UNIVERSITY OF DELAWARE

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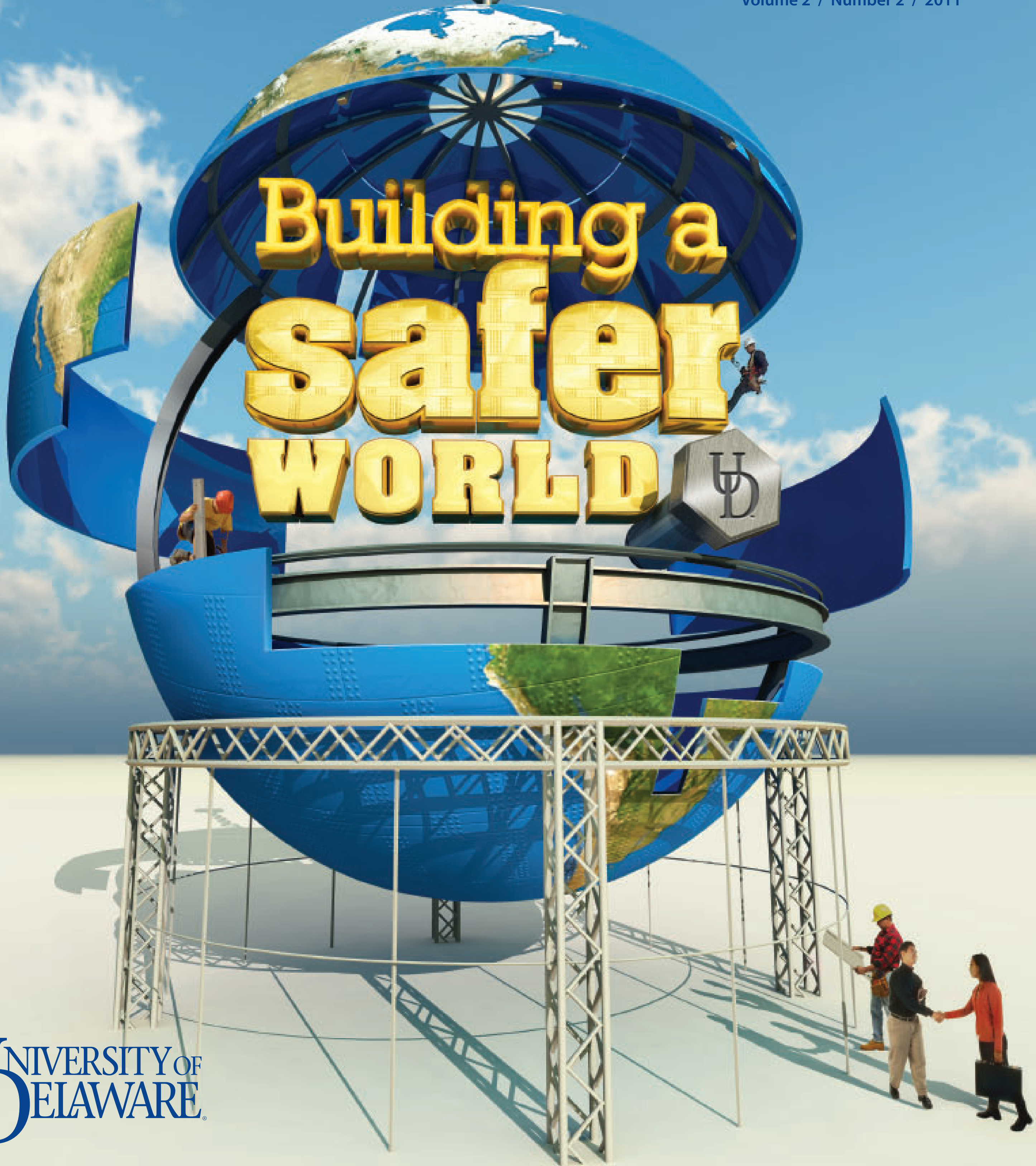

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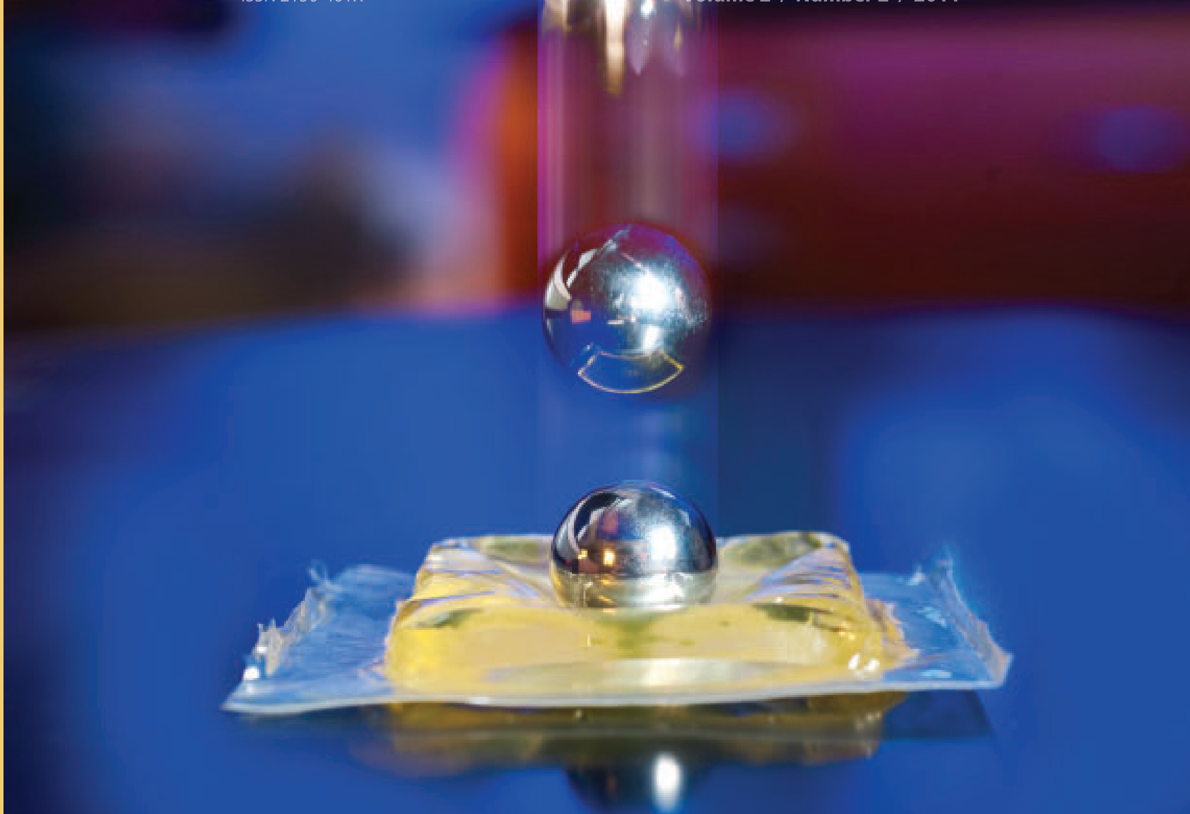

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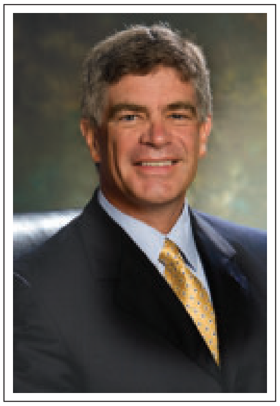
In this issue

FROM THE PRESIDENT



Never before has "Building a Safer World" been a more complex or more challenging proposition. As globalization enables unprecedented opportunities for transnational understanding and partnership, it enables, too, unprecedented opportunities for conflict. Threats to national security are many, and there's scarcely a sector that doesn't introduce a potential vulnerability. In a global world, a "safe nation" is a matter of degrees. But those degrees matter.

The University of Delaware is helping to make the U.S. — and the world — safer places to be. We've long worked with defense agencies and military partners to develop technologies that protect and support our soldiers in war zones and our civilians back home.* UD's Center for Composite Materials, for instance, has been a U.S. Army National Laboratory Center of Excellence for some 25 years.

The University's national security and defense activities were advanced considerably last year with the signing of an R&D partnership with the U.S. Army's Research, Development and Engineering Command, headquartered just 30 miles from UD at Aberdeen Proving Ground in Maryland. That partnership has yielded several statements of work touching everything that goes into the electronic battlefield.

In this issue, you'll read about some of the innovations UD researchers are working on — innovations with significant security and defense benefit:

- Composite materials that mitigate blast effects, like structural collapse and debris impact;
- A mobile ad hoc network that allows secure wireless communication on the battlefield;
- Autonomous underwater vehicles that detect unexploded munitions;
- Liquid "body armor" that hardens within milliseconds when struck with bullets, blades or bombs;
- Millimeter wave spectrum imaging that spots and identifies IEDs;
- Carbon nanotubes that signal defects in advanced composite materials;
- Antidotes that detoxify deadly nerve agents.

As we continue our work in information and defense technologies, as we continue to ensure the U.S.'s bio-, agri- and cyber-security, we know that one of the most important ways UD is helping to safeguard national security is by educating the next generation of leaders — scientists, engineers, policymakers and advisers, analysts and diplomats — prepared for emerging challenges but working, always, for peace.

Patrick T. Harker
President, University of Delaware

**Our support to soldiers continues off the battlefield as well. With a large group of partners, UD recently was awarded a five-year, $19.5-million Department of Defense grant to establish orthopaedic rehabilitation care that helps soldiers with severe musculoskeletal injuries function without impediments in everyday life.*

Building for the future

by Mark Barteau

As we publish this issue of *UD Research,* it is impossible not to reflect on the irony of our theme, "Building a Safer World," chosen months ago to highlight the University of Delaware's significant activities related to safety, security and defense. By the time you read this, we will know more about the recovery from the triple tragedy of earthquake, tsunami and nuclear reactor failure in Japan. And yet while our attention is absorbed by the immediate, the broader issues that face us are timeless. In this country, where divisions about the nation's priorities have rarely been more stark, it is perhaps worth remembering a few words from the preamble of the U.S. Constitution — to "secure the blessings of liberty to ourselves and our posterity…."

To secure for ourselves and our posterity … a safer, healthier, more prosperous, more sustainable, more just world in which opportunities abound for the advancement of our progeny and for the improvement of the human condition. What parent since the dawn of *Homo erectus* has wished for anything less? And however we prioritize the characteristics of the world that we would bequeath to future generations, how much of "our lives, our fortunes, and our sacred honor," to quote another of America's founding documents, are we willing to commit to building that future?

Mark Barteau, *Senior Vice Provost for Research and Strategic Initiatives, and the Robert L. Pigford Chair of Chemical Engineering*

The modern research university plays a unique role in the future of our civilization. On one hand, its role is fundamentally conservative, preserving and transmitting the cumulative knowledge of human society. On the other hand, our role is profoundly revolutionary, creating new knowledge that will transform society in ways that cannot be forecast. Nations that are eager to transform themselves are pouring unprecedented resources into research and development; here in the United States, we debate whether we can afford to invest.

We can't afford not to! Like any prudent investor, we need a balanced portfolio. Support for the full spectrum of R&D, from the fundamental to the applied, has been a hallmark of federal investments since Vannevar Bush's visionary elaboration of science as the "Endless Frontier" at the end of World War II and the subsequent establishment of the National Science Foundation. While NSF is at the core of science and engineering research and education, support for fundamental research across many of the mission agencies of the federal government, including the National Institutes of Health, and the Departments of Defense, Energy, Agriculture, Commerce and others, has been the "seed corn" that has grown up to produce the Nation's leading position in science and technology over the past 60 years. And we must not forget the corresponding support of scholarly and creative efforts in the arts and humanities by the respective national endowments for those fields. Man does not live by bread (or iPads or flat screens) alone.

Why does this matter? Because, according to one study, every dollar invested in R&D returns $40 to our economy in GDP growth. And because the workings of the R&D engine behind that return are far more complicated than media sound bites usually convey. Basic research cannot be summoned at will to solve problems of national importance. Conversely, while curiosity-driven basic research sometimes results in unimaginable breakthroughs, more often it does not. Regardless of whether one sees knowledge creation as providing the push, or application the pull, the route from discovery to application is not one-way — and it is far from straight or certain.

I hope that the stories in this issue will provide some insights into the nature of research in a leading institution like ours as well as into the exciting work that holds the promise of a better and safer world. From the fundamental research in chemical synthesis of UD's own Nobel laureate, Richard Heck, that has enabled the production of new drugs and agrichemicals, to work on flexible body armor that is leading to unexpected applications in the medical arena, to understanding the factors behind undesirable behaviors from bullying to terrorism, to the advances needed to meet the cyber security needs of our military, our banks, and every one of us, the interplay between fundamental research and application is unmistakable.

Finally, our most important investment in building the future is in those who will not only help to build it, but those who will live it. Our students benefit directly from the investment of federal, state and private funding in the research enterprise, and they are the ones who will lead it in the future, who will compete on the global playing field. As we said in the Path to Prominence,™ *we will achieve levels of excellence, intensity and breadth of research and of graduate and postdoctoral education never before seen at the University of Delaware.* We're on our way!

UNIVERSITY OF DELAWARE'S

Richard Heck Wins Nobel Prize in Chemistry

How the challenge of planting an empty yard blossomed into science's highest honor

When Richard Heck was in his early teens, his father moved the family from Massachusetts to a brand-new house on a barren lot in California. Heck, an only child, was given the task of landscaping.

"We had an empty yard, and it was my job to select and install the plants," he says. "I got concerned with fertilizers and sprays and realized I needed to know more about the nutrients and pigments in plants. That got me into chemistry, and I followed it into high school and the university, and I haven't regretted it."

On Dec. 10, 2010, in a stately ceremony in Stockholm, Heck, the Willis F. Harrington Professor Emeritus in the University of Delaware Department of Chemistry and Biochemistry, was presented the Nobel Prize in Chemistry by King Carl XVI Gustaf of Sweden.

Heck, who was recognized first, and Ei-ichi Negishi of Purdue University and Akira Suzuki of Hokkaido University in Sapporo, Japan, were cited "for palladium-catalyzed cross couplings in organic synthesis." The scientists, who shared a $1.5 million award, were honored for discovering "more efficient ways of linking carbon atoms together to build the complex molecules that are improving our everyday lives."

The University of Delaware community was ecstatic as they watched the live webcast of the awards ceremony. Fellow chemists at UD and beyond praised Heck's accomplishments.

"It is wonderful to see our colleague honored so prominently," said Klaus Theopold, chairman of the University's Department of Chemistry and Biochemistry. "Dick Heck did his ground-breaking work at UD in the very early days of organometallic chemistry, and even back then he thought deeply about reaction mechanisms. I remember being inspired by a book of his as a graduate student. Its title, *Organotransition Metal Chemistry — A Mechanistic Approach,* set the agenda for scores of researchers who followed in his footsteps. Heck's contributions extend well beyond the reaction he is now rightly famous for, and we are pleased to no end that he is finally getting the recognition he deserves."

Prof. E. J. Corey of Harvard University, who won the Nobel Prize in Chemistry in 1990, said that recognition for the palladium catalysis discoveries was overdue and may have been delayed by the field's multifaceted nature and its sizable number of distinguished scientists.

"In my mind, Dr. Richard F. Heck stands out among this group as the obvious and early pioneer whose work was not only exceedingly original and important, but also of great heuristic value. He awakened the community of synthetic chemists to the revolutionary nature of palladium catalysis.

"Dick Heck is a modest and admirable person. I hope that the award of the Nobel Prize brings him the satisfaction of knowing how greatly his peers value his contributions to the science of chemistry," Corey said.

"The impact of Heck's chemistry in the field of pharmaceutical manufacturing has been profound," noted William A. Nugent, senior scientific fellow at Vertex Pharmaceuticals. "At my company, palladium coupling is used in the synthesis of over half the drugs currently under development, and I believe this experience is typical across the pharmaceutical industry. Indeed, it is difficult to imagine how some of these molecules could be synthesized at all without chemistry which is traceable to Heck's seminal contributions."

MARKUS MARCETIC

"When you're doing the work, you don't know what's going to become of your efforts. It was not clear in the beginning that this was going to be anything special."

— Richard Heck

UD's **Richard Heck** (center) is presented the Nobel Prize in Chemistry by King Carl XVI Gustaf of Sweden in an illustrious ceremony at the Stockholm Concert Hall on Dec. 10, 2010.

AP PHOTO/SCANPIX SWEDEN/HENRIK MONTGOMERY

Cultivating a new chemical reaction

When Heck graduated from high school, his parents encouraged him to continue his education. His father was a salesman in a department store, and his mother a housewife. Neither had a college degree.

