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To the Babylonians, they were earth, sea, sky and wind. To the ancient Greeks, they were earth, water, air, fire and aether. To the Chinese, they were fire, earth, metal, water and wood.

Empedocles, the philosopher, called them roots; the philosopher Plato renamed them elements. And despite the ancient discovery of physical elements such as platinum, tin and zinc, the classical notion of the elements held sway until 1661, when the philosopher Robert Boyle redefined them as substances that cannot be decomposed into simpler substances — an idea that dominated for another two centuries until the discovery of subatomic particles.

In the 19th century, as a growing number of elements were being discovered, scientists began proposing a periodic table in which elements were arranged in order of increasing atomic weight, and by 1869, chemist Dmitri Ivanovich Mendeleev had published the first of a series of papers outlining a periodic table of the elements similar to the one we have today. More than 40 years later, physicist Henry Moseley recognized that the atomic number of the elements in the periodic table was equal to the charge on the nucleus of its atoms.

Today, if you flip open a chemistry textbook or walk into a chemistry classroom, you'll most likely find a horizontal table of the elements remarkably similar to Mendeleev’s. But despite the ubiquity of his design, a quick search on the Internet will yield a myriad of variations, with ovals, triangles and spirals, some in black and white and others in a rainbow of colors.

And so it is that at Purdue University, we present our own periodic table and a report on the elements that our researchers have worked with as of late — as well as a few that have made their mark on history. As Mendeleev once said, “I wish to establish some sort of system not guided by chance but by some sort of definite and exact principle.” While he may not agree with our reordering of things, it is in this spirit of organizing our own endeavors that we present to you our annual report.
Solving the Mystery of Dark Matter

**XENON** | At yearend 2015, a new kid was on the block in Italy’s 34,000-square-foot Gran Sasso National Laboratory, part of the Italian National Institute of Nuclear Physics. Tucked under nearly a mile of rock, the lab is valuable to scientists because of its absence of cosmic-ray background.

The newcomer, named XENON1T (short for Xenon One Tonne) is a detector whose task is to identify dark matter — the undefined mass in the universe whose gravitational pull keeps galaxies and related structures together.

“We know dark matter exists, but we don’t know what it’s made of,” says Rafael Lang, a physics professor. He’s on an international team creating and installing the new detector, which uses the noble gas xenon as a pseudo fishing net.

“It’s 100 times more sensitive to even the faintest particle signals than anything we’ve ever built,” he says of the detector, which replaces XENON100, an earlier model that narrowed their search. “While we don’t yet know what dark matter is, we now know what it isn’t.”

One thought is that dark matter might get its mass from the Higgs Boson, he says. “If so, XENON1T has an excellent chance of discovering dark matter particles within the next couple of years.” – K.M.
Mass Spectrometry, Grocery-Store Style

HELIUM | Five years ago, Purdue University researchers took their miniature mass spectrometer on a road test — to a grocery store to test for traces of chemicals on standard and organic produce.

In the technology's first venture out of the lab, it successfully identified specific chemical residues on apples and oranges in a matter of minutes right in the produce section without having to peel or otherwise prepare a sample of the fruit.

Graham Cooks, the Henry Bohn Hass Distinguished Professor of Chemistry, and Zheng Ouyang, a professor of biomedical engineering, led the team that used the miniature mass spectrometer — which some have likened to Star Trek's "tricorder" — to test for a fungicide on oranges and a scald inhibitor on apples.

"We're trying to take powerful, sophisticated instruments out of the lab and into the real environment where they could help monitor fresh produce all along the supply chain from production and supply to the consumers," said Cooks, who is co-founder of Purdue’s Center for Analytical Instrumentation Development.

In scaling down mass spectrometry for the portable mini-mass unit, the team incorporated low temperature plasma ionization, which uses a slow stream of helium gas to spray charged particles onto a sample. The particles then ionize molecules on the surface, which bounce off and can be vacuumed into the mini mass for analysis.

Conventional mass spectrometers also are cumbersome instruments that weigh more than 300 pounds. The miniature mass spectrometer that the Cooks and Ouyang team developed, called the mini 10.5, is a handheld device roughly the size of a shoebox that weighs 22 pounds.
CHLORINE | Cheap, flexible and easy to install, PEX pipe systems are used in 75 percent of new home construction in the United States today. But while PEX is touted as an eco-friendly alternative to copper piping, which can corrode over time, leach copper metals into the water, or form metal coatings on the inside of pipes, little is known about PEX’s long-term effects.

Andrew Whelton wants to understand how chemicals in water like chlorine, which is used as a disinfectant, react to PEX pipes. Cutting apart different types of PEX pipes and putting clean drinking water inside, his team performed leeching tests and characterized the chemicals that came out.

When chlorine reacted with chemicals leached by the plastic pipes, odor levels for one brand of PEX pipe tripled. While the total mass of chemicals leached by PEX pipes was found to decline after 30 days of testing, odors generally continued as the pipes aged.

“What we found was that how smelly your water is depends on the brand of PEX you select,” says Whelton, an assistant professor of civil engineering and environmental and ecological engineering. He’s working with other engineers and scientists to design future studies. | S.A.
In 2013, a Purdue University-led team of researchers discovered sunlit snow to be the major source of atmospheric bromine in the Arctic, the key to unique atmospheric chemical reactions that purge pollutants and destroy ozone. The team’s findings suggest the rapidly changing Arctic climate — where surface temperatures are rising three times faster than the global average, resulting in a substantial loss of sea ice — could dramatically change its atmospheric chemistry.

While it was known that there is more atmospheric bromine in polar regions, the specific source of the natural gaseous bromine has remained in question for several decades, said Kerri Pratt, a National Science Foundation postdoctoral fellow (now assistant professor at University of Michigan) in polar regions research at Purdue who participated in the research. “We thought that the fastest and best way to understand what is happening in the Arctic was to go there and do the experiments right where the chemistry is happening,” Pratt said.

Henry Hass, known as the father of gas chromatography, led Purdue’s Department of Chemistry from 1932 to 1949. In World War II, he joined the top-secret Manhattan Project to work on the synthesis of fluorine gas for uranium enrichment at Clinton Laboratory (now Oak Ridge National Laboratory) in Tennessee.

Hass student Earl McBee, who co-authored papers on fluorine with his professor, and served as a faculty member and later head of chemistry from 1949 to 1967, is also remembered as a pioneer in organic fluorine chemistry. Like Hass, who left Purdue in 1949 for a career in industry, McBee later served as CEO of Great Lakes Chemical Corp. (now Chemtura).

Purdue’s fluorine legacy continues today with globally recognized fluorine researcher P. V. Ramachandran, a Purdue chemistry professor, whose lab develops methodologies to prepare fluoro-organic molecules for applications such as anti-cancer agents; energy storage for fuel cells; and high-power electronics and weapon systems. “Fluorine is present in most of the blockbuster drugs and is used for PET scanning,” Ramachandran says. “It is also used in Teflon utensils and is important in proton conductor membranes for fuel cells.” L.T.
Hyperthyroidism is one of the most common diseases of older cats, and the prevalence has been increasing since the late 1970s. Iodine is essential for the synthesis of thyroid hormones, and it is possible that hyperthyroidism is related to the amount of iodine in cat food. Catharine Scott-Moncrieff, a professor of veterinary medicine and a specialist in endocrinology, is looking for an answer to this question from a variety of angles.

If left untreated, a hyperthyroid cat may exhibit excessive hunger, vomiting, diarrhea, nervousness, unkempt hair coat and tachycardia. Treatment options for hyperthyroid cats include administration of oral anti-thyroid drugs, thyroidectomy or administration of radioactive iodine. A diet containing a restricted amount of iodine has been shown to decrease thyroid hormone concentrations and improve clinical signs in hyperthyroid cats.

Iodine content of cat food varies widely among commercial cat foods, especially in canned cat food. Scott-Moncrieff and co-authors have called for a review of iodine supplementation standards used in commercial cat foods.

“This research has resulted in improved recommendations for the use of iodine-limited diets for management of hyperthyroidism in cats and has the potential to lead to a greater understanding of the pathogenesis of hyperthyroidism in cats,” Scott-Moncrieff says. | L.T.
Turning Off the Genes for Metabolic Syndrome

If Type 2 Diabetes and obesity run rampant in your family, you might already have resigned yourself to an inevitable future of carb-counting and glucose checks.

But predisposition doesn’t necessarily mean predestination, and so researchers such as Tara Henagan, an assistant professor of nutrition, are examining how epigenetics — the effect of the external environment on our genes — influence the development of metabolic syndrome.

In one experiment, Henagan fed three separate groups of mice a normal, low-fat diet, a high-fat diet and a high-fat diet supplemented with sodium butyrate, respectively. Then she studied their effects on the Pgc1a — a gene which regulates genes involved in energy metabolism.

In addition to improving insulin sensitivity, the sodium butyrate actually helped prevent obesity even when the mice consumed a high-fat diet. In fact, the sodium butyrate combined with a high-fat diet was “strikingly similar” on an epigenetic level to the effects of a low-fat diet without supplementation, she and her co-authors wrote.

