECHNOLOGY ALREADY IN MY CONSUMER PRODUCTS?

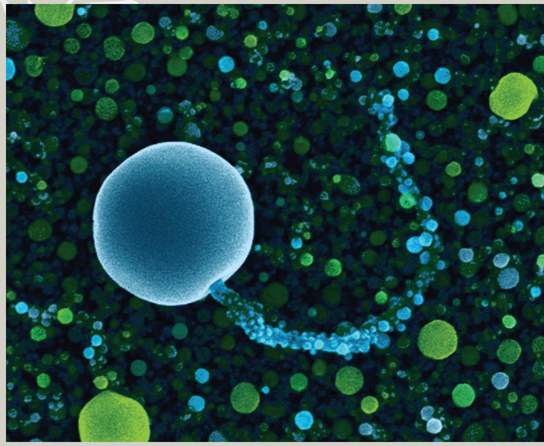
CARRADO GREGAR: I just saw a report that named 1,628 products using nanotechnology...so I'd say yes, definitely!

When you say nanotech, a lot of people are thinking of tiny machines or robots. There is a long way to go before that becomes reality. But simpler nanomaterials are very much in common use.

Technically, "nano" means the structures are between one and 100 nanometers in one dimension. (That's about how much your fingernails will grow while reading this.) They've been in some paints and cosmetics for years. For example, titanium dioxide or zinc oxide nanoparticles are a common ingredient in sunscreens. That's because the individual particles absorb UV radiation. And silver nanoparticles are in some toothpastes and shampoos because of their antibacterial properties.

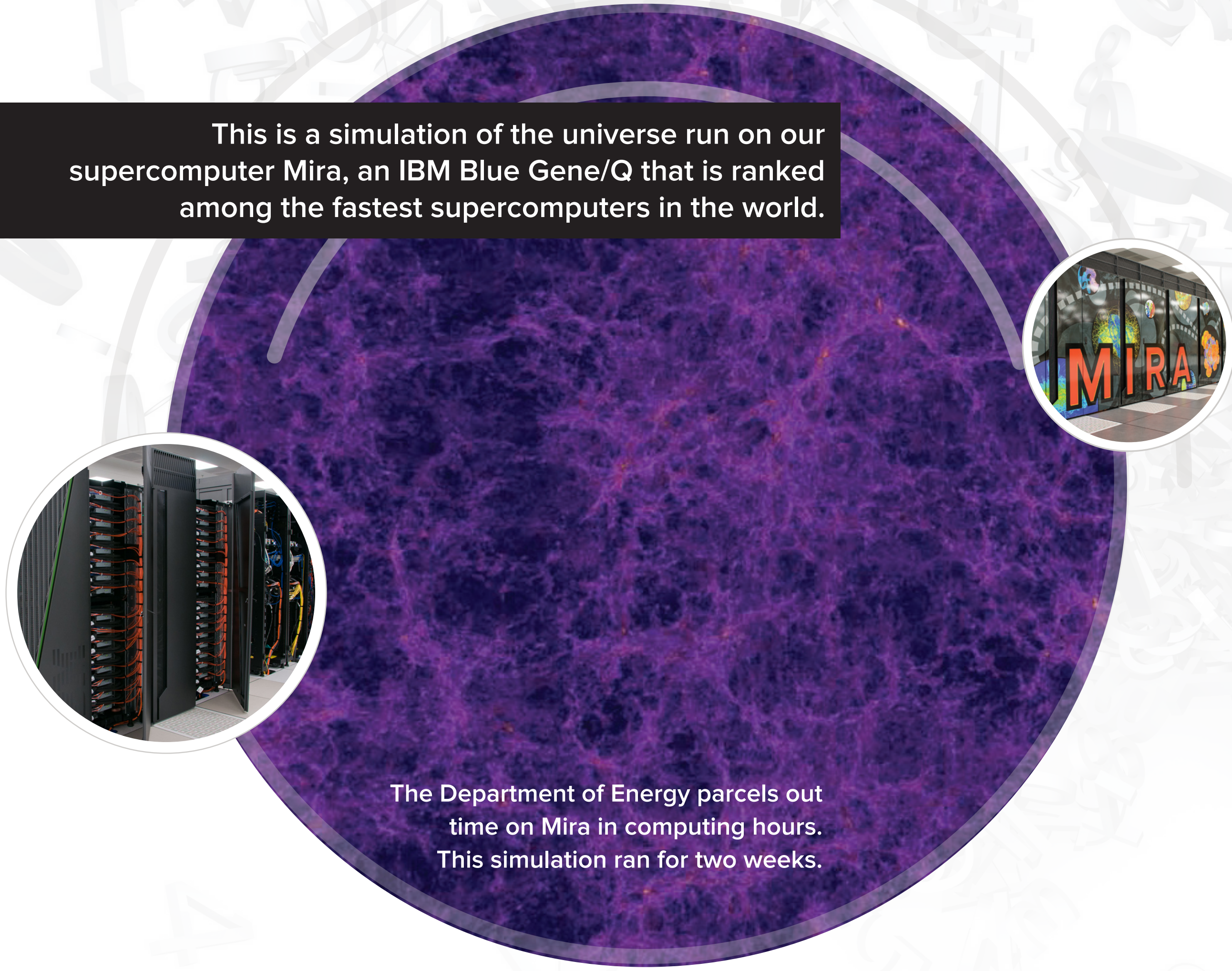
Carbon nanofibers are used to reinforce plastics in sporting equipment such as composite tennis rackets and baseball bats. Nanotechnology in this way is useful because it can be as light as plastic, but stronger.