Heck enrolled at UCLA and earned a bachelor's degree in chemistry in 1952 and a doctorate in 1954, working under the supervision of Prof. Saul Winstein, whom Heck deemed "brilliant."

"He had a very good reputation, and that's why I went to work for him," Heck says.

After postdoctoral research in Winstein's lab, Heck took a position with Hercules in Wilmington, Del., in 1957. In 1971, he joined the faculty in the UD Department of Chemistry and Biochemistry, where he remained until his retirement in 1989.

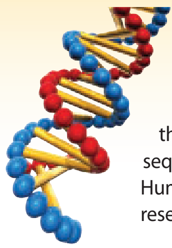
While at UD, he discovered the "Heck Reaction," which uses the metal palladium as a catalyst to get carbon atoms to connect up —a difficult feat in nature.

The discovery has enabled the production of new classes of pharmaceuticals for treating cancer to HIV, asthma, migraine headaches, stomach ailments and other

How Heck's Discoveries Changed the World

New Pharmaceuticals

The Heck Reaction revolutionized the manufacture and discovery of drugs — for treating arthritis, cancer, HIV and many other diseases. The painkiller Aleve and asthma treatment Singulair are just a few examples.



DNA Sequencing

A modification of the Heck Reaction, Sonogashira Coupling, is key to preparing the fluorescent dyes in DNA sequencing — essential for the Human Genome Project, disease research and forensics.

Sun Protection

Sunscreens and sun-protective cosmetics rely on the Heck Reaction for the production of octyl methoxycinnamate, a compound that absorbs the sun's UV rays and is used to reduce the appearance of scars.

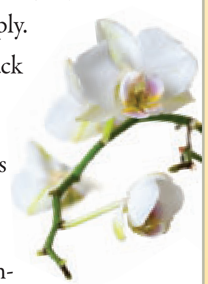
maladies. The work revolutionized DNA sequencing, making possible the coupling of organic dyes to the DNA bases, which was essential for the Human Genome Project. Heck's achievements reverberate throughout our lives every day, in products ranging from sunscreens to super-thin computer monitors.

Rather than a "Eureka moment," Heck says the research "sort of grew slowly and developed into something of value. When you're doing the work, you don't know what's going to become of your efforts. It was not clear in the beginning that this was going to be anything special."

Susan James was hired in 1974 to be Heck's secretary. An administrative assistant in the department today, she remembers her former boss and now-Nobel laureate as a prolific writer.

"He was very serious and dedicated. It seemed that he was publishing at least one journal article a month," she says, recalling the multi-step roll-the-paper-in, roll-the-paper-out process on her IBM Selectric typewriter to make the long dashes forming the sides of the hexagonal benzene molecules in scientific figures.

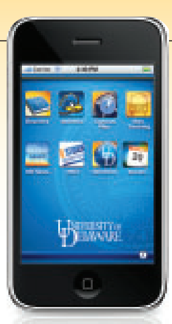
Today, Heck says, his research days are over and he is "completely retired. I've done my share," he notes simply.



Coming full circle, he's back working with plants, raising orchids at home in Quezon City, the Philippines, with his wife, Socorro. They've been married since 1979.

"I really enjoyed my chemistry very much, and that's why I think I was successful," he says. "It was a fascinating subject to me and things worked out well for me, which led me to keep at it."

— Tracey Bryant

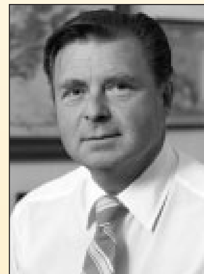


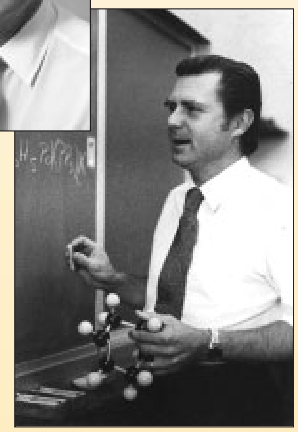
Future Electronics

PPV, a polymer made with the Heck Reaction, emits light in response to an electrical current, thanks to a layer of organic compounds. Organic LEDs are being used in the screens of next-generation TVs, smart phones and computers.

Symposium celebrates Nobel Laureate Richard Heck

On Thursday, May 26, 2011, the University of Delaware will host "Frontiers in Catalysis," a symposium in honor of Richard F. Heck, Willis F. Harrington Professor Emeritus of Chemistry and Biochemistry, and winner of the 2010 Nobel Prize in Chemistry. Register at **www.udel.edu/nobelsymposium/**.





Richard Heck *served on the UD faculty from 1971 until his retirement in 1989.*

"Prof. Heck's discoveries have changed the world, leading to significant advancements in human health and medicine to electronics and energy research," said UD President Patrick Harker. "We are delighted to welcome him back to the University of Delaware for this day of science and celebration, honoring his ground-breaking contributions."

The chemical process Heck invented, known as the "Heck Reaction," fundamentally changed how molecules are made, according to Tom Apple, University provost and professor of chemistry. Apple was a graduate student in the Department of Chemistry and Biochemistry when Heck was on the faculty.

"Dick Heck's research launched entire new classes of pharmaceuticals for fighting diseases such as cancer," Apple said. "His work was essential for the Human Genome Project and fields such as proteomics, as well as the development of new energy technologies ranging from organic LEDs to sugar-based fuel cells."

The symposium will feature internationally prominent speakers from academia and industry. Heck's co-laureate Ei-ichi Negishi, the Herbert C. Brown Distinguished Professor of Chemistry at Purdue University, will deliver the keynote address as the 2011 Heck Lecturer.

Other speakers include Stephen L. Buchwald, the Camille Dreyfus Professor of Chemistry at the Massachusetts Institute of Technology; Todd Nelson, director of pharmaceutical sciences at Merck; Melanie Sanford, professor of chemistry at the University of Michigan; Victor Snieckus, Bader Chair in Organic Chemistry at Queen's University; and Dean Toste, professor of chemistry at the University of California Berkeley.

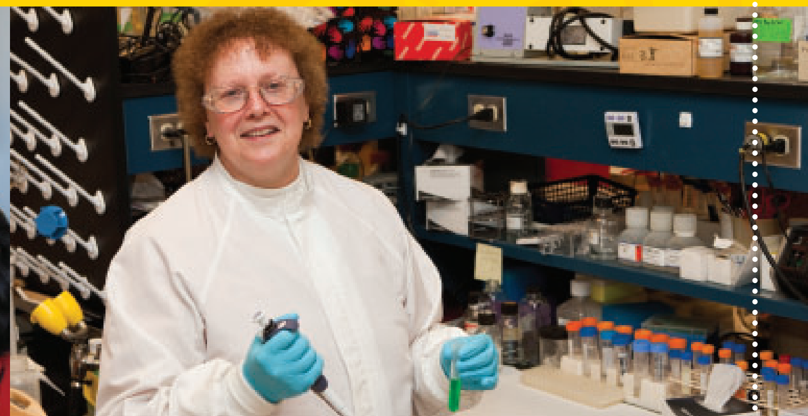
Primary sponsors include the University of Delaware through the Office of the Provost, the College of Arts and Sciences, and the Department of Chemistry and Biochemistry; Dow Chemical Company; and Ashland Inc.

Additional support is being provided by the American Chemical Society, DuPont, the Center for Catalytic Science and Technology at UD, and the Delaware Biotechnology Institute.

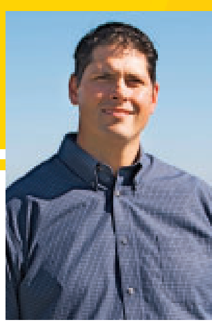
University of Delaware | Dow | International Year of Chemistry 2011 | Ashland — With good chemistry great things happen.

FACULTY & STUDENT HONORS

Mary Ann McLane, the Carnegie Foundation for the Advancement of Teaching's Delaware Professor of the Year, mentors all levels — from high school to undergraduate and graduate students, to junior faculty.



Matt Oliver is one of only 100 researchers nationwide selected to receive the 2010 Presidential Early Career Award for Scientists and Engineers.



Oliver receives presidential award

Matt Oliver is providing a new view of the ocean. He's analyzing biological and physical signatures that appear in satellite data streams to identify where marine organisms live, at what abundance and under which environmental conditions.

The assistant professor of oceanography in UD's College of Earth, Ocean, and Environment won the 2010 Presidential Early Career Award for Scientists and Engineers (PECASE). It is the highest honor bestowed by the U.S. government on young professionals early in their research careers. Winners are selected based on their pursuit of frontier research and a commitment to community service.

"Science and technology have long been at the core of America's economic strength and global leadership," said President Obama at the awards announcement this past November. "I am confident that these individuals, who have shown such tremendous promise so early in their careers, will go on to make breakthroughs and discoveries that will continue to move our nation forward in the years ahead."

Award winners receive up to a five-year research grant to further their study in support of critical government missions. Oliver's grant is from the National Aeronautics and Space Administration (NASA).

"Understanding the spatial and temporal distribution of ocean ecosystems with satellites has allowed us to make predictions about a wide variety of ocean processes, including the vertical structure of the ocean, the expansion of ocean deserts and the abundances of key commercial fisheries," Oliver said. "These results are directly applicable to marine resource management and marine spatial planning."

McLane chosen Delaware Professor of the Year

Mary Ann McLane believes that education is all about empowerment. The professor of medical technology in the College of Health Sciences at UD teaches by sharing her extensive experience, as well as her passion for the medical technology profession and for lifelong learning. She encourages and challenges the young adults in her classroom and mentors them in her research laboratory.

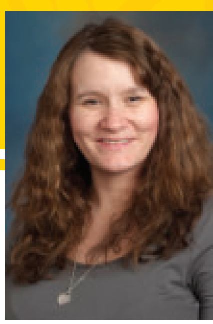
McLane's dedication recently was recognized by the Carnegie Foundation for the Advancement of Teaching, which selected her as the 2010 Delaware Professor of the Year. McLane was one of more than 300 nominees across the United States.

"I am thrilled for my department, our college, the University, our state and my profession to win this award," said McLane. "As president of the American Society for Clinical Laboratory Science in 2009–2010, I worked to 'put a face' on this profession as a critical component of modern health care. My role as a teacher is an important part of that mission — I want to make this discipline more visible and inspire students to follow careers in clinical laboratory science."

Many of the students who have worked in McLane's research lab have gone on to complete graduate programs in biochemistry, molecular biology, optometry, physician assistant and medicine.

Yet McLane's teaching impact has gone far beyond her own classroom and lab. She has published teaching materials used nationally and receives requests for her teaching expertise from around the world.

Cara Robinson is one of only eight students selected nationally for the K. Patricia Cross Future Leaders Award given by the Association of American Colleges and Universities.



Doctoral student honored with national leadership award

Cara Robinson, a doctoral student in UD's School of Public Policy and Administration, has won the K. Patricia Cross Future Leaders Award, an honor given by the Association of American Colleges and Universities (AAC&U) to graduate students who show "exemplary promise as future leaders of higher education."

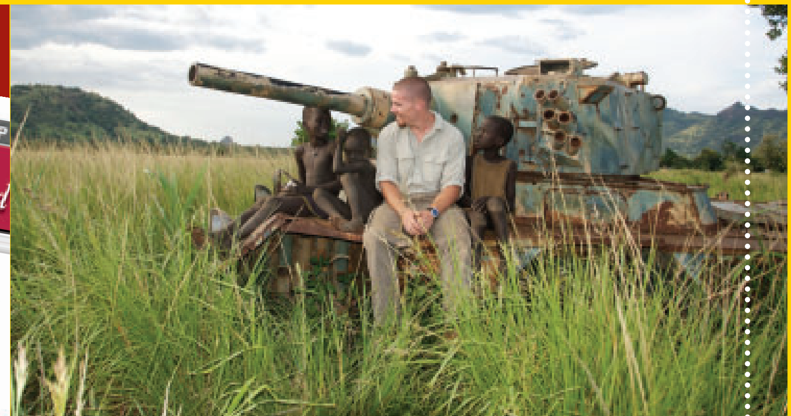
AAC&U is the leading national association concerned with the quality, vitality and public standing of undergraduate liberal education. It was founded in 1915 and comprises more than 1,200 member institutions, including UD.

Robinson is one of eight students selected from a pool of more than 225 nominations. She and her fellow awardees "represent the finest in the new generation of faculty who will teach and lead higher education in the next decades," said AAC&U President Carol Geary Schneider.

As a doctoral student, Robinson has taught undergraduate and graduate courses, mentored incoming freshmen, conducted graduate research for UD's Center for Community Research and Service (CCRS), collaborated with local non-profits on community-based research projects and served as executive director of the Homeless Planning Council of Delaware, an independent non-profit organization.

"Cara is not satisfied by just posing questions and finding answers, but seeks to apply them to real-world issues and problems and encourages others to do the same," said Steven Peuquet, her adviser and CCRS director. "She has a rare blend of intelligence, vision, practicality, diplomacy and friendliness that combine to make her an outstanding young educator, researcher and leader."

Matthew Watters, the 12th Rhodes Scholar in UD history, plans a career in global health science where he can continue helping others, including communities in Sudan and Haiti where he volunteers.



Watters named Rhodes Scholar

Matthew T. Watters, of Ramsey, N.J., a senior neuroscience major and political science minor at the University of Delaware, recently joined an elite class. He was named a 2010 Rhodes Scholar.

One of the most prestigious academic awards available to American college students and the oldest award for international study, the Rhodes Scholarship covers all expenses for two or three years of study at the University of Oxford in England.

Watters is UD's 12th Rhodes Scholar.

Watters volunteers as an emergency medical technician (EMT) in Haiti and has helped raise $50,000 to rebuild a hospital there destroyed by the earthquake. He also has worked with tribal leaders in Sudan, teaching hospital staff how to reduce mortality and helping to create infection control committees.

"The Rhodes Scholarship, which recognizes recipients' dedication to service alongside academic accomplishment, is an appropriate honor for Matt, whose work in Sudan and Haiti is a testament to his commitment to helping others — and, I think, a good prediction of how his future studies will profoundly benefit humanity," said UD President Patrick Harker. "As one of 32 students nationwide awarded this honor, Matt finds himself in exceptionally good company. I know we're all excited to see what he does next."

Watters will begin his studies at Oxford in October 2011 and plans to work toward a master of science degree in global health science. Following Oxford, he plans to attend medical school and pursue a career in health policy.

Lightweight materials enable a host of new protective functions

A bumper sticker issued by the University of Delaware Center for Composite Materials in the 1970s proclaimed: "The future is composites." Center director Jack Gillespie, who was a UD graduate student at the time, believed that message then, and he still believes it today.

"What we're doing now is capitalizing on the traditional advantages of composites — they're strong, lightweight, corrosion resistant and tough — while infusing new functionality into these materials," says Gillespie, who is the Donald C. Phillips Professor of Civil and Environmental Engineering and also holds a faculty appointment in UD's Department of Materials Science and Engineering.

Polymers were first reinforced with fiberglass in the early 1940s. Since then, engineers across the globe have found thousands of ways to capitalize on the properties of composite materials, designing them into aircraft parts, boat hulls, pipes and tanks, car bodies, prefabricated bridge decks, bike frames, wind turbine blades and a variety of other applications.

But glass-reinforced polymers are just one example of a myriad of combinations that can be used to form advanced composites. Metals, ceramics, carbon and even natural substances are employed in these materials, whose properties are superior to those of the individual constituents.

Composites can be tailored to specific applications through the choice of an appropriate combination of reinforcement, matrix material and manufacturing method — a fact driving both the benefit and the challenge of these "materials by design."

Enter CCM

Referred to by a visiting committee member as "the top nationally and internationally recognized academic research center for composite materials," the Center for Composite Materials (CCM) at UD brings together a unique cadre of people and a state-of-the art assemblage of facilities and equipment to address composites design, analysis and processing.

More than 300 faculty, students, professionals and visiting researchers from industry and government agencies work together in CCM's two laboratories, which occupy a total of 52,000 square feet of space.

> "Composites are an ideal lightweight host for a variety of functions, including communication, personal protection and sensing."
>
> — Jack Gillespie

"Like the components of the materials themselves, our researchers work together to accomplish things that couldn't be accomplished by individuals," Gillespie says. "Composites are inherently multidisciplinary, and we have involvement from all branches of engineering as well as physics, chemistry and business."

With funding from the National Science Foundation and the Department of Defense (DoD), including in particular the Army Research Laboratory, CCM has been designated a Center of Excellence for 25 years. At the same time, the center has received strong support from industry through its consortium, "Application of Composite Materials to Industrial Products," which was established in 1978.

Although the center's industrial and government programs initially ran in parallel, over the years they developed a productive synergy and now are highly complementary, according to Gillespie.

"With our mix of people, we can cover the entire gamut from basic research to applied research to technology transfer. As we carry out fundamental research for our public-sector sponsors, we become involved with their private-sector contractors, enabling us to jointly transition technology into valuable applications," he says.