Clinical studies may show that sodium butyrate has similar effects on humans who consume high-fat diets or who have obesity and Type 2 Diabetes. Meanwhile, Henagan is digging deeper into the epigenetics. “Understanding the epigenetic mechanisms whereby nutrition and physical activity regulate nuclear gene expression is crucial in understanding, treating and preventing obesity and Type 2 Diabetes,” she says. | A.R.
Improving the Competitive Ability of Native Plants

POTASSIUM  |  Before Europeans settled central North America, prairies dominated the landscape, their tall grasses peacefully coexisting with colorful wildflowers. But in places such as Indiana’s Prophetstown State Park, where the prairie is being restored, invasive weeds are threatening its sustainability. Inspired by research done in the tropics on infertile soil, Kevin Gibson, a professor of botany and plant pathology, is studying how biochar could help or hurt the restoration process.

Biochar is a manmade product similar to charcoal that is created from agricultural waste. Rich in nutrients including potassium, nitrogen, carbon, phosphorus and calcium, biochar releases these into the soil, where they ultimately enhance crops.

“There is some evidence that biochar increases the amount of potassium available for plants” Gibson says. “The potassium may be released directly from the biochar, or biochar helps make it more available in the soil.”

Gibson and his lab have conducted greenhouse experiments ... His conclusion: that biochar appears to have potential to favor the early growth of big bluestem over sericea. Next up are field experiments to assess the long-term effects of biochar on prairie species. | S.A.
CESIUM | A wireless device the size of a rice grain could someday be implanted in tumors to tell doctors the precise dose of radiation received and locate the exact position of tumors during treatment. In 2006, researchers at Purdue’s Birck Nanotechnology Center announced development of a “passive wireless transponder,” which has no batteries and would be activated with electrical coils placed next to the body. Researchers tested the prototype with the radioactive element cesium. The device, which contains a miniature version of dosimeters worn by people in occupations involving radioactivity, could provide up-to-date information about the cumulative dose a tumor is receiving over time. “It’s basically like a very small tuning circuit in your radio,” said Babak Ziaie, professor of electrical and computer engineering. “This will be a radiation dosimeter plus a tracking device in the same capsule. It will be hermetically sealed so that it will not have to be removed from the body.”

LITHIUM | Purdue research probing the complex science behind the formation of “dendrites” that cause lithium-ion batteries to fail could bring safer, longer-lasting batteries capable of being charged within minutes instead of hours. The dendrites form on anode electrodes and may continue to grow until internally short circuiting the device, which in turn may result in battery failure and possible fire. The researchers have developed modeling tools to engineer the size and shape of pores in the polymer fiber-based separator (insulating layer between cathode and anode) to fully suppress dendrite growth. “We are trying to define the fundamental science behind the dynamics of these complex objects so that in collaboration with experimentalists we can make batteries that do not have this problem, last longer, and provide higher energy,” says Edwin García, an associate professor of materials engineering.

RUBIDIUM & LITHIUM | Purdue researchers have created a new type of “ultracold” molecule (LiRb), using lasers to cool atoms (lithium and rubidium) nearly to absolute zero and then gluing them together, a technology that might be applied to quantum computing, precise sensors and advanced simulations. “It sounds counterintuitive, but you can use lasers to take away the kinetic energy, resulting in radical cooling,” says Yong Chen, an associate professor of physics and electrical and computer engineering, who teamed up with Daniel Elliott, a professor of electrical and computer engineering and physics. Other researchers have used the method to create cold molecules out of atoms of other alkali metals, but this is the first milestone with lithium and rubidium.
The Shape-Shifting Promises of Microgels

**BARIUM** Squishy and mushroom-shaped, flexible microgels hold promise as customized drug delivery vehicles and building blocks for tissue engineering. Now, Arezoo Ardekani and her team have created a new, relatively simple method for producing these shape-shifters that could greatly widen their use.

Using microfluidics, in which tiny tubes and channels control micro-quantities of fluids, the researchers mix sodium alginate and polyNIPAAm into uniform droplets. They then inject the droplets into a collecting solution of glycerol and barium acetate.

As the barium ions turn the droplets into gel with new chemical bonds to hold it together, the interfacial effects cause the droplets to change shape. The resulting mushroom-shaped, squishy particles can be shaped further by varying the concentration of glycerol in the collecting solution.

“The novelty of this work is that it is very simple to generate different shapes just by changing the concentration of glycerol,” says Ardekani, an assistant professor of mechanical engineering. Because microgels also can phase-separate, producing a double-sided, or Janus, surface with different physical properties, they could be used to co-deliver two different kinds of medications. Cells also might be encapsulated into the microgels for tissue engineering. | **L.T.**
BERYLLIUM | Purdue nuclear engineers announced in 2005, development of an advanced nuclear reactor fuel that could last longer and burn more efficiently than conventional fuels by using standard uranium dioxide pellets mixed with beryllium oxide (BeO), which conducts heat far more readily. In 2014, three years after the Fukushima nuclear reactor disaster, Deepthi Chandramouli, then a graduate research assistance, and Shripad Revankar, Purdue professor of nuclear engineering, published results of a study that examined how the advanced fuel might operate such conditions as a loss of coolant accident. Their findings: that BeO helps reduce gas gap pressure, the amount of energy stored in fuel and the strain on the outer layer of fuel rods. “The addition of BeO to nuclear fuel will turn out to be advantageous,” they concluded.

CALCIUM | Since 1990, hundreds of teenagers have gathered on the Purdue campus in the summertime to play sports, learn about careers and help set dietary standards for the future.

Camp Calcium, now a staple at Purdue University, was founded by Distinguished Professor and Nutrition Science Department Head Connie Weaver, who wanted to learn more about how diet could improve calcium retention and development of peak bone mass or build stronger bones in young people.

“In the 1980s people were beginning to understand there was a potential link between diet and bone health,” Weaver says. “It was a new idea that what you ate as a child could affect your bone health when you were older, and I wanted to measure that impact. But how could I? It wasn’t feasible for teenagers to eat at home and collect samples on their own, but we could control this in a fun camp format.”

Campers live in a residence hall and eat controlled diets while participating in educational and fitness activities. The six-week camp has evolved over its rich history, adding new fun — and findings — with each session.

“The research from this camp has determined the optimal calcium intake — 1,300 milligrams — for healthy bone mass, and this information is used to set calcium requirements for North America and the national recommended dietary guidelines in adolescents,” Weaver says. | S.A.
MAGNESIUM | De-icing salts help keep our roads safe by preventing ice from freezing on roads and bridge decks. But that safety comes with a price, since the 17 million tons of de-icing salts applied annually to U.S. roadways greatly contribute to their decay. Comparing three different salts, researchers with Purdue's Joint Transportation Research Program found that all three strongly interacted with the concrete to which they are applied, producing additional phases and phase changes that, when expansive in nature, can cause additional cracking and damage to the concrete. And while magnesium chloride is considered more effective at lower temperatures, sodium chloride appears more benign than either magnesium chloride or calcium chloride when reacting with the concrete substrate.

STRONTIUM | Rising at dawn when they hear the mosque’s call for prayer, Michele Buzon and her crew eat a light snack, then head for a burial site more than 3,500 years old. After excavating for a few hours in the northern Sudan desert, they return to their house for breakfast, then dig again until mid-afternoon, when they return home to process findings.

Buzon's bioarcheology team has traveled to Tombos five winters to examine strontium in the dental enamel of human remains to learn about migration in the Nile Valley, where ancient Nubian and Egyptian cultures once coexisted.

With more than 200 remains excavated from individual and group tombs, they have covered about one-third of the site, says Buzon, associate professor of anthropology. Differences in strontium ratios, along with skeletal and mortuary analyses, reveal that biologically and ethnically mixed people lived there, fueling insights on sociopolitical activities and biocultural effects of environmental stress and cultural change.

“These people lived good lives. They have relatively few signs of ill health, nutritional deficiencies, infection or signs of hard labor,” she says. “They also show almost no violent injuries in their bones, and appear to have lived in peace in their multicultural community.” | K.M.

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Here in the United States, where lead-based paint was banned in 1978 and leaded gasoline in 1986, we think of childhood lead poisoning as largely a relic of our past. But in China, where lead regulations have only recently been enacted, medical professionals are eager to find more accurate ways of measuring toxicity.

Linda Nie, an associate professor of health sciences, has developed a portable X-ray fluorescence (XRF) system to measure lead in bone in vivo. She’s now collaborating with physicians at Xinhua Hospital in Shanghai to validate the unit among a group of children with lead poisoning.

While blood lead reflects short-term exposure, bone lead shows long-term exposure, since the majority of lead accumulates in the bone. Nie’s unit shoots a low-energy X-ray into the tibia bone and collects specific signals if lead is present in the bone.

“We want to test whether the portable system is usable. If this is doable, we can use the device in some countries that don’t have access to a large system,” she says.

“We also want to study the effectiveness of lead chelation [removal of heavy metals]. Usually with chelation, we will see blood levels decrease, but they can increase over time because of storage levels in bone.” Measuring lead levels in the bone, then, could give a more accurate measure of chelation efficacy. | A.R.
Robots have traditionally been thought of as rigid, hard systems. Transformers. The Terminator. Roomba home vacuum systems. New technologies by Rebecca Kramer could change that thinking forever.

Kramer, an assistant professor of mechanical engineering and a Forbes 30 under 30 recipient for 2015, is a pioneer in soft robotics. It’s a field that’s developing both flexible robots — for performing surgeries and slinking into tight cracks during search-and-rescue missions — and wearable technology, such as biometric shirts that measure heart rate and respiration.

In order for soft robotics to be produced on a commercial scale, companies need practical manufacturing techniques. With the help of a custom 3D printer, Kramer and her team have created a fabrication method that embeds a gallium-indium liquid alloy inside a rubber-like polymer, forming a network of sensors.