Finally, nanotechnology principles have been used in clothing and textiles as waterproof coatings—the kind that repels moisture and stains. In fact, one company based their technology on the nanomorphology of the lotus plant leaf. If you zoom in on the leaf's surface, you see microscopic spikes covered in even tinier wax crystals that repel water.



In terms of tiny machines—right now we're only at micromachines, which are three orders of magnitude larger than nanomachines. Those are quite commonplace. Micromachines are in the sensors that trigger the airbag in your car, for example. There's a big push to get us to the next level, but it's a huge engineering challenge to have moving parts that small. It's one of the initiatives where I work, at the Center for Nanoscale Materials at Argonne. Find out more about us at **www.nano.anl.gov**.

This is a simulation of the universe run on our supercomputer Mira, an IBM Blue Gene/Q that is ranked among the fastest supercomputers in the world.



The Department of Energy parcels out time on Mira in computing hours. This simulation ran for two weeks.

Mira has **262,144 processors** running **24 hours** a day for **14 days**, so the entire simulation took **88 million** computing hours.

The simulation starts at **5.6 million** years after the Big Bang and goes to **7.68 billion** years later. (Eventually it will simulate up to today, which is **13.7 billion** years after the Big Bang).

It would take **10,000 years** on a single-processor laptop.

The full simulation contains **1.1 trillion** dark matter particles.