Others agree. Another visiting committee member commented after a program review that CCM's large multi-year government programs are relevant to many of the needs of the composites industry. "It is primarily because of the influx of

1. UD's Center for Composite Materials (CCM) has been designated a national Center of Excellence since 1985.
2. Metal fabrication is just one of the capabilities of CCM's Applications and Technology Transfer Lab.
3. Director Jack Gillespie reviews the work of students. They play an integral role in the center's research.
4. Doctoral student Jenny Mueller welds metals using ultrasonic vibration.
5. Undergraduate researcher Maxime Dempah (right) and research associate Hope Deffor run a fatique test of ceramic matrix composites on hydraulic testing machines.
6. A custom-designed Automated Materials Placement (AMP) system showcases the center's newest robotic capability.
7. UD researchers from CCM and the College of Health Sciences are working with U.S. Army scientists to develop novel orthotics such as the prototype leg brace shown here.

AMBRE ALEXANDER / DAWN FIORE / EVAN KRAPE / JOHN TIERNEY / U.S. ARMY RDECOM

government-sponsored work that the industrial program is so successful," he wrote.

CCM has been particularly successful in teaming with small businesses to win grants to transfer technology, accelerate commercialization and create new jobs in the state and nation. "We feel strongly that this is one of the most effective means to transition and commercialize technology," Gillespie says.

Just as CCM provides the framework for multidisciplinary research, composites provide the framework for the multi-functionality that is so hotly pursued in modern applications.

"Composites are an ideal lightweight host for a variety of functions, including communication, personal protection and sensing," Gillespie notes. "Because we design the material and the process at the same time, we can design in these new functions up front."

Multi-scale modeling

An approach known as multi-scale modeling, a high-tech term for being able to see the forest *and* the trees, is what enables all of these elements to come together in the right way at the right time.

"Many researchers today are investigating structures and materials at the nano-scale, but it's easy to get lost in that," says Gaurav Nilakantan, who earned his doctorate in materials science at UD in 2010 and is now a postdoctoral researcher at CCM. "As we explore things at the nano-level, we still have to keep an eye on the big picture."

Multi-scale modeling allows that perspective to be maintained by linking what is happening with a material at all scales.

As an example, Nilakantan points to research he is doing with Gillespie and Mike Keefe, associate professor of mechanical engineering, on the impact behavior of flexible textile composites. These materials are used in a variety of applications, including personal protective equipment such as bullet-proof vests and body armor.

"Common practice to qualify new materials requires testing of some 30 layers of fabric sandwiched together to see how the structure reacts to impact," Nilakantan explains. "But at the same time, we need to understand what's going on at smaller scales—with yarns, filaments, sub-filaments and even nanoparticles — so that we can improve the properties of the fabric, as all of those elements interact with each other.

"You can't look at anything in isolation," he adds, "because the entire structure needs to function in a certain way. A choice that optimizes strength, for example, might compromise the ability to embed sensors or communication devices."

Advanced Composites*, continued on p. 11*

Q&A with Jack Gillespie

Jack Gillespie takes questions from the audience at a lecture.

KEVIN QUINLAN

John W. (Jack) Gillespie Jr., director of UD's Center for Composite Materials, places a premium on putting together the right people and the right materials to do the job — whether it's creating a new road surface for a heavily trafficked bridge in Delaware or custom prosthetics for injured soldiers.

Director of CCM since 1996, Gillespie maintains an internationally recognized facility and an open-lab philosophy to encourage participation in research and educational activities. CCM currently has more than 120 projects under way, involving UD faculty, staff and students, as well as industry and agency collaborators.

Q: What got you hooked on research in this field?

A: It was a combination of experiences — undergraduate research in experimental mechanics, a senior design project on flywheel energy storage, and graduate studies on the design of aircraft joints and damage tolerance funded by the Air Force and NASA.

Composites can be found *Everywhere* from aircraft to wind turbines

Q: What would our daily lives be like without composites?

A: Composites are everywhere: aircraft — the Boeing 787 is over 50 percent composites — high-performance cars like my Corvette Z06, wind turbines for power generation, lightweight bridge systems, electronic circuit boards and soldier protection ranging from body armor to vehicle protection against IED threats.

Q: What are some of the most novel composites that UD has developed and that are in use by the public today?

A: Two of the more novel developments here have come out of research by chemical engineering faculty. Richard Wool has led the development of all-natural composites made from renewable sources such as chicken feathers and soybean oil *(see p. 40)*, while Norm Wagner has developed "liquid armor," a technology based on shear thickening fluids, for penetration-resistant protective clothing *(see p. 25)*. A collaboration with two civil engineering faculty, Michael Chajes and Dennis Mertz, resulted in the design, manufacture and installation of the first all-composite bridge deck on a state road, as well as lightweight bridging for rapid deployment by the military. We have also contributed to all-composite military vehicles, combatant watercraft, novel orthotics for orthopaedic rehabilitation and an ultra-lightweight medical mission module for a military ambulance.

Q: How effective are composites for safety/security applications, and why?

A: If you want to maximize performance and/or protection at minimum weight, composites are key. They provide the highest specific strength and stiffness of all materials and can absorb significant amounts of energy during impact. All DoD [Department of Defense] systems — whether they're light, medium or heavy tactical or combat vehicles, helicopters, unmanned ground and air vehicles, or boat and ship structures — need to be as lightweight as possible. Composites enable payload to be increased and mission range to be extended. They also allow tailoring of a single material solution at minimum weight with a variety of properties.

Q: What role does CCM play as an incubator of new technologies and companies and as a collaborator with local startup companies?

A: CCM has a long history of partnerships with industry, dating back to 1978 with the founding of our consortium, "Application of Composite Materials to Industrial Products." While the center originally served industry as a source of employees through our graduates, that role has since been augmented by a strong commitment to technology transfer with small, medium and large companies, ranging from material suppliers to end users. Along the way, we have incubated new businesses by providing an entrepreneurial environment to our students as well as research expertise and facilities to our industrial partners. We have been particularly successful in teaming with small business to win SBIR/STTR grants to transfer technology, accelerate commercialization and create new jobs in the state. And our collaborations with the Army Research Laboratory will grow as the Science and Technology Campus on the former Chrysler site develops, with spinoff companies developing from new multi-functional composite technology.

Q: What's the future of composite materials — how will they continue to change our world?

A: The need for lightweight materials will continue, just as added multi-functionality in a single material system will change the way new products are designed and raise performance to new levels. The ability to design a stiff, strong composite material — with self-sensing and self-healing properties, embedded electronic functionality, energy storage/generation and tailored electromagnetic properties — will make composites the enabling material for future generations. DoD advances in national security will continue to have commercial spinoffs. Biomedical applications — for example, prosthetics to rehabilitate soldiers with traumatic lower-limb injuries — will become increasingly important. And nanotechnology opens the door for applications that we can't even envision yet.

EVAN KRAPE

Students win $10,000 prize at Composite App Challenge

The integrated structural composite fuel cell developed by Cedric Jacob (left) and John Gangloff may someday help transform the world of renewable energy. For their innovative idea, the UD doctoral students in mechanical engineering won a $10,000 cash prize in the Owens Corning Composite App Challenge, a global competition to find new applications for composite materials. The duo plans to invest the winnings in future projects.

"When we do research here at the center," Gangloff said of UD's Center for Composite Materials, "we're trained to think about how what we're doing will impact government and industry, as well as how their needs and problems can provide direction for our work. The Composite App Challenge embodied that way of thinking, so it was the perfect outlet for our creativity."

***Advanced Composites**, continued from p. 9*

Mark Mirotznik, associate professor of electrical and computer engineering, is working with Shridhar Yarlagadda, assistant director of research at CCM, and other center researchers to create the next generation of electromagnetically functionalized composite materials.

"By tailoring the electromagnetic properties of structural composites," Mirotznik says, "it may be possible to integrate antennas, electronics, frequency-selective surfaces, and other electromagnetic components into the structural skin of future commercial and military vehicles and structures." Funded primarily by the U.S. Navy and Army, the team is exploring new design methodologies and fabrication processes for producing structural composites with these unique properties.

While CCM has received strong support from the DoD and its industrial subcontractors, Gillespie emphasizes that the research conducted with this funding has benefits to all.

"Many of the technologies that we take for granted today grew out of wartime needs," he points out. "Military aircraft led the way for commercial aircraft, body armor for soldiers paved the path to protective clothing for prison guards and police officers, and armored vehicle technologies provided the foundation for automotive applications."

As an example of this at CCM, work done under the Advanced Materials Intelligent Processing Center (AMIPC), a program funded by the Office of Naval Research, resulted in significant advances in the understanding of material behavior and flow during liquid composite molding processes.

Led by Gillespie and Suresh Advani, George W. Laird Professor of Mechanical Engineering, the AMIPC resulted in the development of simulations that have helped reduce the cost of traditional trial-and-error molding and manufacturing practices for a broad range of applications, from car hoods to bridge decks — far beyond the Navy's interest in inserting composites into ship applications.

If the future is indeed composites, what does that future hold? Gillespie sees increasing exploitation of the system benefits of these complex materials. "This is where we can do better," he says. "We already know that composites are the best way to reduce weight without miniaturization. Now we just have to keep working on ways to increase the functional work that these lightweight but strong hosts can do." — *Diane Kukich*

Tsu-Wei Chou (right), recently named among the top 100 materials scientists of the past decade, and mechanical engineer **Erik Thostenson** are using nanotubes to detect micro-cracks in composites.

KATHY F. ATKINSON

Tiny tubes track trouble

Imagine what you could do with a material that is 30 times stronger than high-strength steel, as stiff as diamonds and a thousand times more conductive than copper, yet weighs only half as much as aluminum. While this might sound like the stuff of science fiction, the carbon nanotube actually has all of these properties and more.

Two researchers at the University of Delaware have done more than just imagine what they would do with these tiny cylinders that are about 1/50,000th as wide as a human hair — they have discovered a way to use them in detecting defects and damage in advanced composite structures. The technology is similar to the way the human body signals injury through the nervous system.

The research is the work of Tsu-Wei Chou, Pierre S. du Pont Chair of Engineering, and Erik Thostenson, assistant professor of mechanical engineering. In August 2010, the pair was awarded a patent on the method and system for this application.

The composite materials Chou and Thostenson are working with comprise a polymer matrix reinforced with glass fibers. The difference in strength between the matrix and the fibers can result in areas of weakness at the interface between the two, where tiny microcracks can develop. Over time, the microcracks can grow and threaten the integrity of the composite.

"Nanotubes are so small they can penetrate the areas in between the bundles of fiber and also between the layers of the composite, in the matrix-rich areas," Thostenson said. "Because the carbon nanotubes conduct electricity, they create a nanoscale network of sensors that work much like the nerves in the human body."

When an electrical current is passed through the network, any microcracks present will break the pathway of the sensors, and the response can be measured.

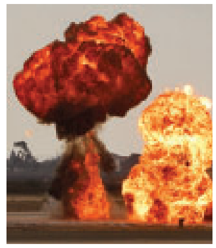
The work provides a new tool for laboratory research now and has many potential applications in the future. By identifying and tracking defects in a laboratory setting, the researchers can develop strategies for more accurate prediction of material lifespan.

"Being able to detect defects and understand the life cycle of a given composite is critical to the widespread use of these materials," Thostenson said. "It comes down to knowing how long the composite will last and at what point the structure will no longer be viable."

Chou, considered a pioneer in the science and technology of fiber-reinforced composites, credits his colleague with developing the technique for uniformly dispersing the carbon nanotubes in the matrix material. Thostenson earned his doctorate in materials science at UD in 2004 with Chou as his adviser. Chou joined the UD faculty in 1969 and was instrumental in founding the Center for Composite Materials. Earlier this year, he was named among the top 100 materials scientists of the past decade by Times Higher Education.

The two have received funding for their work from the Air Force Office of Scientific Research, the Office of Naval Research, the Army Research Office and the National Science Foundation. In addition, they are collaborating with researchers at the Korea Institute of Materials Science on a program funded by the South Korean government, and they currently have two related Phase II Small Business Technology Transfer grants with small companies aimed at addressing scale-up issues and new applications of the technology. — *Diane Kukich*

Composites may help reduce blast effects



An explosion in a Moscow airport on January 24, 2011, was yet another act of terrorism in a world that has seen an increase in public violence over the past decade. The effects of such explosions, whether they occur in crowded city venues or remote battlefields, include structural collapse, debris impact and fire. Additional casualties can result when collapsed structures and accumulated debris block quick evacuation from a site overcome by flames or smoke.

Composite materials may provide a solution to at least some of these blast effects by mitigating collapse and containing debris.

Research led by Jennifer Righman McConnell, assistant professor in UD's Department of Civil and Environmental Engineering, is aimed at designing composite materials to resist the devastating effects of blasts. The work focuses on optimizing the material properties as well as the geometry of blast-resistant composite structures.

"Composite sandwich panels made of glass-fiber-reinforced plastic face sheets and aluminum foam core have excellent energy absorption capabilities under dynamic loading," McConnell says. "One effective approach to providing blast resistance is to design a sacrificial layer surrounding the protected structure and maximize the potential for energy absorption of that sacrificial layer."

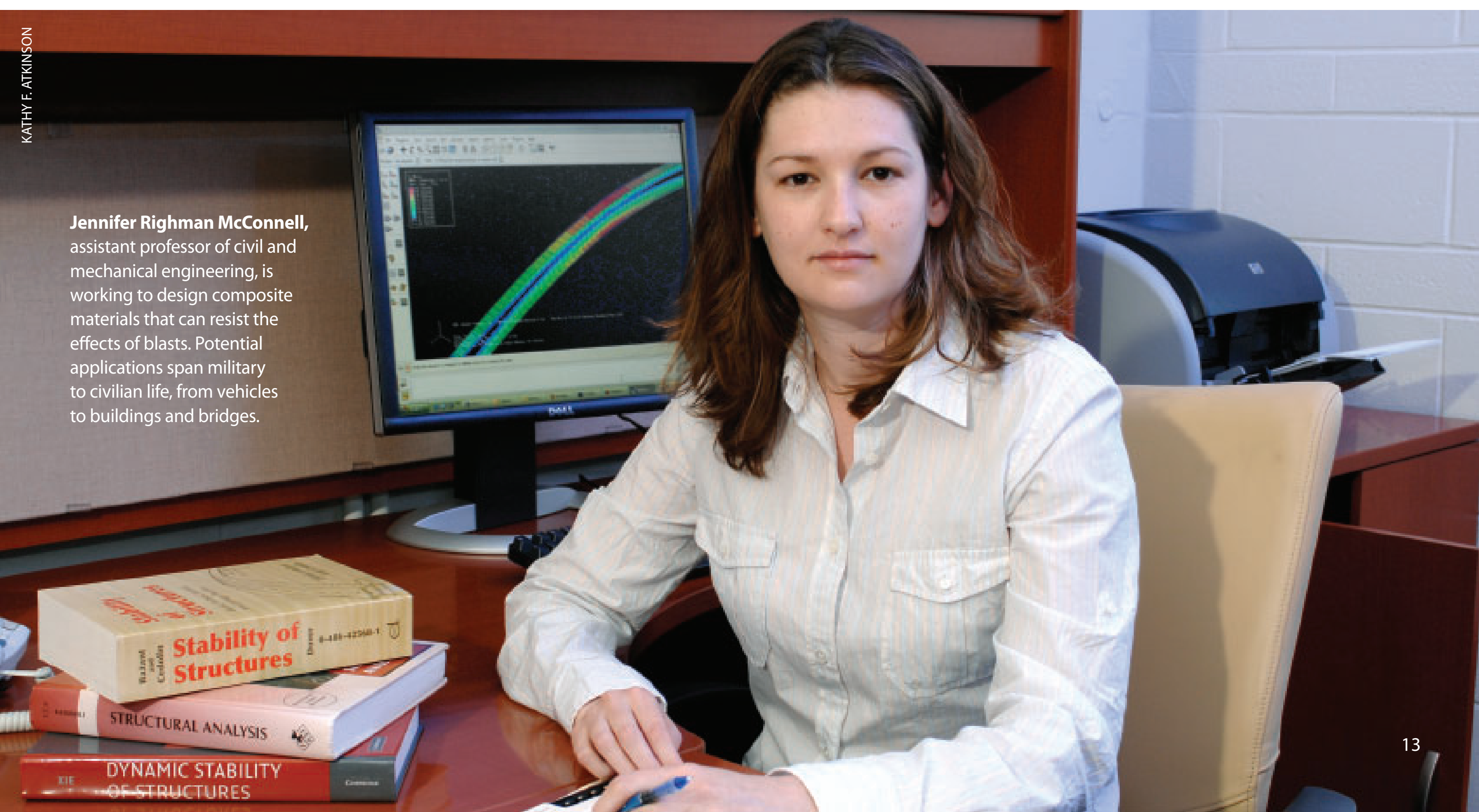
Past research has focused on comparing the energy-absorption characteristics of existing composite configurations — for example, glass-reinforced polymer or Kevlar-reinforced polyester. Composites, however, can be tailor-designed from the nano to the macro-level, so McConnell is taking a different approach.