“Soft robotics is such a new concept, but the field has really taken off within the last decade,” says Kramer. “All the components that make up a soft robotic system really don’t exist yet. The Faboratory is part of a small but emerging community that is trying to create these new technologies from the ground up.”

For more information on the Faboratory, visit www.engineering.purdue.edu/Faboratory.
Modern-Day Readings Confirm Little Foot’s Age

**ALUMINUM** In a 31,000-square-foot laboratory punctuated by enormous machines in bright blues and oranges, Purdue scientists have solved a mystery more than 3 million years in the making.

Using state-of-the-art equipment in the Purdue Rare Isotope Measurement (PRIME) Lab, they’ve dated the Little Foot skeleton at 3.67 million years old. That beats Lucy by half a million years.

Little Foot, from South Africa’s Sterkfontein cave, has been studied for two decades. Darryl Granger had previously used his radioisotopic dating technique to measure aluminum-26 and beryllium-10 in rock samples surrounding the fossil, suggesting that Little Foot came before Lucy. His results were questioned, however, since cave formations near the skeleton only dated back 2.2 million years.

But in 2014, the lab’s new gas-filled magnet detector increased the accuracy of his aluminum-26 measurements and verified his earlier results.

“I knew right away this would be big news,” says Granger, an earth, atmospheric and planetary sciences professor who collaborated with researchers around the world. “The new stratigraphy supports our results for the age of the skeleton, while also explaining the considerably younger age for cave formations dated by other methods.”

Marc Caffee, physics professor and PRIME lab director, is impressed by the increased precision. “We hope to measure radionuclides that we can’t measure at all now,” he says. | K.M.
A Breakthrough in Battery-Charging Technology

TIN | Smartphones, golf carts and cochlear implants all benefit from rechargeable lithium-ion batteries. Now, tin could be the key to getting the batteries in these devices to charge in minutes instead of hours.

Vilas Pol, an associate professor of chemical engineering, has found that by replacing conventional graphite electrodes with a network of tin-oxide nanoparticles, charging time can be drastically reduced.

Batteries have two electrodes, an anode and a cathode. The anodes in most of today’s lithium-ion batteries are made of graphite. The theoretical maximum storage capacity of graphite is limited to 372 milliamp hours per gram, hindering significant advances in battery technology.

When replacing graphite “porous interconnected” tin-oxide based anodes, which have nearly twice the theoretical charging capacity, Pol’s team charged experimental anodes in 30 minutes and with a capacity of 430 milliamp hours per gram. That’s because the tin oxide nanoparticles, when heated at 400 degrees Celsius, can self-assemble into a network containing pores, which allows the material to expand and contract during the charge-discharge battery cycle.

“We are not using any sophisticated chemistry here. This is very straightforward rapid ‘cooking’ of a metal-organic precursor in boiling water,” Pol says. “It will certainly become fully affordable in the perspective of broad scale application.” | L.T.
Crossing Phases

**ARSENIC** | An ultrapure gallium-arsenide material taken to pressures greater than that in the depths of the ocean and chilled to temperatures colder than outer space has revealed an unexpected phase transition that crosses two different phase categories.

“To our knowledge, a transition across the two groups of phases had not been unambiguously demonstrated before, and existing theories cannot describe it,” says Gábor Csáthy, an associate professor in the Department of Physics and Astronomy. “It is something like changing water from liquid to ice; except the two phases we saw were very different from one another.”

The ultrapure crystals used in the research were grown by a group led by Michael Manfra, professor of physics and astronomy, materials engineering and electrical and computer engineering. “Our gallium arsenide is unique among semiconductors and other novel materials due to its extremely low level of disorder,” says Manfra. “The extremes required for this science — extreme purity, extreme temperatures — are not easily achieved, but it is worth the effort to discover new phenomena involving the entire sea of electrons acting in concert. This is the biggest kick for scientists like us and why we try to push our experimental techniques to the absolute limit.”

| A.R. |
Nobel Laureate’s Pioneering Work Lives On

BORON  | Delivering his 1979 Nobel Prize in Chemistry Lecture, “From Little Acorns to Tall Oaks – From Boranes through Organoboranes,” Purdue Chemistry Professor Herbert Brown expanded on poet David Everett’s metaphor, predicting the equivalent of new continents in the study of boron compounds.

“We have only scratched the surface,” said Brown, who shared the prize with University of Heidelberg chemist Georg Wittig for developing boron-and phosphorous-containing compounds into important reagents in organic synthesis.

“It will require another generation of chemists to settle that continent and to utilize it for the good of mankind,” Brown said. “But is there any reason to believe that this is the last continent of its kind? Surely not.”

He was right.

By the mid-1980s, Brown’s reagents had contributed to the development of Lipitor and Prozac, two blockbuster pharmaceuticals that have helped revolutionize treatments for high cholesterol and depression respectively. Brown’s impact continues today, says P. V. Ramachandran, a Purdue chemistry professor and longtime Brown research associate who works in boron and fluorine chemistry.

“More and more chemists are contributing to the area of boron compounds, which has great impact in many aspects of societal needs,” Ramachandran says. Among those needs are hydrogen research for alternate energy and the use of organic synthetic methodologies to lower the cost of chemicals in electronics.

“The ‘boron continent’ that Brown discovered is getting populated with time,” Ramachandran says. | K.M.

“Why did I decide to undertake my doctorate research in the exotic field of boron hydrides? As it happened, my girlfriend, Sarah Baylen, soon to become my wife, presented me with a graduation gift, Alfred Stock’s book, The Hydrides of Boron and Silicon. I read this book and became interested in the subject. How did it happen that she selected this particular book? This was the time of the Depression. None of us had much money. It appears she selected as her gift the most economical chemistry book ($2.06) available in the University of Chicago bookstore. Such are the developments that can shape a career.” – Herbert Brown

PHOTO BY DAVID UMBERGER
Purified germanium semiconductors developed by Purdue physicists provided a critical part of the world’s first transistor in 1947. They were ultimately replaced by silicon. Germanium, however, could soon make a stunning return to the semiconductor industry.

Peide Ye, a professor of electrical and computer engineering, is leading a team exploring new uses for germanium, which has a higher mobility of electrons and holes than silicon. This makes for ultra-fast circuits that are used in complementary metal-oxide-semiconductor (CMOS) devices.

Ye’s team has created the first modern CMOS device. The material had previously been limited to “P-type” transistors. Now, the researchers have shown how to make “N-type” transistors. Because both types of transistors are needed for CMOS circuits, the work points to possible applications for germanium in computers and electronics.

Silicon is used to fabricate computer chips, powering everything from smartwatches to supercomputer clusters. But with technological advances quickly outpacing silicon’s capabilities, the semiconductor industry will soon reach the smallest silicon transistor size possible, threatening future advances. “This study provides strong evidence of germanium as a promising candidate to replace silicon in future low-power and high-speed CMOS logic applications,” Ye and his co-authors write. | L.T.
First-in-nation Computer Science Department Marks Milestones

**SILICON** | Big data, cryptography and bioinformatics were as unheard of as Silicon Valley when Samuel Conte left industry to help Purdue launch the nation’s first computer science department in 1962. Now, they’re research topics for faculty and students, with graduates landing jobs in the San Francisco Bay area and other tech hubs.

Conte’s first challenge was establishing computer study as a science rather than vocational training. That achieved, the department admitted 24 master’s and doctoral students, awarding its first degrees in 1963. Undergraduates soon followed, along with new faculty and key research.

After multiple campus homes, the department settled into the new Lawson Computer Science Building in 2006, where a lobby display pays tribute to software engineering, security and science-of-information milestones.

“Conte’s profound vision played a vital role in defining the discipline as we know it today,” says Sunil Prabhakar, professor and department head.

“More than 50 years later, our department is at a critical juncture of growth. In the next few years, we will expand the department by 30 percent and increase the number of graduates, to meet the needs of a workplace eager for our students,” he adds. “Unleashing the potential of big data will be one of our greatest challenges and ultimate achievements, as computer science continues to transform agriculture, industry, medicine, transportation and entertainment.” | K.M.

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1962: Purdue’s Department of Computer Science is created — the first in the nation. Samuel Conte is founding head.

1978: The Department of Computer Science installs a VAX 11/780 computer system running UNIX, the first at a university.

1979: Purdue professor Peter Denning begins collaborating with six other universities on a Computer Science Research Network (CSNET). A representative from Defense Advanced Research Projects Agency (DARPA), which had created the Advanced Research Projects Agency Network (ARPANET) in 1969, advises.

1981: National Science Foundation and (DARPA) agree to establish ARPANET nodes at Purdue University and a few other institutions.

1982: Purdue professor Douglas Comer designs the Xinu operating system instruction and research.

1984: As one of the early collaborators in the ARPANET, the Computer Science Department is assigned one of the first Class B network IP address ranges — 128.10.XX.XX — the address range still used by the department today.

1985: In collaboration with other universities, Purdue establishes the Software Engineering Research Center, funded by the National Science Foundation.

1998: The Center for Education and Research in Information Assurance and Security (CERIAS) is formed at Purdue under the direction of Eugene Spafford, professor of computer science.