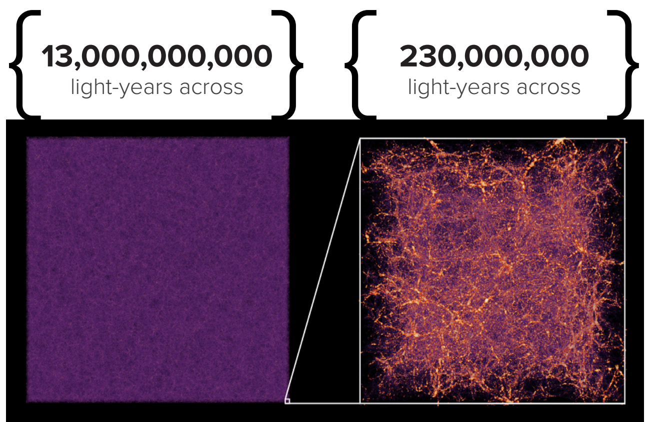
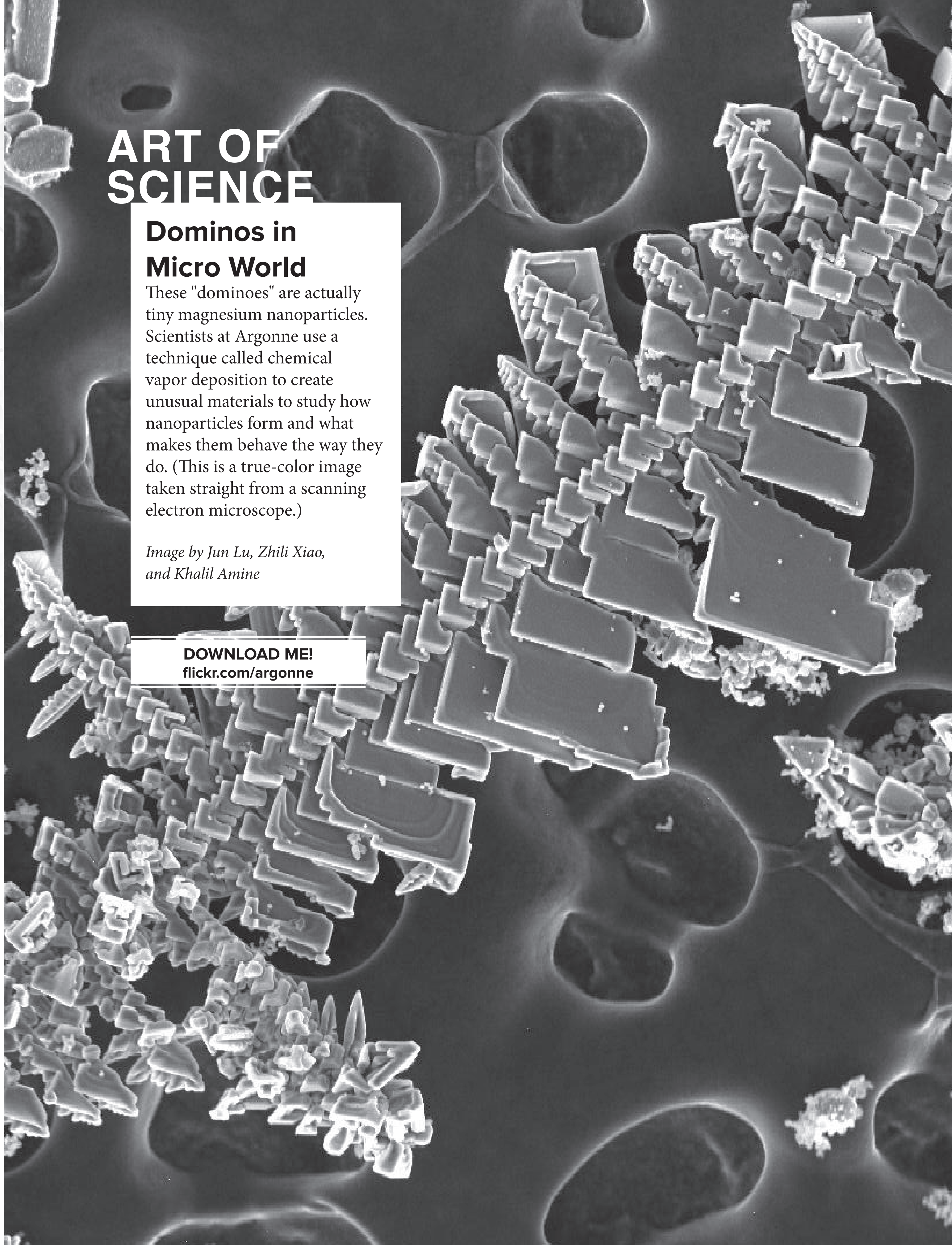


Image by H. Finkel, S. Habib, K. Heitmann, K. Kumaran, V. Morozov, T. Peterka, A. Pope, T. Williams, M. Papka, M. Hereld, and J. Insley, Argonne National Laboratory; D. Daniel, P. Fasel, N. Frontiere, Los Alamos National Laboratory; and Z. Lukic, Lawrence Berkeley National Laboratory.

www.alcf.anl.gov

Watch the full video at http://bit.ly/universesimulation

ART OF SCIENCE



Dominos in Micro World

These "dominoes" are actually tiny magnesium nanoparticles. Scientists at Argonne use a technique called chemical vapor deposition to create unusual materials to study how nanoparticles form and what makes them behave the way they do. (This is a true-color image taken straight from a scanning electron microscope.)

Image by Jun Lu, Zhili Xiao, and Khalil Amine

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SCIENCE BEHIND THE FICTION: PACIFIC RIM

| by Chelsea Leu

Science Behind the Fiction critiques the science and engineering portrayed in popular films and literature.

As a science fiction blockbuster, Guillermo del Toro's *Pacific Rim* isn't necessarily pretending to be totally realistic. The movie pits giant robots against equally large monsters that emerge from an inter-dimensional rift deep in the Pacific Ocean. But a closer look at the science of *Pacific Rim* reveals that quite a few events in the movie couldn't have happened for a more conventional reason: its engineering is all wrong.