She and her students are starting with a generic base material and changing various material properties one at a time so that they can determine the influence of each one on energy absorption. Once the ideal parameters are known, a material can be tailored to this function.

The design philosophy underlying the work is that progressive collapse of the core structure in the sandwich panels dissipates energy while the face sheets remain relatively intact to avoid secondary damage from debris strikes on humans and structures.

Like the materials making up the sandwich panels, the panels themselves can be tailored to minimize the energy transferred from blast waves to the main structure. McConnell is methodically exploring various geometries of square-celled honeycomb sandwich panels to determine the optimum configuration for absorbing blast energy. Variables include the thicknesses of different structural components and the number of cells.

McConnell's work is supported by a grant from the Army Research Office through the Defense Experimental Program to Stimulate Competitive Research (DEPSCoR). Potential applications include not only military vehicle bodies and temporary military shelters, but also civilian infrastructure such as bridges and building facades. — *Diane Kukich*



KATHY F. ATKINSON

Jennifer Righman McConnell, assistant professor of civil and mechanical engineering, is working to design composite materials that can resist the effects of blasts. Potential applications span military to civilian life, from vehicles to buildings and bridges.

On the Move

Human migration has lots of consequences for society, including national security

Mark Miller says he was thought of as "an oddball" for choosing human migration as the focus of his studies when he was an undergraduate and later on in graduate school.

"Today, thirty to forty years later, people see a logic to my madness," Miller says softly.

Mark Miller, Emma Smith Morris Professor of Political Science and International Relations, tells how human migration re-shapes our world.

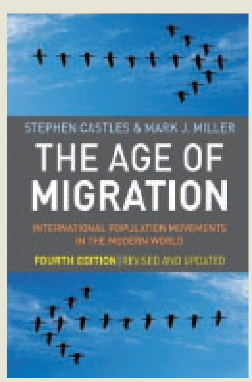
AMBRE ALEXANDER

Miller, the Emma Smith Morris Professor of Political Science and International Relations at UD, is a leading expert on international population movements and their consequences across society, from economic development to national security.

Governmental organizations and the United Nations have sought Miller's expertise, and he has testified before Congress and various U.S. commissions on immigration questions. He also has helped lead six Fulbright Institutes on U.S. national security and foreign policy and currently directs the National Security Institute at UD. The latter program, sponsored by the U.S. Department of State, seeks to connect its participating policy specialists and scholars from around the world in an "epistemic community," a network of knowledge-based experts who have been taught together and will maintain lasting ties.

International migration is nothing new, Miller says, but understanding where people are moving now and why can help policymakers better navigate the more globally integrated world ahead.

Since 1970, Miller says, the world has been experiencing a new age of migration, and not just on a trans-atlantic scale.



This classic by Stephen Castles and Mark Miller is a recommended text in political and social science courses around the globe. The fifth edition is slated for publication in 2012.

Throughout history, groups of people have left their homeland to look for new opportunities or to escape conflict. And many millions too were enslaved and forcibly transported. Indeed, Africans long outnumbered Europeans arriving in the New World, Miller notes.

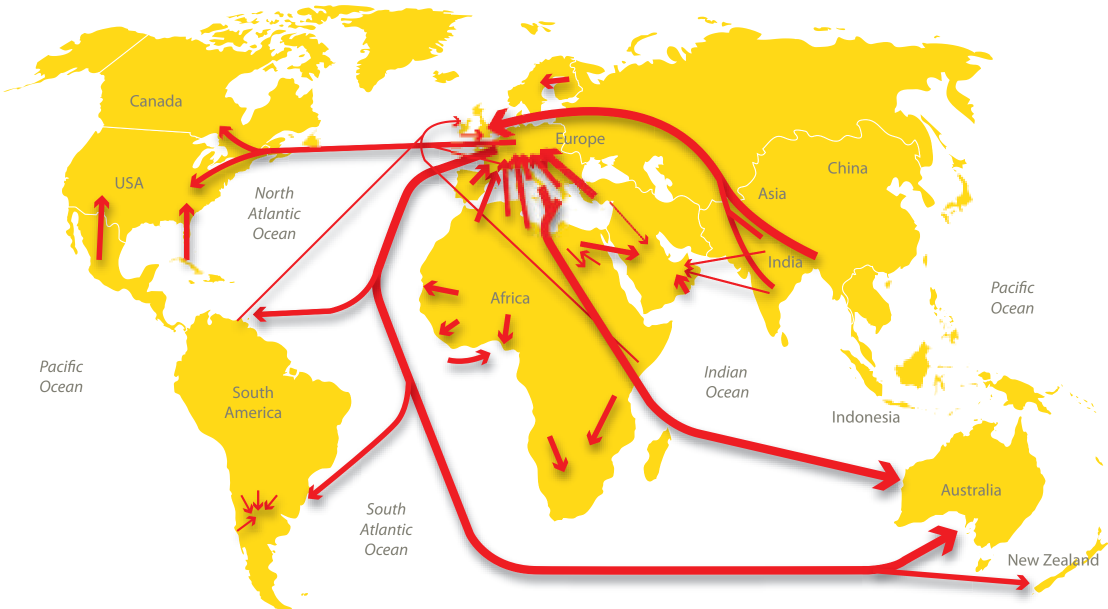
Miller's Irish farmer ancestors, besieged by the Irish Potato Famine, sailed across the Atlantic Ocean to the United States to seek a better life. They were part of one of the largest mass migrations of people in history — between 1820 to 1920, some 60 million Europeans emigrated to the New World, principally to the United States.

The flow of a new age

Since 1970, Miller says, the world has been experiencing a new age of migration, and not just on a transatlantic scale. Growing socioeconomic gaps in Latin America have propelled people to the United States and southern Europe. Asians and Africans began migrating, with significant numbers of Black Africans moving to France and elsewhere in Europe. Eastern Europeans poured into western Europe, particularly Poles into Ireland and the United Kingdom. And countries along the Persian Gulf

Global migrations, 1945–1973

Red Arrows: The arrow dimensions give an approximate indication of the volume of flows. Exact figures are often unavailable. Adapted from *The Age of Migration* (Guilford Press).



"The gist of American immigration history is that groups viewed as problematic and a security threat at one juncture in time will go through an incorporation process if we give them a chance." — Mark Miller

began hiring migrant workers — first from other Arab countries and then from Asia.

In addition to these phenomena, in 1990, the Cold War ended with the implosion of the Soviet Union, which marked the need for a new national security policy in the United States.

But developing such a policy was much more complex now, crossing over into the domestic and foreign policy realms. The rise of the Internet and new communications technologies, ethnic cleansing and other violent conflicts, the increasing role of women as migrant laborers and as victims in human trafficking, and concerns about climate change and displaced peoples became new factors in the flow of people and in the flow of policy.

And then came 9/11.

"Al-Qaeda was under the radar screen because of the way our country's security experts were trained," Miller notes.

Although the intertwining subjects of international migration and terrorism came to the fore after 9/11, as Al-Qaeda sleeper cells were identified far beyond the Middle East — in England, Germany and elsewhere — Miller had been studying the dual subjects since he was an undergraduate and says he has always seen them as "one piece of cloth."

"Although radical groups like Al-Qaeda constitute a tiny fraction of the Muslim population," Miller says, "a long time ago, in studying the evidence, I argued that international migration from the Middle East to Europe had important security implications for the United States."

Since the launch of the U.S. War on Terrorism–invasion of Iraq in 2003, thousands of radical Muslims have received military training in camps in the Middle East and North Africa and some have subsequently returned to Europe.

Miller also sees these threats to U.S. national security in the future:

- Failed states and weak states such as Somalia, where terrorist groups like Al-Qaeda can find safe haven.
- Major population growth in Yemen, where there are concerns about Al-Qaeda and other Muslim radical groups. World population will increase by 3 billion in the next 30 years; most growth will occur in the least developed areas of Africa, the Middle East and Asia.

Acceptance of Muslims in Western democracies

Miller is optimistic, however, that Muslim immigrants can continue to incorporate into Western democracies.

"Muslims in the United States are different — they came here for different reasons. They were not recruited as foreign workers, as was the case for so many in Europe," he says.

"The gist of American immigration history is that groups viewed as problematic and a security threat at one juncture in time will go through an incorporation process if we give them a chance.

"The classic case was the Irish," Miller notes. "I think that will be the outcome for Muslims, as well as for Mexicans and for Guatemalans in the U.S. The historical evidence is on my side."

Miller's book *The Age of Migration* (**www.age-of-migration.com**), co-authored with Stephen Castles and published by Guilford Press, is regarded as a classic by policymakers, scholars and journalists. It is a recommended text in political and social science courses around the globe. The fifth edition is slated for publication in 2012.

Additionally, Miller is the author or co-author of *The War on Terror in Comparative Perspective; Foreign Workers in Western Europe: An Emerging Political Force; The Unavoidable Issue: United States Immigration Policy in the 1980s;* and *Administering Foreign Worker Programs: Lessons from Europe.*

Miller also has written more than 100 articles, chapters and monographs on immigration, including two commissioned monographs for the U.S. Commission on Immigration Reform. Learn more on Miller's web site: **www.udel.edu/poscir/faculty/MMiller/**.

— *Tracey Bryant*

HOW NOT *to* RAISE A RADICAL

Juris Pupcenoks

Anjem Choudary, British citizen and former leader of Islam4UK, a now-banned radical group in the United Kingdom, doesn't have much support among British Muslims. But you might think otherwise based on the extensive media coverage the extremist Choudary receives.

"Choudary is estimated to have no more than 200 followers in the United Kingdom, which has over 2 million Muslims," says Juris Pupcenoks, a doctoral candidate in political science and international relations at the University of Delaware. "Yet the media talk about these people for hours and create a greater sense of threat."

Media attention is just one contributing factor to the success of radical groups, according to Pupcenoks, who is working to find out why political violence, including extremism, occurs in some communities but not in others.

Through his research with Muslim communities in Detroit and London, Pupcenoks has identified three measures to help prevent radicalism:

- "Try to minimize media coverage of the 'crazies' – some extremists wouldn't exist without it," he says.
- Create a strong partnership and open dialogue between Muslim community groups and law enforcement through successful models like the BRIDGES program in Detroit.
- Support the work of Muslim community groups that educate youth properly about Islam because Muslim radicals and would-be terrorists tend to be misguided about the basic principles of Islam.

MEASURES TO PREVENT RADICALISM

1

Minimize media coverage.

2

Create a strong partnership and open dialogue between community groups and law enforcement.

3

Support the work of Muslim groups that educate youth properly about Islam.

In London, UD's Juris Pupcenoks interviews Sayeed Ferjani of the Muslim Association of Britain about Muslim political activism.

In Detroit, top religious and secular leaders are involved in the Building Respect in Diverse Groups to Enhance Sensitivity (BRIDGES) program, which was instituted after the 9/11 terrorist attacks on the United States. Community leaders and police departments meet regularly to discuss concerns and to diffuse tensions. The FBI is a partner as well, Pupcenoks says, and is kept informed about any Arab and Muslim discrimination issues.

"There is no appeal for radical groups among the Muslim community in Detroit," Pupcenoks says. "Instead, they care about things like jobs and women's rights."

There are an estimated 200,000 Muslims in Detroit, but they are far from a homogeneous community, Pupcenoks explains.

"Even though there's talk of 'Muslim this, or Muslim that,' it's not that way at all. Yemeni Muslims go to Yemeni mosques, and Lebanese Muslims go to Lebanese mosques, and so on. Communities are very distinct, bound by ethnic ties."

As part of his doctoral research, Juris Pupcenoks meets with Shamiul Joarder, of the Muslim Safety Forum, which was formed in the United Kingdom following 9/11 and is a key advisory body to the British police service.

Youths who don't really know the Muslim religion may be vulnerable to the messages of charismatic activists who have connections with violent groups abroad, particularly Pakistan.

"If the youth don't know what Islam is about, that's of concern," Pupcenoks says. "There are verses in the Koran that are violent, just as there are verses in the Bible that are violent, such as 'an eye for an eye,' when taken out of context. Therefore, Detroit's religious community and certain youth groups work to educate about different beliefs of Islam."

Such religious teaching groups should not be government sponsored because that can erode community trust, Pupcenoks says.

Pupcenoks credits his advisers, Mark J. Miller, Stuart Kaufman and Muqtedar Khan — all on the faculty of the UD Department of Political Science and International Relations — for their guidance throughout his research. After he receives his doctorate, he plans to teach and pursue further studies into the causes of violent radicalization in the U.S. and Europe.

— Tracey Bryant

Service to nation extends beyond research

It's not just research and well-prepared graduates that University of Delaware faculty help contribute to national security issues.

Chemistry professor Murray Johnston, for example, recently served on two National Research Council committees — one to evaluate the Department of Defense's testing methods to rapidly identify airborne microbes that might be involved in a terrorist attack, and the other to assess the Federal Bureau of Investigation (FBI) response to the anthrax letter attack in 2001.

In examining the scientific approaches used and conclusions reached by the FBI during its investigation of the 2001 *Bacillus anthracis* mailings, Johnston, an expert on aerosols, and his fellow committee members determined that it was not possible to reach a definitive conclusion about the origins of the anthrax in letters mailed to New York City and Washington, D.C., based solely on the available scientific evidence. The committee's evaluation was released Feb. 15, 2011.

Each National Research Council panel has a different charge, Johnston explains, but typically, the panels involve experts from a variety of disciplines who contribute to the scientific analysis of data and information that reside in reports and technical documents.

"In the end, the entire committee discusses the matter, makes a decision and reports information. It is very much a 'we' effort, and not from a single individual's expertise or perspective. Usually, a public report is issued by the National Academies at the conclusion," Johnston says.

Stanley Sandler, Henry Belin du Pont Chair of Chemical Engineering, served for more than five years on three National Research Council committees dealing with the destruction of armed chemical weapons, including bombs, rockets, mortars, land mines, and projectiles loaded with nerve or mustard agents. He now serves in a consulting capacity to projects at Hanford, Savannah River and Idaho Falls dealing with the safe processing and eventual storage of highly radioactive wastes remaining from the production of nuclear weapons.

"In other words, I am a WMD [weapons of mass destruction] person, but a good one in the sense of trying to get rid of them," Sandler notes.

Other faculty are leading programs to engage scholars and policy makers from other countries in the pursuit of greater world harmony.

Stuart Kaufman, professor of political science and international relations, is the Fulbright-Diplomatic Academy visiting professor of international relations at the University of Vienna during spring 2011. Drawing on his experience on the U.S. National Security Council staff, Kaufman is teaching a graduate seminar on American foreign policy and a course on ethnic conflict, as well as presenting public lectures in Europe on options for resolving ethnic conflicts.

Also with the support of the U.S. Department of State, Mark J. Miller, Emma Smith Morris Professor of Political Science and International Relations, has hosted the six-week Institute on National Security Policy Making in a Post-9/11 World several times since 2003, with the latest program concluding in February 2011.

The program brings together university professors, military officers, government officials and diplomats from around the world, forming a community of scholars with lasting ties. The institute's goal is mutual understanding, according to Kevin Orchison, program officer for the Study of the U.S. Branch of the U.S. Department of State's Bureau of Educational and Cultural Affairs.

"We're very happy with the program and the faculty here at the University of Delaware," says Orchison. "There's great institutional support, and the faculty are very creative in exploring the topic through a very nuanced presentation so that when the participants return home, they have a very illuminating perspective on, not just the U.S., but Nepal, India, Kenya, and so on."

— Tracey Bryant

The battle at the synapse

UD and Army researchers work to detoxify nerve agents

Nerve agents such as VX and Sarin act swiftly and mercilessly. A victim can die in seconds as nerves go haywire, resulting in seizures and suffocation. The poisons are feared as weapons of warfare, and of terrorism.

The morning of March 20, 1995, members of the cult Aum Shinrikyo released Sarin in the Tokyo subway during rush hour, killing 13 and sickening more than 6,000 people. Survivors continue to experience paralysis, impaired vision, speech impediments and post-traumatic stress disorder.

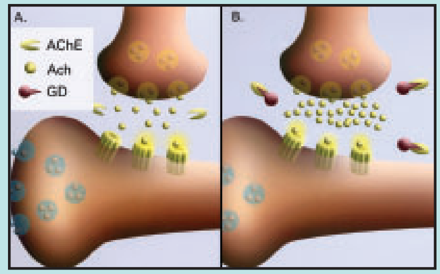
In the United States, the 9/11 terrorist attacks raised new concerns about bioterrorism. In 2004, Congress passed the Project Bioshield Act, a 10-year program to acquire, for civilian use, medical countermeasures to biological, chemical, radiological and nuclear agents.