2010: Purdue creates the first National Science Foundation Science and Technology Center in Indiana, the Center for the Science of Information, under the direction of Wojciech Szpankowski, the Saul Rosen Professor of Computer Science.
Slippery, slinky and the largest aquatic salamander in the United States, hellbenders, which sometimes stretch more than 25 inches, need clean water and high levels of dissolved oxygen to survive. Because hellbenders keep crayfish from overpopulating, our ecosystem needs them. But their habitats are degrading, and they’re vulnerable to predators when young, so numbers are dwindling.

A Purdue University team headed by Rod Williams, associate professor of wildlife science, has come to their rescue, transporting hellbender eggs from Indiana’s Blue River, their only habitat in the state, to the Aquaculture Research Lab. In the 4,000-square-foot wet lab, hellbenders are hatched and nurtured. After a year, they go to one of three Indiana zoos to mature before releasing them. The zoos offer programs to educate people on hellbenders’ importance and conservation practices that improve water quality.

“If we can find the eggs, we hope to rear and release from 200 to 1,000 over the next three years,” says Williams, whose interest is multifaceted.

“From the research side, there are an unlimited number of questions to ask. From the conservation side, they are the vertebrate group with the highest number of threatened or endangered species. And from the Extension side, they are the least understood vertebrates, making our education work important.”

K.M.
Fatal Bait for Invasive Ants

HYDROGEN | The rapacious Argentine ant is one of the most widely spread invasive species on the planet, taking over cities, orchards and nature parks and building “supercolonies” that link hundreds of nests and millions of workers. The pests can cause serious ecological and economic damage and outcompete native ants. But controlling Argentine ants has proven tricky for growers and natural resource managers because of a lack of effective baits.

Now, associate professor of entomology Grzegorz Buczkowski has helped develop an inexpensive, easy-to-apply solution: spiking water-storing polymers known as hydrogels with a tiny amount of the pesticide thiamethoxam. Often used in gardens to trap soil moisture, hydrogels can absorb 300 times their dry weight in water, expanding into large blobs with a juicy consistency that has proven irresistible to Argentine ants.

“When you drop hydrogels on the ground next to a colony, the ants really go crazy. It’s like a big party,” Buczkowski says.

In his study, hydrogels saturated with sugar water and 0.007 percent thiamethoxam reduced the Argentine ant population in an orchard by about 94 percent in two weeks. “This has great potential for managing invasive ants in agricultural systems and natural environments,” Buczkowski says. | N.V.H.
Transforming the Mindset Around Farm Drainage

NITROGEN | Corn grows during only five months of the year, and drainage is essential to its growth. The other seven months while cornfields are empty, water and nutrients continue to drain away from farms. That’s a long-accepted farming practice, but it’s also harmful environmentally. With $5 million from the United States Department of Agriculture, Jane Frankenberger is devising resources and tools to help with water drainage problems.

There are two main problems, says Frankenberger, a professor of agricultural and biological engineering. One, drainage releases nitrate into waterways, which can harm humans and animals.

Two, water supplies are inconsistent. Even in humid states, there are often reductions in crop yields because there isn’t enough water at critical times. These problems are expected to worsen with climate change.

To combat both issues, Frankenberger is investigating ways to retain water from farm fields through new types of drainage systems, saturated buffers and reservoirs.

“Our goal is to transform the mindset around drainage, Frankenberger says: “Instead of just draining everything off, you actually hold it, and just drain during the parts of the year that you need to.” | S.A.

A Game Changer in Biofuel Production

CARBON | No carbon left behind. This core mission in Discovery Park’s Center for Direct Catalytic Conversion of Biomass to Biofuels (C3Bio) has not changed since its inception in 2009. With a new, $12 million, four-year grant, the center is progressing with game-changing ways of making biofuel production more energy-efficient.

Plant bodies trap carbon from atmospheric carbon dioxide into components of cell walls, a type of chemical storage process. The C3Bio team, led by Maureen McCann, professor of biological sciences and director of the Purdue Energy Center, is harnessing the power of chemical catalysis to transform cell wall molecules into liquid hydrocarbon fuels such as those of gasoline or aviation fuel. Team members are working on new catalytic conversions that deal with the complexity of the biomass substrates.

Moving forward, they aim to translate their basic research into products for the marketplace. McCann hopes to see many more startups using C3Bio-derived technology, such as Spero Energy, a West Lafayette, IN, startup is doing.

“It’s important that we think about how to get a portfolio of fuels and high-value chemicals from biomass,” she says. “We need to think about the integrated bio-refinery, what are the most energy-efficient routes to desired products, what is the life-cycle analysis, what are the most carbon-efficient pathways to the portfolio, because biomass carbon is abundant, but every single carbon atom in it is very precious to us.” | S.A.
Studying the Role of Phosphorus in Kidney Function

PHOSPHORUS | Imagine not being able to drink a glass of water whenever you want or not being able to enjoy a cherished family recipe. These are some of the dietary issues people with chronic kidney disease (CKD) face because of multiple food restrictions.

One nutrient of concern for these patients is phosphorus, found virtually everywhere in our food supply. CKD impairs the kidneys’ ability to remove excess phosphorous from the blood, which can ultimately lead to bone fractures, vascular calcification and death.

Patients with dietary phosphorus restrictions struggle to eat enough protein and often must forgo favorite foods. These challenges might be reduced by better understanding what influences how phosphorous is absorbed from food.

Kathleen Hill Gallant, assistant professor and director of the didactic program in dietetics in the Department of Nutrition Science, studies phosphorus metabolism in humans and rats, both healthy and those with CKD, at two sites: Purdue’s Clinical Research Center and the Indiana Clinical Research Center at IU Health University Hospital, Indianapolis.

“There are many missing pieces in our understanding of phosphorus absorption,” she says. “I hope our work will lead to better therapies to prevent disease progression, comorbidities and death, while improving quality of life.” | K.M.
A Golden Mean for Prostate Cancer Prevention

**SELENIUM** | What does Aristotle have to do with selenium and prostate cancer? According to David Waters, a lot.

“As it turns out, more is not always better,” says Waters, paraphrasing Aristotle’s golden mean, that moral sweet spot between the extremes of excess and deficiency. “With selenium, it’s easy to over-supplement.”

Waters, a professor emeritus of veterinary clinical sciences and director of the Gerald P. Murphy Cancer Foundation in the Purdue Research Park of West Lafayette, points to one of his research team’s studies, whose results were reported in the peer-reviewed scientific journal BioFactors.

In controlled laboratory experiments, selenium triggered the elimination of prostate cells with the most genetic damage — a kind of “homeostatic housecleaning” process that helps keep cancer at bay.

But that only happened at mid-range selenium levels, Waters says.

If you imagine the letter “U,” with one tip being very high selenium levels and the other tip being very low, the ideal level seems to be the trough of the curve. “Measuring selenium status and then titrating selenium levels to mid-range status would seem to offer men a practical and informed approach, rather than blindly taking selenium supplements and risking the downside of unnecessary over-supplementation,” he wrote for the medical website UroToday. | **A.R.**

**SULFUR** | Spiraea alba, a shrub with white flowers, and Spiraea tomentosa, a shrub with pink flowers, are native to much of the Midwest and Northeast in the United States and have great potential for landscape use. However, the acidic soils of their wild habitats are not the kind you’d find in urban Midwestern landscapes, which typically have neutral to alkaline soils. So Michael Mickelbart, an associate professor of horticulture, and colleagues evaluated the growth of these shrubs in landscape soils of different pH levels. Soil pH was reduced by the addition of sulfur. While the size of the shrubs was lower at neutral pH, leaf color was not affected. The research demonstrated that these shrubs can be grown in typical Midwest landscape soils.
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From lighting up color TVs to recharging hybrid car batteries, rare-earth metals like lanthanum have become essential in our tech-driven world. But the inefficiencies and hazards of extracting these bright, silvery metals have prompted Nien-Hwa Linda Wang to engineer a more efficient, environmentally-friendly method.

In 2015, the Purdue Research Foundation filed a patent for Wang’s method for producing high-purity rare earth elements. Crude mixtures of rare earth elements are first separated from rare earth ores or coal ash. The mixtures are then dissolved in a solution and separated into pure fractions using an advanced chromatography method.

The new design produces double the current yield with purities greater than 95 percent. “This is very clean and very compact, and the impact on the environment is much, much less,” says Wang, the Maxine Spencer Nichols Professor in Chemical Engineering. “We use benign chemicals for this very
DYSPROSIUM | Hard disk drives, electric vehicles and wind turbines all benefit from the power of rare earth permanent magnets. But when supplies of rare earth metals, such as dysprosium and neodymium, are low, as they have been in recent years, the use of these elements for magnets has become cost-prohibitive. Teaming up with other researchers at Purdue as well as Lawrence Livermore and Oak Ridge National Laboratories, John Sutherland, Professor and Fehsenfeld Family Head, Environmental and Ecological Engineering, offers this solution: recover and reuse, via recycling and remanufacturing, the magnets that are embedded within consumer products and industrial machinery. Using a hard disk drive as a case study, the researchers concluded that recycling could be cost-effective. This is especially the case if companies are willing to pay someone to manage the used hard disk drives in a manner that destroys or erases the data.

EUROPIUM | In the plant world, the Tobacco mosaic virus (TMV) is prolific and devastating, wreaking havoc on tobacco plants, peppers and tomatoes. But when Michael Harris, the Reilly Professor of Chemical Engineering, teamed up with University of Maryland researchers, they discovered the virus could help them build a new generation of small, powerful and highly efficient batteries and fuel cells. By modifying the TMV’s rods, they provided a nano scaffold that could be loaded with metals including europium. The team filed a patent application in 2010.

high-resolution separation; they’re not toxic or environmentally harmful.”