In one memorable sequence, the robot Gipsy Danger clobbers a monster amid the skyscrapers of Hong Kong by whacking it with a container ship.

But because of the way it's constructed, the container ship would have taken far more damage than the monster. "You couldn't even drag a container ship, much less use one as a bat," said Argonne engineer Roger Blomquist.

Container ships are only structurally stable when supported by water. "When submarine torpedoes sink ships," Blomquist explained, "the torpedoes don't actually touch the ship at all. Instead, they detonate under the keel, blowing all the water out from under the ship. The ship loses the support it got from the water and easily breaks in half."

The robots in the movie probably wouldn't work all that well in reality, either. Gipsy Danger is the only robot left to defend Hong Kong after an electromagnetic pulse takes all the other robots out of commission. Why? Because, according to pilot Raleigh Becket (Charlie Hunnam), Gipsy Danger is analog, powered by a nuclear reactor. But nuclear reactors aren't analog or digital.

"Calling the reactor 'analog' doesn't make any sense," said Blomquist. "The term 'analog' refers to electronics. It has nothing to do with nuclear power."

Blomquist has experience with both nuclear reactors and really big machines: he served as a nuclear propulsion officer on a U.S. Navy nuclear-powered submarine. At Argonne, he studies the physics of nuclear reactors, investigating how neutrons move and interact within reactor cores.

Nuclear reactors, Blomquist explained, generate lots of heat. That heat can be harnessed to generate electricity, which can then be used to power cities, submarines, and (at least in theory) giant robots. However, a nuclear reactor is controlled by electronic equipment, and this equipment, not the reactor itself, can be either analog or digital.

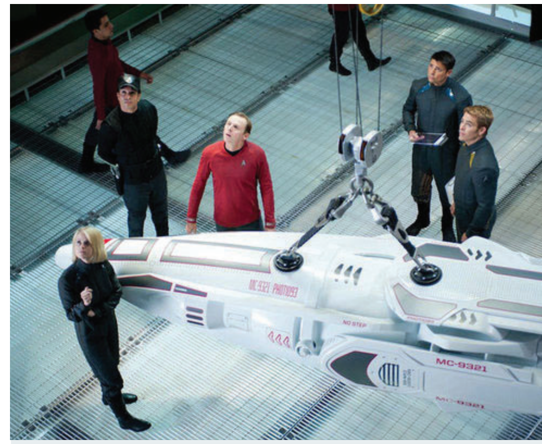
An electromagnetic pulse would have fried all electrical circuits, analog or digital. So it's unlikely that Gipsy Danger would have survived the pulse that took out the other robots.

The size of the nuclear reactor rang true to Blomquist, though. The robot is so gargantuan that it would probably need the same amount of power as a 7,000-ton submarine. Both would require a reactor and power plant the size of say, a Toyota Camry. So the reactor and turbine housed in Gipsy Danger's chest seemed large enough to power the entire robot.

"The nice thing about nuclear energy is that it can produce huge amounts of energy from very small volumes," Blomquist said. "You can get a million and a half times more energy from a kilogram of uranium than from a kilogram of natural gas."

This makes nuclear power a handy fuel supply. So handy, in fact, that some nuclear-powered submarines don't need to refuel for 20 years at a time. Even the Mars rover Curiosity is powered by a small nuclear battery that will last it through its mission.

Questionable science aside, Blomquist was pleasantly surprised to find that nuclear-powered Gipsy Danger is the hero of *Pacific Rim.* This is a welcome departure, he said, from the way nuclear power is usually depicted in science fiction. In *Pacific Rim*, nuclear power is not a fearsome threat, but a viable technology with both risks and rewards. "Instead of relying on tired tropes, this movie's really thinking creatively, and the writers clearly thought about how you would power a machine that size," Blomquist said. "I admire that."



DID YOU KNOW?

Parts of the film *Star Trek: Into Darkness* were filmed at the National Ignition Facility at one of Argonne's sister labs, Lawrence Livermore National Laboratory, in 2012. Normally the facility is being used around the clock by scientists, so the filming had to wait until it was closed for one of its regular maintenance cycles.