Associate Professor Brian Bahnson and Professor John Koh in the Department of Chemistry and Biochemistry at UD, are collaborating with scientists from the U.S. Army Medical Research Institute of Chemical Defense (USAMRICD) at Aberdeen Proving Ground in Maryland to find ways to combat the effects of nerve agents.

"We're the good guys," says Koh, a bioorganic chemist. "We're trying to counteract these poisons by using our knowledge of chemistry and biology to detoxify or deactivate them. These are huge Homeland Security issues."

Chemically speaking, nerve agents are organophosphates, couplings of carbon and phosphorus. They operate by inhibiting *acetylcholinesterase* (AChE), an enzyme in blood and tissue that regulates the neurotransmitter *acetylcholine*.

If a nerve agent blocks the AChE, the neurotransmitter will keep firing continuous signals across the gap between the nerve cells called the synapse — to muscles, organs and glands, sending them into hyperdrive. Among the grim effects: contracted pupils, excessive mucus, tears, saliva and sweating, vomiting, loss of bowel and bladder function, convulsions, respiratory failure, cardiac arrest and death.



How Nerve Agents Work

Panel A shows normal communication between two neurons (shaded brown). The neurotransmitter acetylcholine (Ach), shown as the yellow spheres, regulates this chemical signaling. Excess Ach is rapidly terminated by the enzyme acetylcholinesterase (AChE), depicted as yellow "Pac-Man" shapes.

Panel B shows neuron-to-neuron communication being disrupted by the nerve agent soman (GD), shown as purple cones. Soman inhibits AChE by blocking its active site. This causes Ach to accumulate in the synaptic space between the cells, resulting in overstimulation and eventually causing muscle convulsions, loss of consciousness and death.

Graphic courtesy of Steve Kirby, USAMRICD

KATHY F. ATKINSON

2 approaches:

How do you unnerve a nerve agent? A UD-Army collaboration is making progress on two major fronts. UD chemist Brian Bahnson (left, foreground) and Army researcher Steve Kirby are identifying "bodyguard proteins" in the human body, which show potential for literally locking up a nerve agent in chemical bonds. Kirby, a civilian scientist for the U.S. Army Medical Research Institute of Chemical Defense (USAMRICD) at Aberdeen Proving Ground, Md., is working on his doctorate part-time at UD.

Although antidotes exist, they are only moderately effective in the field. Developing a more efficient, faster-acting antidote is the aim of Koh and collaborators Doug Cerasoli, a civilian research leader at APG, and Linn Cadieux, a scientist on Cerasoli's team. Cadieux is working part-time on her doctoral degree in chemistry and biochemistry at UD, with Koh as her adviser.

Thanks to the Koh lab's emphasis on molecular modeling, computer simulations of 3-D molecules now enable the team to examine potential antidotes at the atomic level and assess how well these compounds reactivate the critical AChE enzyme.

Bahnson's goal is to find catalytic bioscavengers — chemical "bodyguards" — to protect the AChE.

"When a nerve agent hits, these protectors would attack and destroy the neurotoxin by first ensnaring it in a dead-end complex with covalent bonds and then facilitating the chemical breakdown of this complex with water — a process called hydrolysis — to free up the enzyme to do its work again," Bahnson explains.

In research funded by the Army and the National Institutes of Health, Bahnson's group already has identified two promising bioscavenger candidates — plasma platelet-activating factor acetylhydrolase (PAF-AH), which is a marker for cardiovascular diseases, and human senescence marker protein 30 (SMP30), an enzyme whose crystal structure the UD-Army team recently solved. Resembling a pinwheel, the molecule has a six-bladed beta-propeller fold and contains a single metal ion, which appears to have a catalytic role.

Further investigations are now under way to understand the relationship between the molecule's crystal structure and function, in addition to analyses of protein expression and kinetics.

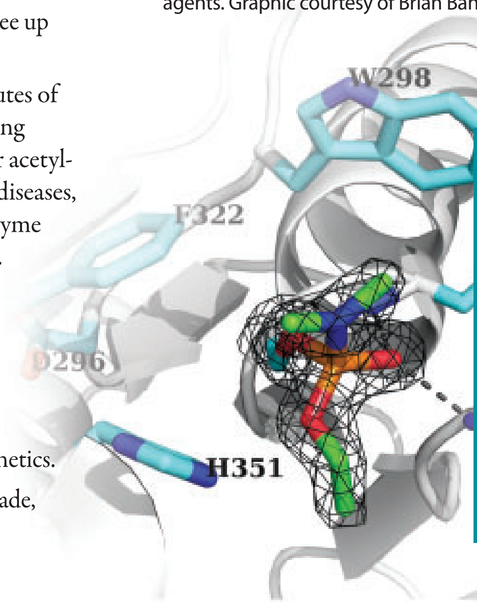
Bahnson, a collaborator on Army research for the past decade, describes the partnership as one of "positive synergy."

Steve Kirby, a civilian scientist at APG, has been pursuing his doctorate as a part-time student in Bahnson's lab for the past several years.

"I certainly didn't expect to be working on nerve agents," Bahnson says. "Then Steve came to me with a proposal that expanded on our enzyme work here at UD. He became a student in my lab, and soon he will graduate with his doctorate."

"The grass-roots relationships between scientists is what it's all about," Koh adds. "We're taking a field that's been looked at for fifty years — in new directions not considered before, and exploring the unknown. It's very rewarding to be able to do fundamental research which is yielding discoveries that are important for the military and for civilians."— *Tracey Bryant*

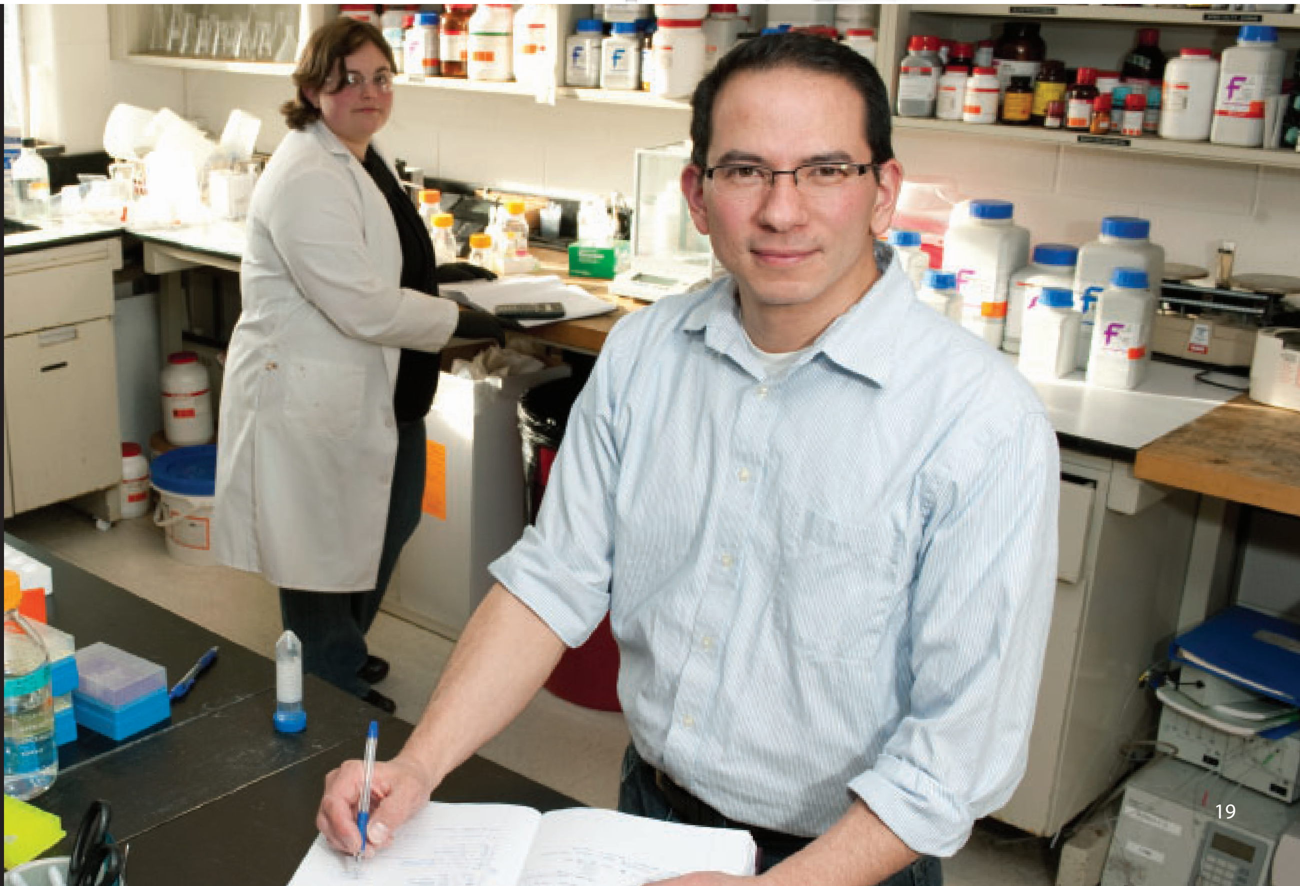
The 3-D model below shows how human plasma platelet-activating factor acetylhydrolase (PAF-AH) has ensnared the nerve agent Tabun. UD and Army researchers are exploring the potential of PAF-AH as an antidote to nerve agents. Graphic courtesy of Brian Bahnson.



"We're taking a field that's been looked at for fifty years — in new directions not considered before, and exploring the unknown."

— John Koh

KATHY F. ATKINSON



one goal

In his lab near colleague Brian Bahnson's in the UD Department of Chemistry and Biochemistry, bio-organic chemist John Koh (right, foreground) and Linn Cadieux, a civilian scientist for the USAMRICD at Aberdeen Proving Ground, are creating 3-D computer models of potential nerve agent antidotes to explore how they function at the atomic level. (Work with actual chemical nerve agents is restricted to the Army.) Cadieux also is a part-time doctoral student at the University.

ESCAPE *from* FORT DELAWARE

"Oh how hard it is to die in such a place as this after escaping so miraculously many bloody battlefields."

— Thomas Jenkins, Confederate Prisoner, Fort Delaware

Main entrance ("sally port") to Fort Delaware, post-Civil War, circa 1868–1870.
Photograph by John L. Gihon, courtesy of the Delaware Historical Society.

Student sheds light on Civil War mystery

In the early days of the Civil War, prison life at Fort Delaware on Pea Patch Island in the Delaware River was, by most accounts, tolerable. In its first year of operation in 1862, the population varied from 3,434 prisoners in July to only 123 later that year due to routine prisoner exchanges between the North and the South. While the prisoners were mostly Confederate soldiers and officers, some notable political prisoners also were held there.

By August 1863, however, the fort's population had swollen to over 12,000 due to the influx of prisoners from the battles at Vicksburg and Gettysburg.

The brick-and-granite fort, the largest in existence in the United States when completed in 1859, originally was designed as a harbor defense — to keep hostile invaders from sailing upstream to the ports of New Castle, Wilmington and Philadelphia — not to hold prisoners of war.

Wooden barracks sprang up across the island, which was 75 acres at the time, to imprison the growing masses as the Civil War raged on and prisoner exchanges were curtailed.

This sea of humanity, coupled with the stifling heat and humidity of summer and the freezing cold in winter, incubated an epidemic of smallpox and other diseases at Fort Delaware. Lice and bedbugs abounded.

In the end, some 2,400 men — Confederate prisoners, as well as Union guards—would wind up in coffins and be transported across river for burial at Finn's Point cemetery in New Jersey.

Not surprisingly, some prisoners at Fort Delaware would risk their lives in the swift current of the Delaware River in hopes of reaching shore and then venturing south on the "reverse underground railroad."

"A thousand ill; twelve thousand on an island which should hold four; the general level three feet below low water mark; twenty deaths a day of dysentery and the living having more life on them than in them. Occasional lack of water and thus a Christian(!) nation treats the captives of its sword."

— Dr. S. Weir Mitchell
Fort Delaware, July 1863

Rev. Isaac W. K. Handy

PRISONER *with* UD TIES

While having dinner in Delaware in 1863, the Presbyterian minister Isaac Handy made a comment about the flag not representing its original "high and noble principles." Handy, who once served the congregation at Port Penn, was reported and arrested without trial, as habeus corpus was suspended during the war.

Handy was held at Fort Delaware as a political prisoner for 15 months in 1863–64. In 1874, he published a detailed diary, right down to the measurements of his barracks. It was titled *U.S. Bonds; or Duress by Federal Authority*.

Handy became involved in Delaware College (forerunner of the University of Delaware) in 1851 when he was hired to sell scholarship certificates on the Delmarva Peninsula and was appointed a professor of mathematics although he never taught. His brother-in-law, William Purnell, would become the college's president in 1870. *Right, Confederate officers and Rev. Handy (center) at Fort Delaware in April 1864. Both photographs by John L. Gihon, courtesy of Fort Delaware Society.*

Reconciling official records with reality

"The official record suggests a low number of prisoner escapes from Fort Delaware. Confederate circles said there were hundreds, maybe thousands. Where is the truth?" asks Jonathan Russ, associate professor of history at the University of Delaware.

Kevin Mackie decided to tackle that question in an undergraduate independent study project last year, with Russ as his adviser. Mackie got the idea for the study from his mother, Laura Lee, interpretive program manager and park historian at Fort Delaware State Park. Lee received her history degree from UD in 1992.

"My mom helped me figure out a topic," Mackie says. "She told me that something she really wanted to find out, and something people always ask about on tours is, how many people escaped from the fort?"

During spring semester 2010, Mackie pored through dozens of official reports, Confederate newspapers and testimonies. He drew on the extensive archives of the Fort Delaware Society. He used JSTOR, a database of journals in the humanities, social sciences and sciences available through the UD Library, to access other primary and secondary sources.

The result of his efforts is "Fort Delaware Prisoner Escapes: 1862–1865," a 293-page report containing a fascinating array of historical information. In it, Mackie checks the accuracy of the official records by establishing a list of escaped prisoners and comparing the list to those records.

He provides information sheets on each escaped prisoner, as well as the research he uncovered to back up the escaped claim. Although the official reports by the U.S. military put the total prisoner escapes from Fort Delaware at 54, Mackie's research points to a higher number, between 64 and 103.

Mackie provides a year-by-year account that both paints the scene at the fort and points out questionable statistics relating

Today, Fort Delaware is a state park. Visitors take a half -mile ferry ride from Delaware City to Pea Patch Island, where costumed interpreters transport visitors back to the summer of 1864. Photograph by Laura M. Lee

Kevin Mackie (left) with Jonathan Russ, UD associate professor of history. Russ served as Mackie's undergraduate adviser on the project.

KATHY F. ATKINSON

Prisoner letter from Fort Delaware, Oct. 26, 1864.

to prisoner escapes. "Official Reports show that zero prisoners escaped in 1862, which is very clearly not the case," he writes in the report. "According to my research, at least 22 prisoners escaped in 1862, with the majority making their escape in the summer. It is likely that this can be attributed to the brutal hot summers on Pea Patch Island, and better conditions in warmer months for braving the river."

LIVING HISTORY

Kevin Mackie has been fascinated by history all of his life and says he hopes to teach the subject someday.

As shown here, Mackie took part in a living history program at Fort Delaware in Sept. 1995, when he was eight years old. He portrayed John Redd, a noncombatant who was captured at Gettysburg and brought to the fort. The boy's father died in battle, making him an orphan. Redd is documented as being nine years old in 1863. Photo by Anne L. Markey

He also documents a number of prisoners who escaped en route to Fort Delaware because of the prison's fearful reputation.

"After 1863, Fort Delaware received the reputation among Confederate soldiers as a horrendous prison, compared by one prisoner to the 'Black Hole of Calcutta,'" Mackie writes. "The post earned this because after the Battles of Vicksburg and Gettysburg, Fort Delaware's crowding contributed to poor conditions. A smallpox epidemic and the brutal summers and winters broke down a prisoner mentally, physically and emotionally. Whether this reputation was exactly true is not of consequence. It does matter though that the Confederate soldiers perceived this reputation."

The great escapes

"Due to poor recordkeeping during the war, we may never know the real number who escaped, but I believe it is on the higher end of the range Kevin suggests," Russ says.

On the Union side, prison officials were under a lot of pressure, and there was a disincentive to report real numbers. At one point, there were only 300 Union soldiers to guard nearly 12,000 prisoners, Mackie notes. On the Confederate side, there was great propaganda value for the Richmond newspapers to cite more escapes to boost southern morale.