Wang is in discussions with companies in North America to bring the technology here. But she also hopes China, which dominates the rare-earth market and in recent years has limited exports, will adopt the new process as well.

“If they license the technology from Purdue, they can replace thousands of conventional separators with 20 chromatography columns. The new method will be much more efficient and environmentally benign,” she says. | A.R.
Acoustic pickups used for electric guitars and stringed instruments could have greater sound quality and be much easier to manufacture than conventional ones, thanks to a flexible printed circuit developed at Purdue.

Existing pickup design dates to the 1930s and uses very fine copper wire wound around a bobbin to detect a moving magnetic field. The wires are delicate and easy to break, and the manufacturing process is time-consuming. It is also easy for upper turns of wire to compromise the insulation on the lower winds, which makes for quality problems and lots of build variation.

A novel pickup that replaces the wound wire with flexible printed circuits has been developed by Richard Mark French, associate professor of mechanical engineering technology and director of Purdue’s Engineering Technology Acoustics Lab, and Davin Huston, a clinical assistant professor in Purdue Polytechnic Institute. “The pickups, which use neodymium magnets, are smaller than conventional ones, so they are easier to package. There is also less variation in sound,” French says. The team has filed a patent for the pickup. | L.T.
The types of compounds we are exploring relate to what those working in nuclear energy are thinking about.

Researchers use depleted uranium because it is less expensive and more abundant than transition metals, especially precious ones, such as gold, iridium and platinum. Understanding the reactivity of uranium-carbon bonds is key to harnessing its chemical potential to replace the expensive metals.

Bart’s group is one of only a few in the United States studying the f-block, lower elements, on the periodic table.

“This gives students an opportunity to learn about these elements and their activity, and to train them in safe-handling practices,” she says. | K.M.
Unlocking the Mystery of Neurodegenerative Disease

**MANGANESE** When Yulia Pushkar, associate professor of physics, learned that increased metal concentrations have been found in the brains of people with Alzheimer’s and Parkinson’s diseases, she saw an opportunity.

“The problem of neurodegenerative disease is not solved, and there are many patients diagnosed,” Pushkar says. Using sophisticated x-ray imaging to detect heavy metal, such as iron, copper, manganese and zinc, she got to work.

Her workspace includes a sample prep lab, laser lab and synchrotron facility, needed because its bright, focused x-ray can detect low concentrations of metals.

“The x-ray fluorescence imaging we use is a high-resolution, quantitative technique which can answer some important questions regarding roles of metal ions in the brain,” Pushkar says.

In a recent article, she and co-authors discuss their imaging process and how an overabundance of manganese in the brain, likely caused by occupational
CHROMIUM | The worldwide population of people now younger than 40 who receive hip implants is expected to be 80 million by 2030. In order to speed production to meet the anticipated increased demand, and to create implants that last longer than today’s ones, Yung Shin, a professor of mechanical engineering and director of Purdue’s Center for Laser-Based Manufacturing, is developing technologies using lasers to create longer-lasting, easier-to-produce, more human-friendly and less expensive medical implants. The system, methodology which he announced in 2009, works by depositing gradient layers of a powdered mixture of metal and ceramic materials, melting the powder with a laser and then immediately solidifying each layer to form parts. The process creates patient-customized implants with gradient material structures and compositions that are more compatible with human bodies in a much shorter turnaround time.

exposure, can cause manganism. That’s a neurological condition similar to Parkinson’s. The article appears in Metallomics, and the publication’s cover art, featuring a gold human-head with a padlock, was created by Pushkar with the assistance of Purdue graphic artists.

Gaining new understanding, both of abnormal and normal concentrations of minerals, could help scientists design appropriate therapies to combat manganism.

“I feel good about that,” she says. | K.M.
Creating a Sweet, Disease-Resistant Organic Tomato

COPPER | Consumer demand for organic tomatoes is rising, but growers are struggling to keep pace. Many of the sweetest-tasting crops are susceptible to foliar pathogens, but conventional organic treatment with copper fungicide poses risks to beneficial soil microbes and water quality.

Help is on its way. Lori Hoagland, an assistant professor of horticulture, is leading a multi-state, interdisciplinary team of researchers in developing a new variety of organic, sweet-tasting tomato and undertaking fundamental research in beneficial plant-microbial relationships. The goal of the Tomato Organic Management and Improvement Project, funded by a $2 million grant from the U.S. Department of Agriculture’s National Institute of Farming and Agriculture, is an organic tomato variety that is resistant to foliar disease and can be grown with safe and effective fungicide and biopesticides.

Tomatoes are one of the most important vegetable crops in the world, but the challenges to organic growers are especially felt in the Midwest and Southeast regions of the United States where warm, humid conditions favor these diseases and severe outbreaks can destroy tomato crops. Conventional growers could also benefit from the research, because they could reduce the amount of pesticides used, which would lower their costs.

“The research will serve as a model of how to integrate basic research on plant-microbial relationships with plant breeding and disease management,” Hoagland says. “The project will also serve as a model for participatory varietal development, increase the productivity and sustainability of tomato growers, and develop effective disease management strategies that can be applied in multiple crops.” | L.T.
Detecting cancer can be complicated. Conventional methods require samples of hundreds of cells and can’t provide details on how cancer genes are expressed in individual cells.

But professor of agricultural and biological engineering Joseph Irudayaraj and former graduate student Kyuwan Lee have found a solution, at least for breast cancer detection. Tagging tiny particles of gold — more than 1,000 times smaller than the diameter of a human hair — with “tails” of synthetic DNA, they’ve shown how to measure BRCA1 mRNA splice variants in live cells.

BRCA1 is an oncogene, a gene that can transform a healthy cell into a cancerous one. The number of BRCA1 mRNA splice variants in a cell can indicate the presence and stage of cancer.

When released into a cell, the gold nanoparticles link up on either side of these mRNA splice variants, forming a dimer configuration. Scattering light into the cell makes the configurations twinkle red while free-floating gold nanoparticles shine green. The technique allows BRCA1 mRNA splice variants to be counted, presenting a snapshot of cancer in a single, living cell.

“This is a simple yet elegant technique,” says Irudayaraj. “With this method, we are basically able to count the needles in a haystack.”

While having a positive impact on natural resources and wildlife, wildlife conservation measures can also negatively affect the health of local communities.

This unintended consequence has become apparent to Melissa Remis, a professor of anthropology, who initially studied gorillas in the Central African Republic but has turned her attention to the indigenous BaAka people.

Remis examined 141 people using physical measures and dietary surveys. Her findings indicated poor health and nutritional status, with low protein and iron-deficient diets among the BaAka. These measures have declined relative to data collected before conservation zoning restrictions in 1990 that restricted the BaAka’s forest use and subsequent influxes of migrants and new hunting technologies to the region.

Remis concluded that foragers in transitioning economies are at increased risk of negative health outcomes as they undergo changes in subsistence patterns and diet. “When focusing on conservation and protecting endangered wildlife, we need to remember that those populations live within communities of people who rely on them for material and cultural sustenance,” she says.
**MOLYBDENUM** | When it comes to devices such as cell phones and tablets, the faster and lighter, the better. But the semiconductor industry is reaching the size and speed limits of silicon-based transistors, and new technologies are needed to continue advances. One promising new material candidate for electronic device applications is molybdenum disulfide, which can exist in a “two-dimensional nanocrystals” form with individual sheets less than a nanometer thick. Joerg Appenzeller, the Barry M. and Patricia L. Epstein Professor of Electrical and Computer Engineering and the scientific director of nanoelectronics in the Birck Nanotechnology Center, is actively employing this material for various novel device applications with particular emphasis on demonstrating that molybdenum disulfide based structures can be scaled beyond the limits of conventional transistors.


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**CADMIUM** | Water is essential to boosting agricultural production, but throughout much of the world the idea of using treated municipal wastewater for irrigation struggles to gain traction, largely because of poor public perception and concerns over potential exposure to pathogens and heavy metals. To evaluate the quality of treated wastewaters in study locations in Palestine, Tunisia, Qatar, as well as the state of Indiana, postdoctoral research associate Anne Dare sampled and tested treated wastewater for various heavy metals, including cadmium. For samples taken from Indiana study locations in Kewanna and Bourbon, heavy metal concentrations were well below standard limits and below detectable limits in many cases. While those results can’t be generalized to all Indiana municipalities, Dare notes that treated wastewater quality is closely monitored in Indiana. “Raising public awareness of the strict oversight provided and the relatively low risk associated with land application of treated wastewater may increase farmer and public confidence in this practice,” she adds.

**NICKEL** | Inexpensive microrobots capable of probing and manipulating individual cells and tissue for biological research and medical applications are closer to reality with the design of a system that senses the minute forces exerted by a robot’s tiny probe. David Cappelleri, an assistant professor of mechanical engineering, has designed and built a “vision-based micro force sensor end-effector,” which is attached to the microrobots like a tiny proboscis. The microrobot body is made from a nickel magnetic layer driven by an exterior magnetic field.
Handy References for Healthful Fish Eating

MERCURY | Seafood is an important part of a healthy diet, but too much of certain kinds can have harmful effects. Charles Santerre, professor of nutrition science, studies the risks from mercury- and PCB-contaminated fish and the benefits of healthy fats on sensitive populations such as pregnant women and nursing infants, and has turned his findings into handy reference guides.