Just as the "Star Trek" genre envisions a brighter future for humanity by exploring the universe, NIF's mission is to explore physical realms never before recreated in a laboratory. It has 192 laser beams that focus up to 1.8 million joules of ultraviolet laser energy on a tiny target—creating conditions similar to those that only exist in the cores of stars and giant planets and inside nuclear weapons. It can produce temperatures of hundreds of millions of degrees and pressures of hundreds of billions of atmospheres.

NIF experiments explore many areas, including fusion energy, supernova explosions, and the formation of ultra-high energy cosmic rays.

To learn more about NIF, visit www.lasers.llnl.gov.

PUBLIC LECTURE SERIES

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Argonne is an equal opportunity employer; we value diversity in our workforce.

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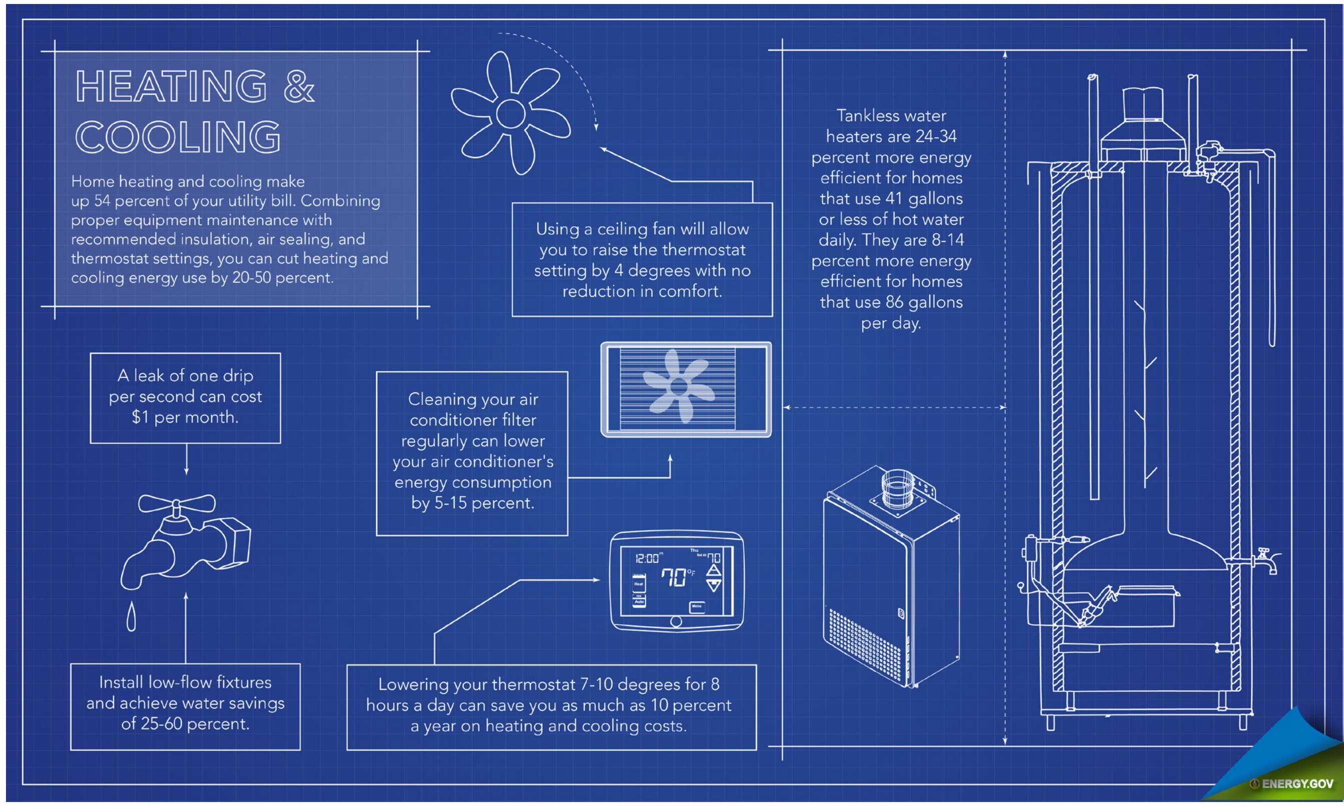
DID YOU KNOW ?

[10] the number of seconds you spend idling before it's more efficient to turn off the car. Turn off your car engine if you will be stopped for more than 10 seconds, except in traffic.