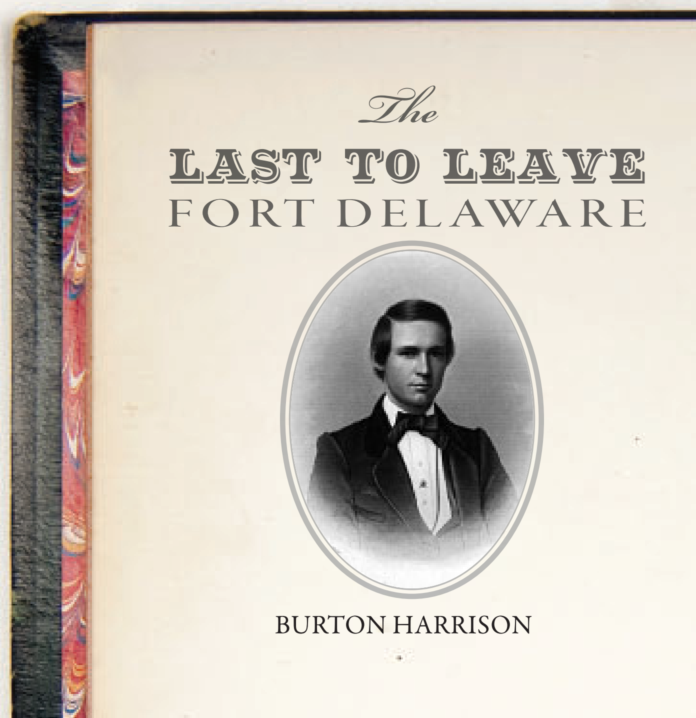
"Still, that's a remarkably small number that escaped," Russ notes. "It confirms how difficult a terrain this was, and many people couldn't swim. Many who were taken as prisoners were exhausted and malnourished, entering the prison in a weakened condition to begin with. If they made it to shore, they were still in hostile territory, and then they had to find people to help them work their way down South."

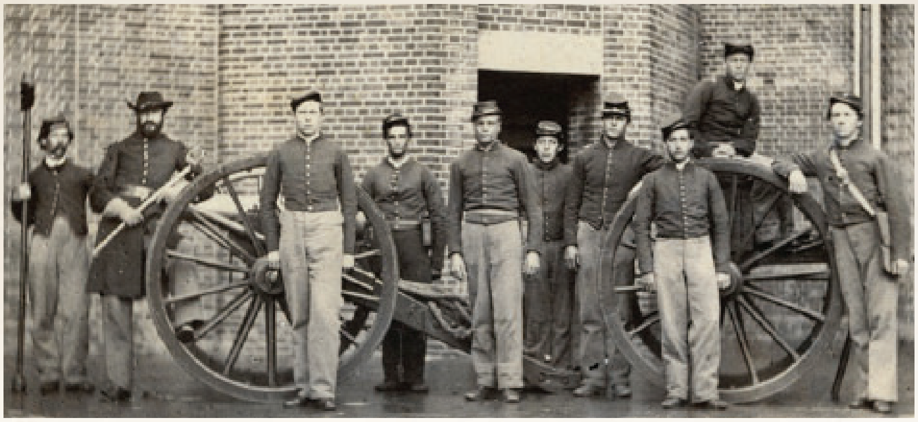
The methods of escape by prisoners were as varied as the southern states they represented in the great fight.

Some escapees impersonated Union soldiers and snuck out with regiments returning to shore. Others created life preservers out of canteens and floated their way to freedom. One got away on a coal boat; another bribed a guard. The stinking privies and sewers became escape routes.

But most impressive to him, Mackie says, in the prison hospital (one of the best in the military), a prisoner removed a body from a coffin, covered it in blankets and then hid inside, so the story goes. When the coffin reached New Jersey (Fort Delaware's dead were buried across the river at Finn's Point National Cemetery near Fort Mott), the prisoner jumped out and ran into an apple orchard. He later stole a boat and rowed across river to the Delaware shore to begin the next leg on his journey south.

In another instance, a Confederate soldier from Florida is said to have ice skated to freedom. The story from Jackson Wrigley of the 21st Georgia Infantry was retold by his great-great grandson Stan Wrigley, of Lubbock, Texas, in the Fort Delaware Society's "Fort Delaware Notes" in April 1981.





Pittsburgh Heavy Artillery at Fort Delaware, summer of 1864. At one point, there were only 300 Union soldiers to guard nearly 12,000 Confederate prisoners. Lt. Henry Warner is the officer (with sword) at left. Others are unidentified. Photograph by John L. Gihon, courtesy of Delaware State Parks.

The river had frozen solid in the winter of 1863–64, and some Confederate prisoners from Florida had never seen snow or ice. The Union soldiers were ice skating on the river and asked the Floridians if they would like a try.

"The guards strapped skates on the prisoners and took them out on the river," Wrigley's account goes. "The Floridians of course were falling continuously with the guards laughing uproariously at them. One kept getting farther and farther out on the river although he was having some of the most hilarious pratfalls. But as soon as he was out of musket range of the guards, he set off down the river like a professional skater and was never seen again."

A "remarkable work"

"This is remarkable work for an undergraduate," Russ notes. "Kevin did a great piece of research. For other students, this is a terrific reference tool to better understand not only the conditions of prison life, but to gain insight into recordkeeping in this area and the disincentive to honestly report."

Mackie, a member of the Delaware National Guard, served in Iraq in 2007–2008. Because of the experience, he says the prisoner escapes "hit home" with him.

"I understood the desire to get back into the fight," he says.

Mackie's military service has since paid his way through college. After returning from Iraq, he took classes year-round and graduated from UD with his bachelor's degree in history in January 2011. He is now working at ING Direct in Wilmington, Del.

"I always grew up doing the history thing," Mackie says, noting that he took part in his first Civil War re-enactment at Fort Delaware at the age of eight. "It's where my passion is. My biggest hope is that another historian can take my research, expand it and get an even better number."

Copies of Mackie's report have been provided to the Delaware Historical Society and to the University's Special Collections.

— Tracey Bryant

Editor's Note: Special thanks to Laura Lee and Brendan Mackie for their assistance with the historic photographs included in this article.

The 153rd Military Police Company, Delaware Army National Guard, visited Fort Delaware as part of their annual training in summer 2009. Kevin Mackie is in the front row, second from right. He and his brother, Brendan, deployed to Iraq in 2007–2008. Photograph by SFC Mark P. Del Vecchio.

Among the more than 32,000 prisoners held at Fort Delaware were Lt. McHenry Howard, grandson of Francis Scott Key; and Capt. Samuel Taylor, grandson of President Zachary Taylor.

Lt. General Joseph Wheeler was the highest-ranking Confederate officer held at the fort. Confederate brigadier generals James Johnston Pettigrew, Robert B. Vance and James Jay Archer also were confined behind its walls.

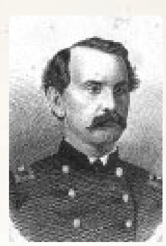
The last prisoner to leave Fort Delaware was Burton Harrison, the private secretary of Jefferson Davis, former president of the Confederate States. Harrison was arriving at the fort just as the last of the prisoners were leaving in mid-July 1865.

Davis and his group had been captured on May 10, 1865, in Georgia, and Harrison and a few others were sent to Fort Delaware. Before becoming Davis's private secretary, Harrison, a Yale graduate, had previously been an associate professor of mathematics at the University of Mississippi and was working on a degree in law.

"Harrison became quite close with General Schoepf, the commandant of the fort, whose entire family befriended him," says Laura Lee, interpretive program manager and park historian at Fort Delaware State Park. "Orders from the war department were that Harrison was to be kept in close confinement and have no privileges. The garrison at the fort thought, for the most part, this strictness was unwarranted."

There was great debate as to whether Harrison was an active traitor, or just performing a job, Lee says. A powerful politician named Frank Blair intervened on Harrison's behalf. Blair was a relative of Constance Cary, Harrison's fiancée from Baltimore.

Harrison was released on Jan. 16, 1866, and said goodbye to the Schoepf family. "There must have been a close connection," Lee says. "On Feb. 11, 1877, General Schoepf's wife gave birth to yet another child (they had many), and they named him Burton Harrison Schoepf!"



General Schoepf

Fear Factor

A driver leaves extra car lengths between his vehicle and the bus in front of him. A woman selects a table in the back of a restaurant to avoid a more public spot at the front. A teenager takes side streets to get to his destination, almost doubling his travel time to avoid taking main roads.

According to Michal Herzenstein, assistant professor of business administration, all of these individuals are acting with a common, if not illusive, goal — to save their lives.

Previously, Herzenstein, who specializes in marketing and consumer behavior, conducted experiments to examine the effect that frequent terror attacks have on consumers. She and Sharon Horsky, a colleague in Israel, focused on that country and the behavior of consumers during times of attacks by suicide bombers targeting buses, restaurants and markets.

Consumer behavior in Israel in times of terrorism has been one focus of the research.

The main research question they asked was, what does a fear of death, especially death arising from unpredictable causes, do to consumer choices? Overall, they found that frequent terrorism affects consumers differently than death in general because it is more conscious.

"When we think about our mortality, most people engage in what we call 'distal defenses' — they try to increase their immortality figuratively," says Herzenstein. "For example, I am a researcher, so even if I die, my published articles will remain and be available to others to read, which somehow makes me immortal."

Herzenstein also says people may turn to increasing their status in society by purchasing luxury products as a way of becoming immortal.

"In areas of frequent terrorism, though, people think about death more often and as a result use proximal defenses — they try to find ways to avoid death," she explains.

With a grant from UD's Institute for Global Studies, Herzenstein and Horsky now are attempting to explain why terrorism makes people more death-conscious and why people engage in proximal defense.

"There is already a good deal of psychological research on a theory called learned helplessness — when people realize that their actions are unrelated to outcomes," says Herzenstein. "For example, no matter what we do or how healthy we seem, we may suffer a stroke or heart attack or get cancer. So we learn to live with a remote fear that someday we may get sick and die."

According to Herzenstein, where terrorism is different is that due to its frequency and the similarities between events (for example, the nature of suicide bombing events — the bomber is often in the middle of the bus or at the entrance to a restaurant), people perceive some control over whether they can get hurt and the extent to which they can get hurt. That is where those cautious citizens come in.

"The best strategy to preserve your life is to stay at home," Herzenstein says. "But if you want to go out, you will be more cautious. This is where people act under an illusion of control. They will go to inconspicuous places, stay far away from buses, take side streets instead of main roads."

So how does this relate to marketing?

"The more people experience that illusion of control, the more they are likely to purchase items for the house and the less likely they are to buy luxury products unrelated to control," she notes.

The managerial implications, then, for sellers of luxury and other safety-related items are high.

"Manufacturers of safety-related items could stand to benefit if they advertise during coverage of a terrorism event," says Herzenstein. "Sellers of luxury and other safety related items might also advertise a lot on CNN and other news channels because the frequency of news related to death is high, which will prompt people to prefer those products."

Herzenstein emphasized, though, that such strategies would not be encouraged nor ethical of marketers.

"It is just interesting to examine how the field of marketing has evolved, and how terror-management theory comes into play," she says. "Ultimately, we hope to expand our research not only to explain why certain products sell, but to help the consumer make the best choices."

Herzenstein joined the UD faculty in September 2006. She earned a master's degree in applied economics and a doctorate in marketing, both from the University of Rochester's Simon Graduate School of Business, and bachelor's and master's degrees from the University of Tel Aviv.

— *Kathryn Marrone*


Michal Herzenstein, assistant professor of business administration at UD, is exploring how terrorism, and a fear of death in general, affect consumer behavior.

EVAN KRAPE

Tough Technologies

Tough challenges are no match for UD innovation. Amazing "Liquid Armor" protects the wearer against bullets, blades and bombs. Light, flexible solar cells are being designed to replace the heavy batteries in soldiers' packs. And new magnets in development may wind up turning on a new U.S. industry.

Tough: Adj. \ˈtəf\ Able to withstand great strain without tearing or breaking; strong and resilient; characterized by uncompromising determination; difficult to accomplish.

Superhero technology flexes its muscles to help save lives

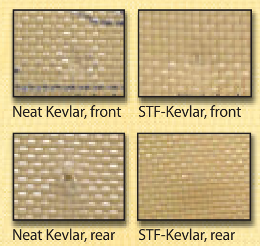
It's enough to make a superhero jealous.

Soft body armor treated with shear thickening fluid (STF), a novel technology invented by University of Delaware and U.S. Army Research Laboratory scientists, protects against practically any weapon the forces of evil can throw at it. It's bullet-resistant, stab-resistant, and can even protect the wearer from the shrapnel of detonated bombs.

> "For first responders, you get not only ballistic protection with Liquid Armor, but you also gain this additional stab and puncture protection."
> — Norm Wagner

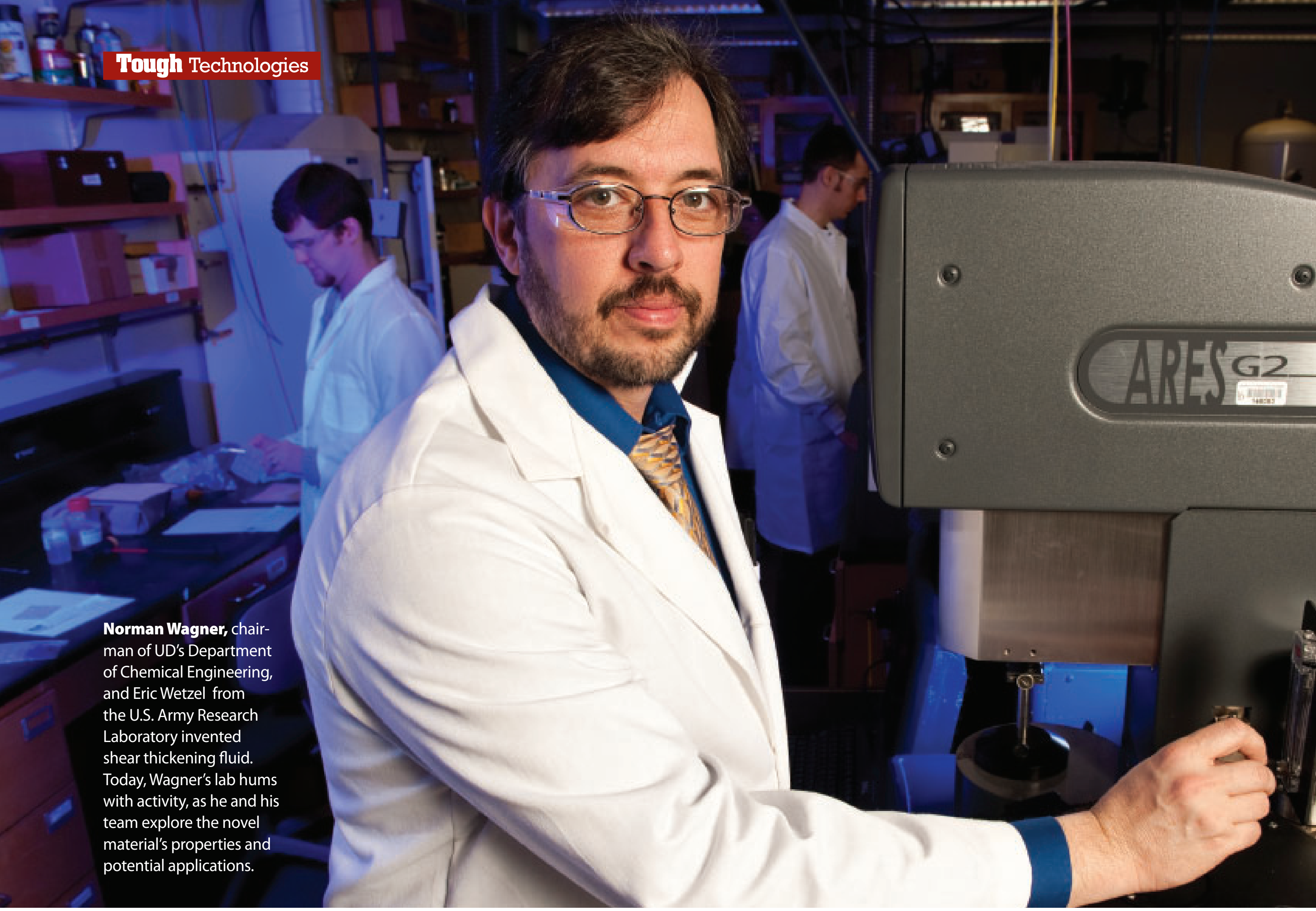
Trademarked as Liquid Armor, the UD innovation is light and flexible — until hit by an object or shaken forcefully. Under this mechanical stress or "shear," the tiny particles of silica and polymers suspended in STF harden instantly, forming a protective shield. The hardening process occurs in milliseconds, and then the body armor becomes flexible again.