Santerre has created a “Fish for your Health” wallet card, which is being used by the Indiana and Florida departments of health to educate pregnant women on safe fish consumption. The card is also being distributed to more than 1 million people by hospitals and health departments nationally.

Santerre has also created an app for mobile devices that can advise pregnant or nursing women on healthful seafood consumption. His colleague, Kathleen Hill Gallant (here and p. 24) used the app during her recent pregnancy.

Fish4Health was the winner of the Babble Top 25 iPhone Apps for Pregnancy in 2011. He hopes to expand his research, and use the app as a method to collect data for future studies.

“It’s amazing how many people in the world have smart phones,” he says. “It’s the best way to deliver information around the planet.” | S.A.
The existence of the Majorana fermion particle — which holds great promise for quantum computing — was predicted in the 1930s, but until recently had eluded observation. In 2012, Leonid Rokhinson paired up with University of Notre Dame researchers to construct a nanowire composed of a semiconductor (indium antimonide) and a superconductor (niobium), providing a solid-state structure where they could observe the particle. “For regular particles, a result of several consecutive exchanges does not depend on the order of the exchanges; but when you swap Majorana particles, the exact order of the exchanges leaves a mark on their quantum mechanical state,” said Rokhinson, a professor of physics and courtesy professor of electrical and computer engineering. “This change in state is like a passport book full of stamps; it provides a record of exactly how a group of particles arrived at the current arrangement.”

In 2010, Purdue chemist Ei-ichi Negishi shared the Nobel Prize in Chemistry for his work pioneering metal-based reactions called palladium-catalyzed cross-coupling — now known as “Negishi coupling” — that allows for easy and efficient synthesis of complex organic compounds.

Negishi, the Herbert C. Brown Distinguished Professor of Organic Chemistry and Teijin Limited Director of the Negishi-Brown Institute, began his pioneering work with palladium in the 1970s. Palladium-catalysis offers a highly precise and selective method for coupling two different (or same) carbon groups, and thus provides a powerful tool for synthesizing a wide range of chemicals used in medicine, agriculture, electronics and many others.

The methods — palladium and sometimes nickel or copper — are widely used in industry and research in a variety of applications, including pharmaceutical antibiotics that work on drug resistant bacteria, agricultural chemicals that protect crops from fungi, and electronic light-emitting diodes used in the production of extremely thin monitors.

In accepting the Nobel Prize, Negishi indicated that the work in palladium-catalyzed cross-couplings in organic synthesis has been ongoing for many years and will continue. “The full impact of it is not yet realized. Others will use what we have learned, build on what we have discovered and use this to help people and technology in ways that we can only imagine today,” he said in 2010.

Negishi shared the 2010 Nobel Prize with Richard Heck of the University of Delaware and Akira Suzuki from Hokkaido University in Sapporo, Japan. (Both Negishi and Suzuki studied at Purdue under Professor Herbert Brown, a 1979 Nobel Laureate.)
**PLATINUM |** A new process developed at Purdue to convert all biomass into liquid fuel could make possible mobile processing plants someday. Purdue researchers filed a patent application on the concept in 2008 and have now demonstrated that it works in laboratory experiments. “The demonstration is a step toward commercialization,” says Rakesh Agrawal, the Winthrop E. Stone Distinguished Professor of Chemical Engineering. “Because the process can produce hydrocarbons in a single tandem step, it clearly has a potential to have a positive impact on the biofuels sector.” Critical to the technology is a new platinum-molybdenum catalyst and an experimental reactor system developed by a team of researchers including Agrawal, Fabio Ribeiro, the R. Norris and Eleanor Shreve Professor of Chemical Engineering and Nick Delgass, Maxine S. Nichols emeritus Professor of Chemical Engineering. The new method offers advantages over conventional technologies because it produces biofuel from all biomass as opposed to a portion of the biomass such as cellulose or lignin only, Agrawal says.

**RHODIUM |** Cancer and viruses may someday find themselves blinded by the light of therapies, thanks to the work of Purdue cancer researchers. A team of scientists announced in 2004 that it had developed a group of rhodium-based compounds that, when exposed to light, could kill tumor cells and deactivate a virus closely related to the West Nile and yellow fever viruses. Unlike the ordinary substances used for chemotherapy, these chemicals are not harmful to the body in general; they only become lethal to DNA when activated by light of a specific frequency. “This research offers hope that someday we may be able to replace standard chemotherapy drugs with others that are far less generally harmful to a patient’s body; they would be lethal only when and where they are activated by light,” said Harry Morrison, now an emeritus professor of chemistry.
**SILVER** | New research findings by Ji-Xin Cheng in 2010 suggested that an experimental ultrasensitive imaging technique that uses a pulsed laser and tiny metallic “nanocages” might enable both the early detection and treatment of disease. The gold-silver nanocages exhibit a bright “three-photon luminescence” when excited by the ultrafast pulsed laser, with 10 times greater intensity than pure gold or silver nanoparticles. The signal allows live cell imaging with negligible damage from heating.

**SCANDIUM** | A future of quantum computers and communications technologies is now one step closer, thanks to work by Purdue’s nanotechnology researchers. Early in 2015, graduate student Mikhail Shalaginov co-authored a paper showing that the Purdue team could enhance the emission of single photons by using “hyperbolic metamaterials,” which harness clouds of electrons called surface plasmons to manipulate and control light. Purdue researchers had previously created “superlattices” from layers of the metallic and dielectric materials, such as titanium nitride and aluminum scandium nitride. Unlike some of the plasmonic components under development, which rely on the use of noble metals such as gold and silver, the new metamaterial is compatible with the complementary metal–oxide–semiconductor manufacturing process used to construct integrated circuits.

**ZINC** | Researchers in Purdue’s Birck Nanotechnology Center have created a new “plasmonic oxide material” that could make possible devices for optical communications that are at least 10 times faster than conventional technologies. Their optical material made of aluminum-doped zinc oxide (AZO) is able to modulate — or change — how much light is reflected by 40 percent while requiring less power than other all-optical semiconductor devices. “Low power is important because if you want to operate very fast — and we show the potential for up to a terahertz or more — then you need low energy dissipation,” says doctoral student Nathaniel Kinsey. “Otherwise, your material would heat up and melt when you start pushing it really fast.”
Creating Durable Thermophotovoltaic Systems

From man-portable systems to residential power generation units, thermophotovoltaic (TPV) systems hold promise as off-grid energy sources. Durability and efficiency, however, limit widespread use.

Now, a team of Purdue electrical and computer engineering researchers has developed plasmonic metamaterial absorbers and emitters that can take the heat, literally. By replacing silver and gold — which cannot withstand high temperatures — with titanium nitride and zirconium nitride, they hope to improve TPV cell performance.

“These materials remain stable at high operational temperatures, required for efficiency and performance,” says Urcan Guler. A former postdoctoral research associate with Vladimir Shalaev, distinguished professor, and Alexandra Boltasseva, associate professor, he is now chief scientist at Nano-Meta Technologies Inc., a startup the three launched.

Besides improving TPV cell efficiency, other promising applications of the trio’s technology include data storage — using heat to record data onto magnetic disks — and cancer care — injecting titanium nitride nanoparticles into the bloodstream, where they seek out and kill cancer cells when illuminated with infrared light.

“These refractory plasmonic materials exhibit unique optical properties that will boost thermophotovoltaic device efficiencies,” Guler says. “These will boost efficiencies, lead to enhanced power generation and promise solutions for a variety of challenges.” | K.M.
TUNGSTEN | Woodworkers who want their cutting tools to stay sharper and last longer might consider splurging for air conditioning. Rado Gazo, a professor of wood processing and industrial engineering, tested tungsten-carbide router bits that use cobalt as a glue to hold the tungsten-carbide molecules together. Friction heats the bits as they make cuts, causing a chemical reaction that results in the loss of some cobalt. Gazo found that treating the router bits cryogenically, as well as cooling them while they cut, could increase the tools’ lives, and in some cases double them. His findings were reported in 2009 in the Journal of Materials Processing Technology.

YTTRIUM | Today’s diesel engines perform better and are more energy efficient than ones of the past, but these changes have placed higher performance demands on the materials used for manufacturing engine blocks. Automotive manufacturers are looking into compacted graphite iron (CGI) as a new engine-block material, but while it’s strong, it’s also stiff and hard. In 2006, a research team led by Yung Shin, professor of mechanical engineering, developed a technique that uses a carbon dioxide laser and a neodymium-doped yttrium aluminum garnet laser to locally soften the CGI prior to machining, thereby making CGI engine manufacturing faster and cheaper.
Researchers at Purdue University, Stanford University and Cornell University announced in 2002 they had produced a carbon nanotube transistor with better properties than silicon transistors of an equivalent size. Instead of silicon dioxide, the device used zirconium oxide, which has a higher dielectric constant, as the gate insulator. “The integration of advanced dielectrics into nanotube materials is promising for pushing the performance limit of molecular electronics,” Mark Lundstrom the Don and Carol Scifres Distinguished Professor of Electrical and Computer Engineering, and his co-authors wrote.
Arun Ghosh, the Ian P. Rothwell Distinguished Professor in the departments of Chemistry and Medicinal Chemistry and Molecular Pharmacology, is the recipient of the 2015 Herbert Newby McCoy Award.

The award recognizes Ghosh for his extraordinary contributions in broad areas of organic, bioorganic and medicinal chemistry that have improved human health.

“I am deeply honored to receive the Herbert Newby McCoy Award,” Ghosh said. “At Purdue University, a lot of exciting things are going on in our laboratories. I am fortunate to work with talented researchers here.”