ENERGY SCIENCE AT HOME



Find more energy tips and infographics from the U.S. Department of Energy at **www.energy.gov**

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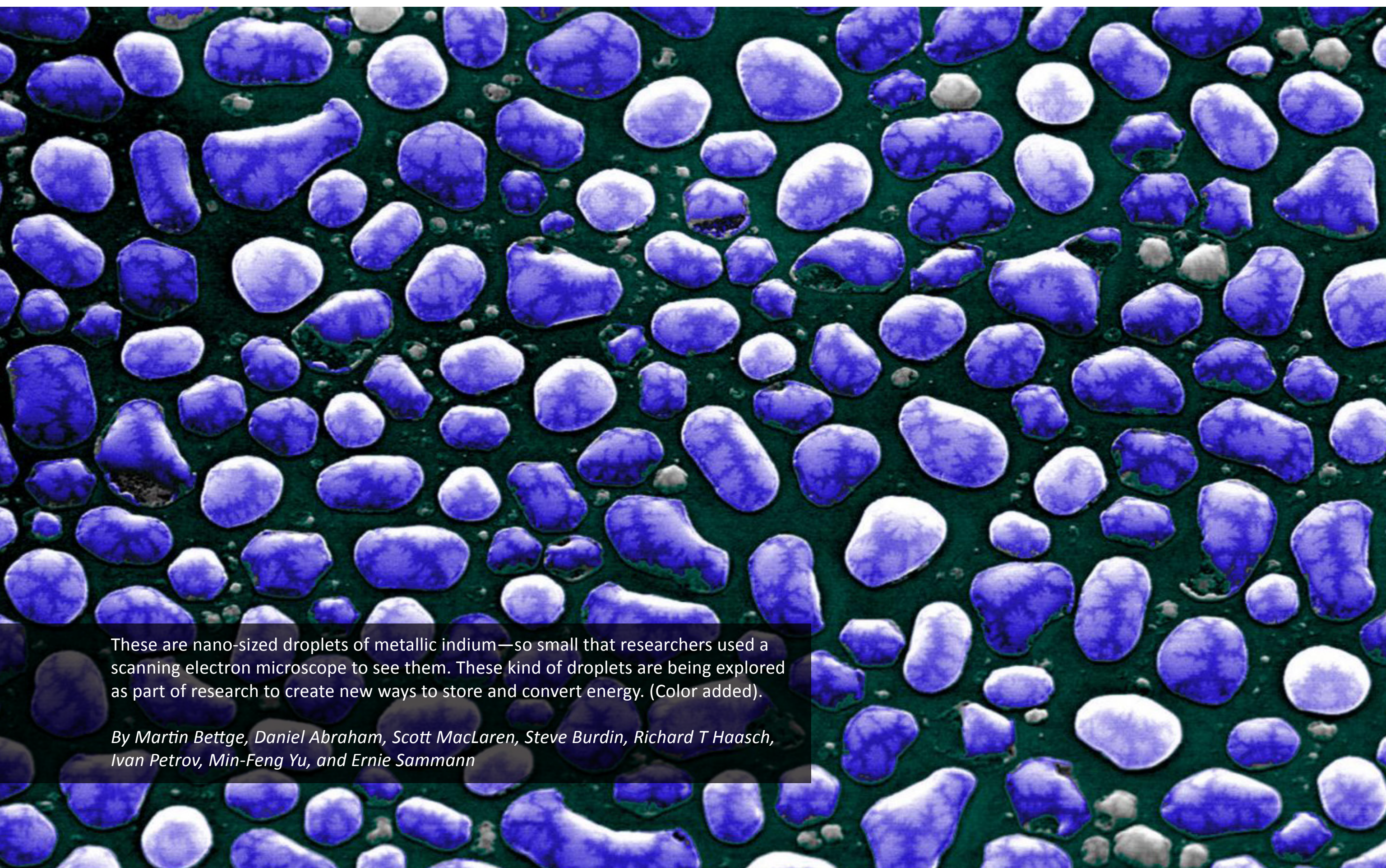

These are nano-sized droplets of metallic indium—so small that researchers used a scanning electron microscope to see them. These kind of droplets are being explored as part of research to create new ways to store and convert energy. (Color added).

By Martin Bettge, Daniel Abraham, Scott MacLaren, Steve Burdin, Richard T Haasch, Ivan Petrov, Min-Feng Yu, and Ernie Sammann