Putting it to the test



Fabric treated with shear thickening fluid (STF) undergoes a series of laboratory tests at the University of Delaware, including stabbings with an ice pick to assess puncture resistance. At right, the photos in the lefthand column show the puncture made in Kevlar. The righthand column shows Kevlar fabric treated with STF. It is fully intact, with no punctures.

EVAN KRAPE



Norman Wagner, chairman of UD's Department of Chemical Engineering, and Eric Wetzel from the U.S. Army Research Laboratory invented shear thickening fluid. Today, Wagner's lab hums with activity, as he and his team explore the novel material's properties and potential applications.

"What's cool is that we have an interdisciplinary team that includes a textile engineer working with scientists, a postdoc, and graduate and undergraduate students in chemical engineering, all involved in basic science technology development." — Norman Wagner

"The multi-threat protection is of particular value," says Norman Wagner, the Alvin B. and Julia O. Stiles Professor of Chemical Engineering and chairman of the Department of Chemical Engineering at UD. Wagner invented the STF technology in collaboration with Eric Wetzel, a scientist at the U.S. Army Research Laboratory.

"For first responders, you get not only ballistic protection with Liquid Armor, but you also gain this additional stab and puncture protection," Wagner notes. "And the material can do all of this while increasing the vest's wearability."

The police officer responding to a robbery, the prison guard making rounds, and the air marshal ever-vigilant on a domestic flight all come to mind as potential beneficiaries of the technology. And Wagner foresees many others someday, including doctors and nurses in the operating room, athletes in high-contact, concussion-prone sports, soldiers on the battlefield, even astronauts suiting up for a spacewalk.

Wagner is collaborating with the University's Office of Economic Innovation and Partnerships (OEIP), and with Barrday, UD's preferred partner on STF, to develop new applications and business opportunities.

"OEIP has been a fantastic partner — they've greatly supported these exciting development opportunities," Wagner says.

"One of the key features of this technology is that it can be customized based upon the threat and desired performance characteristics," notes Bradley Yops, interim director of the Technology Transfer Center within OEIP. "For example, you can optimize the STF formulation as well as the substrate fabric depending upon the level and type of protection desired, whether projectile resistance, stab or puncture resistance, or a combination of both."

Barrday, a specialty textile manufacturer with offices in Cambridge, Ontario, Canada, and Charlotte, North Carolina, makes textiles from aramid (aromatic polyamide) fibers, a class of strong synthetic materials that includes DuPont's Kevlar and Teijin Aramid's Twaron, as well as other fabrics that might comprise the base material for Liquid Armor. Barrday has set up manufacturing facilities to make the Liquid Armor for customers who will then take the material and transform it into products.

"Barrday has invested the time to learn what we do in the lab and to expand that process to a production scale. They are generating very high-quality Liquid Armor,

EVAN KRAPE

which is critical in order for these materials to be certified as ballistic- and puncture-proof," Wagner says.

It's not easy working with STF, Wagner points out, because the material can rapidly become more viscous when subjected to mechanical stress, with the potential to damage processing equipment.

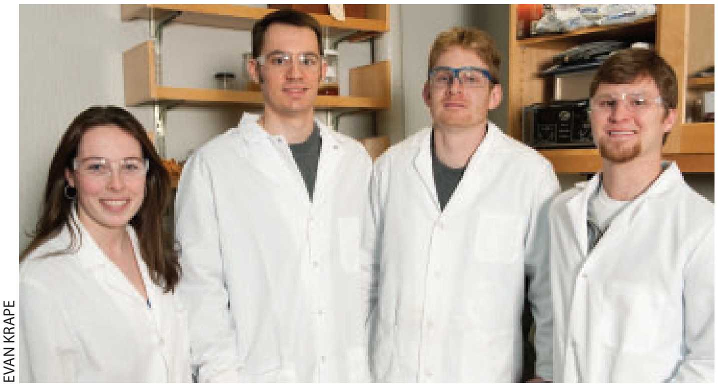
However, working out those kinks is worth it, Wagner points out, because Liquid Armor has a number of uniquely superior properties compared to existing body armor materials. It is thin and flexible, making it ideal for protecting the extremities — the arms and legs, Wagner says.

"We think there are a lot of opportunities to improve body armor, to create lighter, thinner, more wearable clothing while keeping the antiballistic strength intact. In making our material, we add STF to Kevlar or other fabric, but we need fewer layers to achieve the same result," he notes. "What we have to offer in Liquid Armor is a material that becomes a new tool in the toolkit of the armor designer."

Novel applications in development

Wagner's research lab resembles a scene from the movie *Psycho* when it comes to testing his favorite invention. The STF and fabrics treated with it are subjected to repeated knife stabs, not to mention hammering and dropped balls of varying weights and forces.

His research team is exploring the fundamental characteristics of STF using, among other tools, sophisticated rheometers that measure the flow of the STF in response to applied forces. Postdoctoral researcher Jeremy Fowler, recent doctoral graduate Dennis Kalman and doctoral student Kate Gurnon, and undergraduate students Paul Nenno, Tony Pallanta and Anne Golamatis work alongside textile engineer Kathy Zetune, formerly with ILC Dover, and research scientist Rich Dombrowski.



EVAN KRAPE

Wagner has a team of nine working on shear thickening fluid, among them, from left, doctoral student Kate Gurnon, research scientist Rich Dombrowski, and postdoctoral researchers Eric Yearley and Jeremy Fowler.

"What's cool is that we have an interdisciplinary team that includes a textile engineer working with scientists, a postdoc, and graduate and undergraduate students in chemical engineering all involved in basic science technology development. Partnered with interested companies, we have formed a great product development team," Wagner notes.

Currently, Wagner's colleague Jack Gillespie, director of the Center for Composite Materials *(see p. 8),* and doctoral student Kate Gurnon are working to develop novel materials that could help increase the blast resistance of armored personnel carriers by keying on STF's unique combination of strength and damping ability.

The same principle is being explored in sports gear, from football helmets to hockey shin guards and shock-absorbent skis.

"Concussions are serious health issues," Wagner notes. "Shear thickening fluid has the potential to give a bit and absorb the shock waves so they don't damage the brain."

Currently, Wagner and his team are advising two design groups composed of UD seniors working on this promising usage.

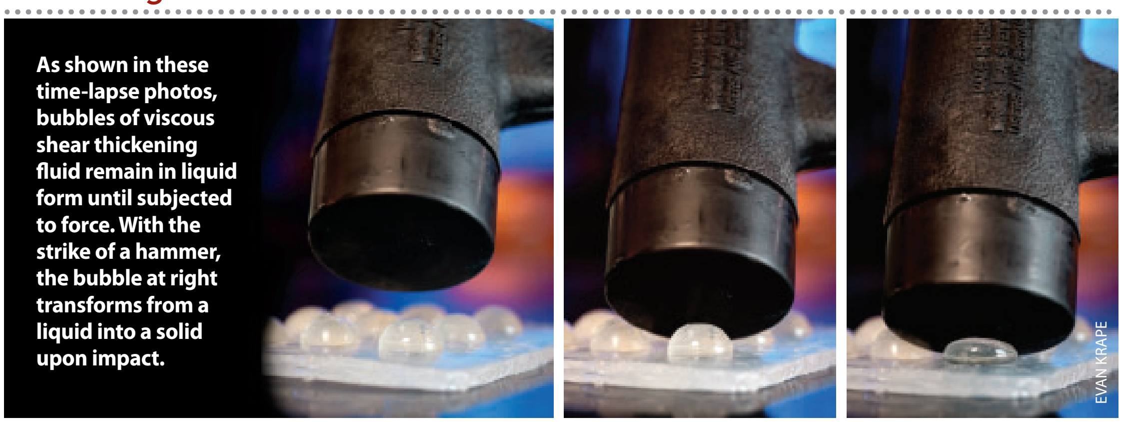
Besides these down-to-earth applications, Wagner and his team also have a proposal under review by NASA for creating the next generation of spacesuits.

"Shear thickening fluid is not an easy technology to do," Wagner says. "It's like Edison showed us, it's easy to make a filament that glows, but harder to make the light bulb. However, it's an exciting technology to work with, and engineers like to tinker and invent things," he notes with a smile. "Good things will come out of it — it's just a matter of time and effort."

Liquid Armor is subject to a number of issued and pending domestic and international patent applications. For more information about Liquid Armor, contact Denise Bierlein, licensing analyst in UD's Office of Economic Innovation and Partnerships, at *deniseb@udel.edu*.

— Tracey Bryant

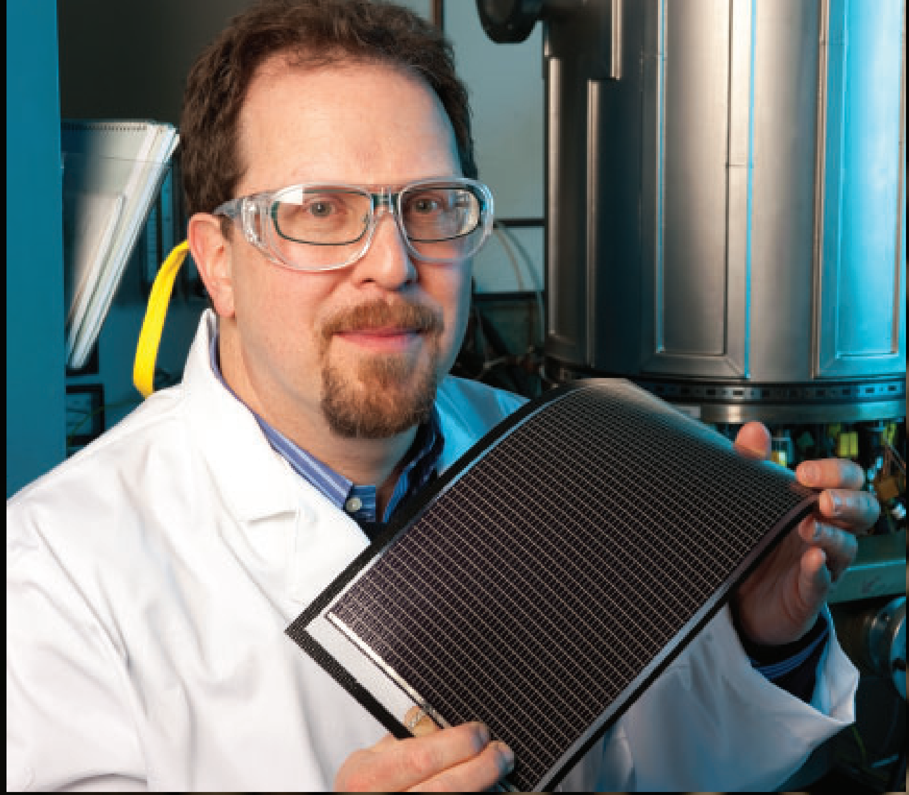
Lowering the hammer



As shown in these time-lapse photos, bubbles of viscous shear thickening fluid remain in liquid form until subjected to force. With the strike of a hammer, the bubble at right transforms from a liquid into a solid upon impact.

EVAN KRAPE

Lightening the load for soldiers in the field



KATHY F. ATKINSON

Bill Shafarman is holding a mini-power plant — a thin, flexible sheet of solar cells capable of converting sunlight into electricity. UD's Institute of Energy Conversion is working to help create lightweight, yet robust and powerful solar cells as a substitute for the many pounds of batteries soldiers must carry in the field for communications operations.

When an Army unit deploys in Afghanistan, the first supply planes carry cargo that is critical to powering communications operations in the field: batteries.

Some soldiers will carry up to 35 pounds of batteries for a three-day mission, according to the U.S. Army Research Laboratory. That's in addition to body armor, weapons, ammunition, rations and other equipment.

The Institute of Energy Conversion (IEC) at the University of Delaware is working with industry to help lighten the soldier's load by replacing those batteries with lightweight, yet powerful solar cells.

The Defense Advanced Research Projects Agency (DARPA), the independent research branch of the U.S. Department of Defense, recently funded four projects nationally through its Low-Cost Lightweight Portable Photovoltaics (PoP) program. UD's IEC is the sole academic institution to be involved in two of the efforts — one led by Ascent Solar Technologies Inc., based in Thornton, Colo.; the other by SiOnyx Inc. in Beverly, Mass.

"The U.S. Army is looking for much higher-efficiency solar cells that are very lightweight, flexible and durable — able to withstand bullet holes and other extreme battlefield conditions," says Bill Shafarman, a scientist at IEC and associate professor in the Department of Materials Science and Engineering at UD.

The UD institute's role in the projects is to make the technology more efficient — to increase the percentage of energy in sunlight converted to electricity in thin-film solar cells — and to explore new manufacturing approaches.

In their project with Ascent Solar Technologies, Shafarman and IEC research associate Greg Hanket are working to boost the conversion efficiency in lightweight copper-indium-gallium-selenide (CIGS) solar cells from 13 percent to 20 percent by replacing some of the copper in the semiconductor with silver. Their previous work has shown that this substitution can help make a higher quality material for the solar cells.

> "The U.S. Army is looking for much higher-efficiency solar cells that are very lightweight, flexible and durable — able to withstand bullet holes and other extreme battlefield conditions."
>
> *— Bill Shafarman*

"This replacement doesn't need to be expensive," Shafarman notes, pointing out that the semiconductor layer has a thickness of only 1 to 2 microns. A typical human hair, in comparison, is 50 microns thick.

In a related project with SiOnyx, IEC research scientist Steve Hegedus and his team are examining substrates other than the traditional plastic for the solar cells.

"The significance of the Low-Cost Lightweight Portable Photovoltaics program is that it will take thin-film, flexible copper-indium-selenide based solar cells to the next level of performance in order to meet DARPA's requirements and will accelerate the implementation of thin-film flexible solar cells to commercial and residential markets," says IEC Director Robert Birkmire.

IEC was founded in 1972 and designated in 1992 as a University Center of Excellence for Photovoltaic Research and Education by the U.S. Department of Energy and the National Renewable Energy Laboratory. The center collaborates with government agencies, industries and other universities around the world.

IEC pioneered the development of flexible solar cells in the early 1980s and was the first to show continuous deposition of thin-film solar cells. The UD institute's discoveries today are in use by a broad range of solar cell manufacturers.

— Tracey Bryant

A new window into aviation safety

An "elegant solution" to a decades-old problem in aviation safety may soon take flight, thanks to a research team in the University of Delaware's Department of Mathematical Sciences.

The pilot's window, or canopy, on U.S. Air Force jets is replaced every few months because the specialized plastic degrades under ultraviolet light, and there is no non-destructive method for testing it.

"If the window breaks where the pilot sits, the whole airplane falls down," says David Colton, Unidel Professor of Mathematical Sciences. "We've developed a mathematical method to determine if these materials have the requisite strength or not."

> "We've developed a mathematical method to determine if these materials have the requisite strength or not."
> — David Colton

If the method is successful, the researchers envision someday having a sensor that can sweep across an airplane canopy and indicate blue, for example, if the window is structurally safe, or red if it's not.

The novel approach, created by Colton and colleagues Fioralba Cakoni and Peter Monk, is based on a new mathematical theory of transmission eigenvalues, which they compare to the tones associated with the different strings of a violin.

"You send in an electromagnetic wave that excites the window, and you can measure the vibrations that come back in certain tones or frequencies," Colton explains.

Nobody knew that transmission eigenvalues even existed until the UD mathematicians discovered them in 1988 while doing research on inverse scattering problems, in which sound waves, as one example, are used to determine an object's characteristics by measuring data from the echoes.

They first thought of applying their new method to the problem of locating cavities in tree trunks and then began pondering other possibilities.