Ghosh’s research group is involved in multidisciplinary projects in synthetic organic, bioorganic and medicinal chemistry. His extensive knowledge of aspartyl proteases’ structure-function relationships and synthetic organic chemistry, coupled with his creativity, has led him to be recognized as one of the world’s foremost leaders in the field of structure-based molecular design.

His seminal contributions in this area include his concept-based design and discovery of a potent HIV protease inhibitor, named darunavir, which has shown unprecedented drug resistance profiles against HIV. It was approved by the Food and Drug Administration as the first treatment for multidrug-resistant HIV and received expanded approval in 2008 for all people with HIV/AIDS, including children.

Ghosh, who joined the Purdue faculty in 2005, also designed a molecule that has significant promise in treating Alzheimer’s disease. Several drugs based on the molecular target have made it to clinical trials, including one based on a molecule Ghosh designed previously.
Ronnie Wilbur, recognized as a pioneer for her interdisciplinary work in linguistics and speech, language and hearing sciences, is the recipient of the 2015 Purdue University Research and Scholarship Distinction Award.

The award honors Wilbur, who holds joint appointments in Linguistics and the Department of Speech, Language and Hearing Sciences, for her work on the linguistic structure of American Sign Language, its perception and production by native deaf signers, and its application to deaf education.

“With its non-traditional vision,” Wilbur said, “Purdue has made it possible for me to work across college boundaries to collaborate with experts in other fields to help keep my research at the leading edge of my field.”

Wilbur, who came to Purdue in 1980 as a visiting associate professor, has conducted groundbreaking research in sign language for three decades and is largely responsible for the genesis of empirical research in the area of sign language.

Technology, particularly the development of new methods for analyzing sign language parallel to what we can do for speech, is a high priority in her Lyles-Porter Hall laboratory, home to the only sign language research center in the Midwest.

Grants from the National Institutes of Health and National Science Foundation have furthered Wilbur’s research into visual syllable structure, grammatical use of facial expression and word order, and how to use those sign language components in digital innovations for educating young deaf children in English and math.

Wojciech Szpankowski, the Saul Rosen Professor of Computer Science, is the recipient of the inaugural 2015 Arden L. Bement Jr. Award. One of Purdue University’s top three awards for research, the Bement award recognizes distinguished research in pure and applied science and engineering.

The award recognizes Szpankowski for his outstanding contributions to the development of innovative analytic methods, leading to solutions of several open problems in analytical information theory and computer science.

Szpankowski’s scholarship and leadership established the Purdue Center for Science of Information, the first National Science Foundation’s Science and Technology Center in Indiana. As the Center’s director, Szpankowski leads an interdisciplinary team of the best minds from across the nation to extend the information theory from Claude Shannon’s seminal mid-20th century work to modern settings, through knowledge discovery and information extraction from massive databases.

“Science is fun, sometimes it is rewarding, but you do it for the joy of it,” said Szpankowski, who came to Purdue in 1985. “I thank Professor Bement and Mrs. Bement for establishing the Arden L. Bement Jr. Award. It is an honor to be the first recipient of this award. I am grateful to my Purdue colleagues for recognizing my research, and I thank all of my collaborators and co-authors for letting me shine for our joint work.”

The Arden L. Bement Jr. Award was established this year by Purdue Professor Emeritus Arden Bement and his wife, Louise Bement.
MASS SPEC PIONEER ELECTED TO NATIONAL ACADEMY OF SCIENCES

Graham Cooks, the Henry Bohn Hass Distinguished Professor of Chemistry and co-director of Purdue’s Center for Analytical Instrumentation Development, has been inducted into the National Academy of Sciences, one of the highest honors given to a scientist in the United States.

Cooks is a pioneer in the field of mass spectrometry, which identifies the contents of a sample by measuring the mass of its ions, or electrically charged molecules.

Cooks is among 84 new members and 21 foreign associates elected to the academy this year. Members are elected in recognition of distinguished and continuing achievements in original research. He joins four Purdue colleagues as current members or foreign associates of the academy: H. Jay Melosh, Distinguished Professor of Earth, Atmospheric and Planetary Sciences and Physics; Ei-ichi Negishi, Nobel laureate and the Herbert C. Brown Distinguished Professor of Chemistry; Michael Rossmann, the Hanley Distinguished Professor of Biological Sciences; and Jian-Kang Zhu, Distinguished Professor of Plant Biology.

PROFESSOR PURSUES NEUROMORPHIC COMPUTING RESEARCH

Kaushik Roy, the Edward G. Tiedemann Jr. Distinguished Professor of Electrical and Computer Engineering, has been named a National Security Science and Engineering Faculty Fellow. He will use his grant to study neuromorphic computing.

Neuromorphic computing is not intended to replace conventional general-purpose computer hardware, based on complementary metal-oxide-semiconductor transistors, or CMOS. Instead, it is expected to work in conjunction with CMOS-based computing.

“There are certain problems CMOS general-purpose computers do very well, such as complex mathematical computations,” Roy says. “However, there are other tasks, CMOS has great difficulty with, such as facial recognition, which the human brain can easily accomplish.”

Computers based on neuromorphic computing with spin-neurons, proposed by his research group to mimic biological neurons and synapses, might be 10 to 100 times better at certain tasks such as handwriting, image and facial recognition, compared with state-of-the-art CMOS technology.

FACULTY MEMBERS BECOME ACADEMY FELLOWS

Three Purdue University professors have been named fellows in the National Academy of Inventors (NAI):
Jan Allebach, the Hewlett-Packard Distinguished Professor of Electrical and Computer Engineering; Graham Cooks, the Henry Hass Distinguished Professor of Chemistry; and Phil Low, director, Purdue Center for Drug Discovery and the Ralph C. Corley Distinguished Professor of Chemistry.

They join two elected last year: Mike Ladisch, director of the Laboratory of Renewable Resources Engineering and Distinguished Professor of Agricultural and Biological Engineering; and Rakesh Agrawal, the Winthrop E. Stone Distinguished Professor of Chemical Engineering. Former Purdue Provost Tim Sands was a charter fellow in 2012.

Election to NAI Fellow status is a high professional distinction for academic inventors who have made a tangible impact on quality of life, economic development, and the welfare of society.

LOW HONORED FOR OUTSTANDING ACHIEVEMENT IN CHEMISTRY IN CANCER RESEARCH

The American Association for Cancer Research (AACR) has recognized Phil Low with the ninth annual AACR Award for Outstanding Achievement in Chemistry in Cancer Research at Purdue University.

Low is the Ralph C. Corley Distinguished Professor of Chemistry and director of the Center for Drug Discovery at Purdue University in West Lafayette, Indiana. He is also a founder and chief science officer of two biopharmaceutical companies, Endocyte Inc. and On Target Laboratories LLC.

He was honored at the AACR’s annual meeting in Philadelphia in 2015 for his pioneering development of low molecular weight molecular weight ligands to selectively deliver attached therapeutic and imaging agents into pathologic cells. This targeted therapeutic approach improves potency and reduces toxicity.

Currently, nine low molecular weights, ligand-targeted drugs are being tested in cancer clinical trials. The technology also has the potential to motivate fundamental changes in surgery.

BIOLOGICAL SCIENCES PROFESSOR ELECTED AS AAAS FELLOW

Stephen Konieczny, a professor of biological sciences, has been named a Fellow with the American Association for the Advancement of Science (AAAS), the world’s largest general scientific society.

The distinction recognizes notable work to advance science or its applications, and fellows are elected by peer members. The association presented 401 new fellows last winter during the annual AAAS meeting in San Jose, Calif.

Konieczny was honored for his contributions to the fields of development and disease, particularly for advances in defining the transcriptional circuits involved in muscle and pancreas development.
THREE HONORED FOR TEACHING, RESEARCH, ENGAGEMENT

Three professors whose careers have demonstrated excellence in their teaching, research and engagement missions received Purdue’s Morrill Awards in 2015. They are:

**Gebisa Ejeta**, Distinguished Professor of Plant Breeding & Genetics and International Agriculture, who has made extraordinary contributions to improving the food supply for millions of poor people, especially in his native Ethiopia and other parts of sub-Saharan Africa;

**Michael Ladisch**, Distinguished Professor of Agricultural and Biological Engineering, and Director of LORRE, who has made key advances in the production of low carbon footprint biofuels from corn, agricultural residues and cellulosic materials;

**Wallace Tyner**, the James and Lois Ackerman Professor in Agricultural Economics, whose clear vision of the energy economics field, bolstered by his undergraduate degree in chemistry, has allowed him to address the economics of biofuels starting in the 1970s and delineate the connection of energy economics with agricultural economics.

PURDUE CALUMET PROF LECTURES ON PHILOSOPHY OF DANCE ON FULBRIGHT SCHOLARSHIP

**Renee Conroy**, an associate professor of philosophy at Purdue University Calumet, spent the spring 2015 semester in the United Kingdom as a Fulbright Scholar.

Conroy was at the University of Roehampton, where she taught a course in the philosophy of dance, conducted research for a monograph on the subject and presented professional papers on such topics as improvisational dance, the nature of grace as an aesthetic property of dance, and modern ruins.

“I have loved the arts, thinking about the arts, and thinking about artful thinking ever since I can remember and have spent much of my life enjoying the pursuit of activities in these domains,” Conroy says.

HUBER WINS 2014 COMMERCIALIZATION AWARD

**Jessica Huber**, a professor in Purdue University’s Department of Speech, Language and Hearing Sciences, received the Outstanding Commercialization Award for Purdue University Faculty in 2014.

The award is given annually to a faculty member in recognition of outstanding contributions to, and success with, commercializing Purdue research discoveries. It was established with an endowment gift from the Central Indiana Corporate Partnership Foundation. Huber is chief technology officer of SpeechVive Inc., whose behind-the-ear smart device helps people with Parkinson’s disease speak more loudly and communicate more effectively.
**ENGINEERING PROFESSOR JOINS FOOD, AG RESEARCH FOUNDATION BOARD**

Michael Ladisch, distinguished professor of agricultural and biological engineering, has been appointed to the board of directors of the newly created Foundation for Food and Agricultural Research, which Congress authorized in the 2014 Farm Bill.

Ladisch, who also is director of Purdue’s Laboratory of Renewable Resources Engineering, member of NAE, and holds a joint appointment in the Weldon School of Biomedical Engineering, was one of 15 board members appointed by U.S. Agriculture Secretary Tom Vilsack.

Operating as a nonprofit corporation, the foundation will leverage public and private resources to increase the scientific and technological research, innovation, and partnerships critical to boosting America’s Agricultural economy.

**PURDUE ENGINEER RECEIVES 2015 HERMAN PINES AWARD IN CATALYSIS**

Fabio Ribeiro, the R. Norris and Eleanor Shreve Professor of Chemical Engineering, has received the 2015 Herman Pines Award in Catalysis. He was honored during the Catalysis Club of Chicago Spring Symposium in 2015 in Naperville, Ill.

Ribeiro has been a faculty member in the School of Chemical Engineering at Purdue since 2003. He is an editor of the Journal of Catalysis, the flagship journal of the field, since 2010. He is a Fellow of the American Institute of Chemical Engineers (AICHE).

**AGRONOMIST BROUDER APPOINTED TO EPA SCIENCE ADVISORY BOARD**

Sylvie Brouder, professor of agronomy, has been appointed to the U.S. Environmental Protection Agency’s (EPA) Science Advisory Board.

Brouder, who is the Wickersham Chair of Excellence in Agricultural Research, was appointed following a rigorous selection process. She will serve through September 2017, providing expertise on ecological and agricultural issues.

The Science Advisory Board was established by Congress in 1978 and provides independent advice on technical issues to the administrator of the EPA. It also reviews the quality and relevance of scientific and technical information used by the agency in proposing policies and regulations.

Brouder focuses her research on crop nutrition and soil fertility, and she provides technical information on plant nutrition, nutrient management and cropping systems to farmers, county educators and industry. She also studies carbon and nitrogen cycling, soil sequestration, the relationship between roots and soil, greenhouse gas emissions and water quality impacts of intensively managed agricultural systems.

**DISTINGUISHED PROFESSOR APPOINTED TO FDA BOARD**

Connie Weaver, Distinguished Professor and head of the Department of Nutrition Science, has been appointed to the Science Board of the Food and Drug Administration (FDA). Her term began in January 2015.

The Science Board advises the FDA commissioner and other officials on specific complex scientific and technical issues important to FDA and its mission, including emerging issues within the scientific community. The board also helps the agency keep pace with technical and scientific developments; provides input into the FDA’s research agenda; and advises on upgrades to its scientific and research facilities and training opportunities.
ENGINEERING DEAN HONORED IN ROCHESTER

Leah Jamieson, John A. Edwardson Dean of Engineering and Ransburg Distinguished Professor of Electrical and Computer Engineering, has received the Rochester Institute of Technology’s first Kate Gleason Medal for Leadership in Engineering Education. The award recognizes the influential role that academic leaders of engineering colleges play in creating the engineers of tomorrow.

Jamieson received the award in 2015 during a ceremony in Rochester. Following the awards ceremony, she presented a public lecture to students and faculty on her vision for the future of engineering education.

FOOD SCIENCE EXPERT TEACHES AT MOSCOW UNIVERSITY

Purdue University professor Kevin Keener was awarded a Distinguished Fulbright Fellowship to teach food science and food engineering at Russian State Agrarian University - Moscow Timiryazev Agricultural Academy in Russia during the 2014 spring semester.

Keener served as the Distinguished Chair in Agricultural Technology and Education, teaching classes to 120 undergraduate students and 30 graduate students. He also helped train colleagues and industry representatives in Russia on food safety, food technology and food security.

Keener’s research into food processing engineering has led to inventions such as a process for rapidly cooling eggs to inhibit the growth of Salmonella and other bacteria. He also developed a radiant fryer, which can cook food that retains its “fried” flavor while containing up to 50 percent less fat and fewer calories than food cooked using conventional deep-fried methods.

PROFESSOR UKKUSURI RECEIVES FULBRIGHT INNOVATION AND TECHNOLOGY AWARD

Satish Ukkusuri, professor of civil engineering, has been named a recipient of a 2015-16 Fulbright-Colciencias Innovation and Technology Award, a block grant designed to support U.S. scholars to conduct research and lecture at a Colombian university.

Ukkusuri is working with computer engineering and civil engineering researchers at Universidad del Norte in Colombia to develop novel data-driven solutions based on data from social media, mobile phone and other information technologies with applications to Barranquilla and the surrounding region. Northern Colombia is expected to be a hub of economic activity in the coming years and will be recognized as one of the “digital smart cities” with tremendous opportunity for future growth. The collaboration is considered an important step in strengthening the Purdue Engineering and Colombia partnership.

PURDUE CALUMET GRAD TRAVELS TO AFRICA ON FULBRIGHT AWARD

Jonathan Wilson, who graduated from Purdue University Calumet in 2015, has received a prestigious Fulbright Student Award for 2015-16. He is believed to be the first Purdue Calumet student to gain the Fulbright recognition.
Last fall, Wilson left for Ivory Coast in western Africa, where he is teaching English to students of various ages and backgrounds.

“I’m excited to be selected, but I’m even more excited about what it means for other Purdue Calumet students — that it’s possible for this to happen,” Wilson said. “And even though I’ll be the teacher, I know I’m going to learn a lot from my students.”

KECK FOUNDATION TO FUND PURDUE RESEARCH ON SPECTROSCOPIC IMAGING

A team of Purdue University researchers has been awarded a $1 million W.M. Keck Foundation grant to develop a new type of imaging technology for cell and tissue analysis.

“This work is potentially very important because if we know the chemical content of tissue we can do early detection of disease with biomarker sensitivity, and this is not possible with current medical imaging technologies,” says Ji-Xin Cheng, a professor in Purdue’s Weldon School of Biomedical Engineering and Department of Chemistry and scientific director of label-free imaging at Purdue’s Discovery Park.

Cheng, who is lead researcher, is collaborating with Andrew Weiner, the Scifres Family Distinguished Professor of Electrical and Computer Engineering, and Mingji Dai, an assistant professor in the Department of Chemistry.

FOOD TOXICOLOGY EXPERT GOES TO WASHINGTON

Charles Santerre, professor of food toxicology and Purdue Extension specialist in the College of Health and Human Sciences, served as a National Academy of Sciences Jefferson Science Fellow for 2014-15. Santerre was a science adviser on foreign policy issues with the U.S. Department of State.

The Jefferson Science Fellows program was created to engage academic scientists in the formation and implementation of U.S. foreign policy. Purdue leads the nation in the number of Jefferson Science Fellows accepted into the program, which started in 2003. Previous Jefferson Fellows from Purdue include Melba Crawford, Suresh Garimella and Jay Gore, all from the College of Engineering.
FROM THE PRESIDENT

Our researchers’ achievements in discovery and commercialization are markers of real progress in Purdue’s goal to become an economic engine for Indiana, the nation and the world. Thanks to their extraordinary contributions, our reach is extending to all corners of the world.

Mitch Daniels
President

FROM THE PROVOST

The multiplicity of disciplines at Purdue creates unmatched richness for our research endeavors. Our university is held in high regard because our diverse faculty members collaborate across disciplines to tackle grand challenges and to offer profound insight into the human experience.

Deba Dutta
Provost and Executive Vice President for Academic Affairs and Diversity

FROM THE EXECUTIVE VICE PRESIDENT FOR RESEARCH AND PARTNERSHIPS

As a 21st century land-grant institution, Purdue University is committed to improving lives through basic and translational research. By partnering across campus and around the globe, our researchers are helping to turn this vision into reality.

Suresh Garimella
Executive Vice President for Research and Partnerships
System-wide Sponsored Program Awards and Expenditures

As a leading research university in the state of Indiana with a global reputation of excellence, Purdue is dedicated to maximizing our resources to build a research enterprise that supports impactful research. During FY 2015, Purdue received more than $401 million in sponsored program awards system-wide.

With these awards, faculty will continue to push the boundaries of discovery and raise the profile of both the research and student experiences at Purdue University.

Last year’s awards from industry and foundations totaled $133.6 million, a 36 percent increase from the previous year. Since 2010, award totals for industrial and foundation projects have more than doubled.

Committed sponsors partner with Purdue, enabling faculty and staff researchers to respond to 21st century global challenges.

**KEY:**
- DOA  U.S. Department of Agriculture
- DOE  U.S. Department of Energy
- DHHS  U.S. Department of Health and Human Services
- PRF  Purdue Research Foundation

**Multiple Sources**

**Funding from the American Recovery and Reinvestment Act of 2009 are included in this chart.**