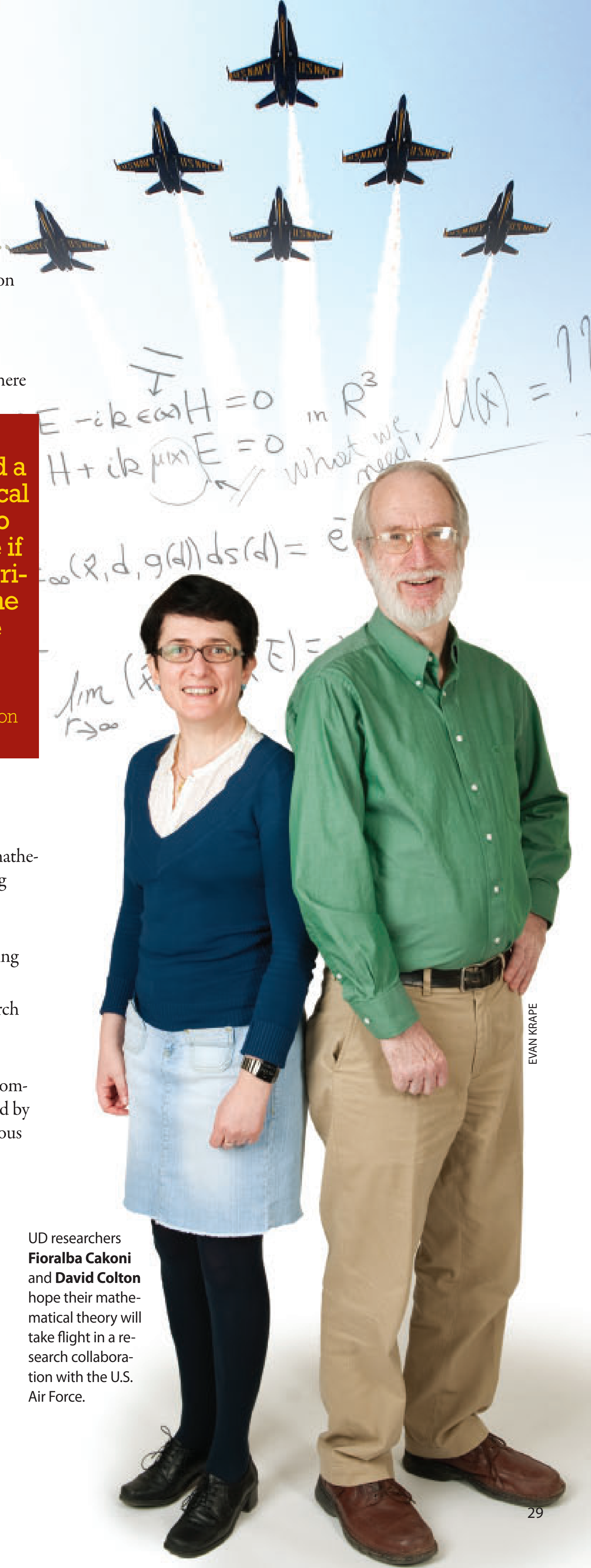
With funding support from the U.S. Air Force Office of Scientific Research (AFOSR), the UD team is now collaborating with researchers at Wright-Patterson Air Force Base in Ohio to put the theory into practice.

A test setup is being developed, consisting of a cylinder fabricated from composite material similar to the kind used for airplane canopies, and surrounded by antennas. The cylinder will be subjected to electromagnetic radiation of various frequencies, and the return vibrations will be measured.

"The mathematical theory is very exciting for us, but as applied mathematicians, we also are thrilled that the research may have practical applications," notes Cakoni. She is the lead author, with Colton and Monk, on "The Linear Sampling Method in Inverse Electromagnetic Scattering" published in February 2011 by the Conference Board of the Mathematical Sciences (CBMS) and the National Science Foundation.

So although Colton jokes that the jar labeled "elegant solutions" on his bookcase is empty, if the UD method works, it would represent a tremendous scientific advance in detecting flaws in materials such as airplane canopies, and perhaps, if the mathematical theory is extended to include biological tissue, even open a new window into medical imaging.

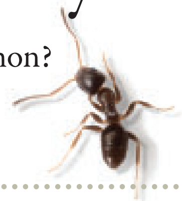
"That's a twinkle in my eye," Colton says. — *Tracey Bryant*



UD researchers **Fioralba Cakoni** and **David Colton** hope their mathematical theory will take flight in a research collaboration with the U.S. Air Force.

Networking Naturally

What do ants and slime mold (cool!) have in common? They're inspiring new wireless communications networks being developed by UD scientists. . . .



Lou Rossi is a mathematician, not a biologist, but he can wow you with his knowledge of ants.

Did you know that there are over 10,000 species of ants?

Or that these little insects add up to 15–20 percent of the total terrestrial biomass — all the living stuff — on Earth?

"Although ants are nearly blind, they are very successful at finding food," says Rossi, who is an associate professor in UD's Department of Mathematical Sciences. "You miss a few crumbs on the countertop, and you find ants there the next morning. How do they do that? Ants are computing machines," he says. "They do spatial computing, leaving chemical markers — pheromones — on the ground to communicate information to other ants."

Taking their inspiration from the social behavior of ants, Rossi and Chien-Chung Shen, associate professor in the Department of Computer and Information Sciences, are developing the complex mathematical algorithms required to operate a secure, wireless communications network for soldiers in the battlefield.

The initial research was funded by the National Science Foundation. The current effort is supported by a U.S. Army Small Business Innovation Research (SBIR) grant and involves an industry collaborator, Scalable Network Technologies Inc., based in Los Angeles.

The mobile ad hoc network (MANET) that Shen and Rossi are developing is very different from cell phone networks that rely on cell towers as base stations for message transmission and reception. Such towers would be easy targets in the battlefield. But setting up a MANET has its own set of complicated challenges.

DID YOU KNOW

There are over 10,000 species of ants.

Ant supercolonies can stretch thousands of miles.

Ants are true team players, working together for their colony's greater good.

"Every node, or device, in a mobile ad hoc network has to relay messages to other nodes, and most messages will be relayed over multiple hops," Shen says. "If you think of a group of soldiers in a battlefield, not all of them are in range, so they have to rely on other soldiers to route messages to them. Every node has to be a router, and all the nodes are moving. You know who you want to send a message to, but you don't know where they are."

Using ant behavior as their model, Shen and Rossi are developing the networking architecture and networking protocols, or "language," that will enable communication between the MANET nodes.

"Ants efficiently self-organize a large number of unreliable and dynamically changing components for various functions, adapting to the failure of individual ants, to changing conditions and to the lack of explicit central coordination, which makes them an ideal model," Rossi says.

"To solve problems that are inherently complex, we need to look at a system that adapts to uncertainty," Shen points out. "Biological systems designed over billions of years are optimized, so presumably they are more adaptive. That's a driving motivation of our work."

The researchers are generating mathematical algorithms for sending packets of data, passing messages to other nodes, keeping messages, and incorporating markers to maintain information to be routed to other nodes.

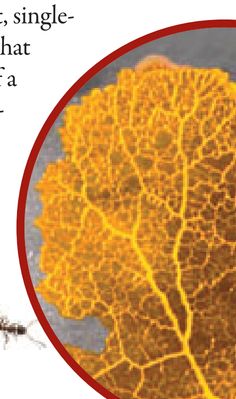
Currently in the second of three phases of their SBIR grant, the researchers will put their networking protocols to the test this summer in real-time video demonstrations.

"Our digital ants are already very good at finding the shortest path between nodes, which real ants do very well," Rossi notes.

Ironically, Rossi and Shen met at a presentation at UD on bio-inspired technologies given by a visiting Princeton researcher several years ago. Now Rossi and Shen's collaboration represents one of a small number of research teams working in this novel field in the United States. For example, Harvard scientists are studying bumblebee behavior.

However, the UD team is just as captivated by slime mold and by schools of fish, as they are by ants.

True slime mold, known scientifically as *Physarum plasmodium,* is a flat, single-celled, amoeba-like organism that can grow to roughly the size of a hand. In response to the chemical cues from nutrients in its environment, slime mold will assemble a complex network of tubes that serves as



Lou Rossi (left) and **Chien-Chung Shen** are developing a new wireless communications network that mimics how ants communicate.

KATHY F. ATKINSON

a resource distribution network for nutrients. This simple creature generates near-optimal networks, connecting multiple food sources throughout the cell body.

"Often, the tubes of a slime mold will be arranged in a geometry that balances efficiency — keeping the total tube length short — and robustness, having multiple paths in case a tube is severed," Rossi says.

The problems faced by slime molds are similar to those that exist in wireless sensor and actor networks (WSANs), which, for example, guide battlefield robots that detect and mark mines.

And in a new National Science Foundation project, the researchers are working to understand swarming by bees and schooling by fish. How many need to be leaders in order to keep the swarm together? With that answer and the anticipated decrease in the cost of robotics in the decades ahead, Rossi foresees the capability to deploy dozens of underwater robots to quickly find the boundaries of the contaminant plume for a disaster like the BP oil spill.

"It would be the ultimate swim team," Rossi says.

— Tracey Bryant

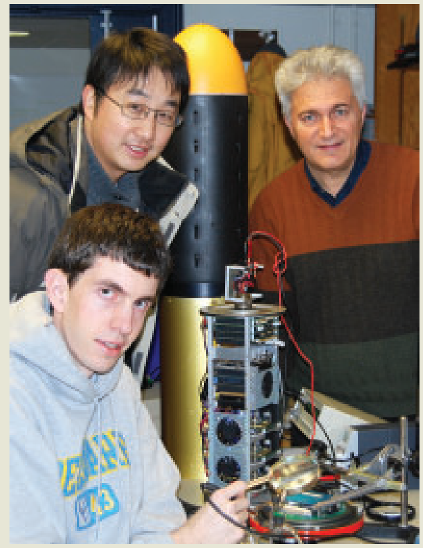
Slime mold creates a food distribution network. Photo courtesy of Prof. George Zabka.

Helping aquabots phone home

Autonomous underwater vehicles swim untethered through the ocean collecting data in places scientists could never go themselves. Thanks to University of Delaware researchers, these tools of the marine studies trade are being upgraded and adapted in new ways.

A UD technology is improving the communications abilities of the torpedo-shaped devices. It lets scientists transmit data back and forth with the AUV as needed, much as if they were using a dial-up Internet connection. Until now, scientists were limited to waiting until an AUV returned from a mission in order to retrieve data or to send the vehicle off in a new direction.

The advancement opens the potential for real-time data streaming. "We hope this leads to technology that lets AUVs communicate even faster so that scientists and AUVs can communicate continuously," said Aijun Song, assistant professor of physical ocean science and engineering (POSE) and a collaborator on the project.



ELIZABETH BOYLE

College of Earth, Ocean, and Environment faculty **Mohsen Badiey**, right, and **Aijun Song**, and doctoral student **Justin Eickmeier**, front, at work on UD's autonomous underwater vehicle.

The technology's creation involved the development of hardware and instrumentation, as well as software to decode communication signals under water. It is based on cell phone technology, but with one major difference: Instead of relying on radio waves moving through the atmosphere, it uses sound waves moving through the water.

"The radio waves that are used in the atmosphere can't be used in the ocean because they don't penetrate the water," said project leader Mohsen Badiey, professor and director of UD's POSE Program.

Members of the research team are working through UD's Office of Economic Innovation and Partnerships to patent two inventions based on the project, which is funded in part by the U.S. Navy through Office of Naval Research and Defense University Research Instrumentation Program grants.

First to benefit from this new technology will be the users of UD's AUV, which is serving as the test vehicle for the project. Known as *Dora* (short for Delaware Oceanographic Research Autonomous underwater vehicle), the robot has helped study everything from coral reefs off the Caribbean island of Bonaire, to a Byzantine shipwreck in the Black Sea, to underwater habitats in Delaware Bay.

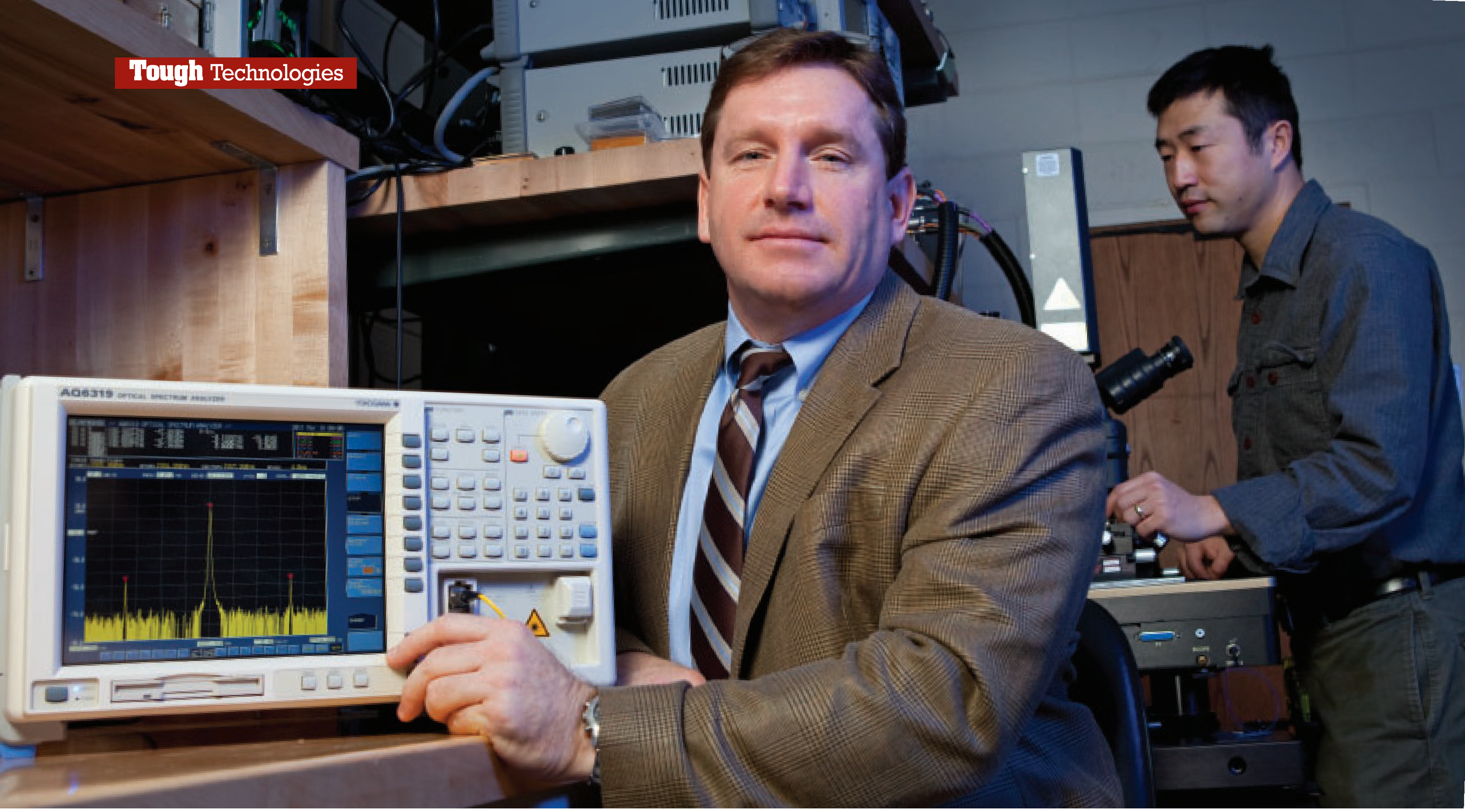
And *Dora* continues to grow her resume. Working with partners Weston Solutions Inc. and Geometrics Inc., in November 2010 UD received a $1 million grant from the Department of Defense Environmental Security Technology Certification Program to integrate the AUV with instrumentation expected to facilitate underwater munitions and explosives detection.

"This project brings the age of robotics into unexploded munitions detection to reduce the threats to humans and to make detection more efficient," said Art Trembanis, assistant professor of geological science and *Dora*'s chief operator.

The AUV will be outfitted with a total field magnetometer, which locates iron-containing objects such as bombs, shells and rockets. Such objects were used or discarded in coastal and ocean waters, swamps, rivers and lakes around the world during military combat, training and weapons testing.

Today those unexploded munitions, which may still detonate despite their age, pose a physical threat to everyone from contractors clearing underwater routes for telecommunications, to dredge operators, and fishermen bringing in their nets. The materials also threaten the environment as they deteriorate and leach toxic chemicals.

Integrating the magnetometer with the AUV is expected to provide cost savings over current approaches by requiring less manpower for operation and reducing or eliminating the need for support from a large ship. Other expected benefits include improved safety, portability, maneuverability and the ability to operate multiple sensing systems simultaneously. — *Elizabeth Boyle*



Safeguarding our soldiers

UD researchers unveil technology to reliably detect IEDs

According to U.S. military statistics, improvised explosive devices (IEDs) are the number-one killer in the Middle East, particularly in Afghanistan and Iraq. They are the largest cause of casualties to U.S. troops and NATO forces combined.

"It's a huge issue. We believe IEDs are going to impact all types of warfare scenarios because they are easy to make, hard to detect and tremendously destructive because you never know where they will turn up," says Dennis Prather, Alumni Professor of Electrical and Computer Engineering at the University of Delaware.

To help overcome this problem, Prather and his research team have developed a highly sensitive, low-cost application for accurately detecting and identifying IEDs using millimeter waves (MMWs). The approach involves using high-frequency photonic modulators, which convert millimeter waves, found in the electromagnetic spectrum between infrared and microwaves, into an optical signal that can be more easily imaged.

"Imaging in the millimeter wave spectrum offers many of the advantages common to infrared imaging, but allows for the ability to see through obscurants, such as blowing sand, fog, dust, smoke and light rain. It also offers the ability to see through certain types of materials, like outer garments, fiberglass, drywall and others," Prather notes.

Prather has extensive experience in the development and application of photonic devices and their integration into systems for imaging, communications and photonic applications. He is also a commander in the U.S. Naval Reserves and the United States representative on the NATO Technical Group for High-Performance Millimeter Wave Imaging.

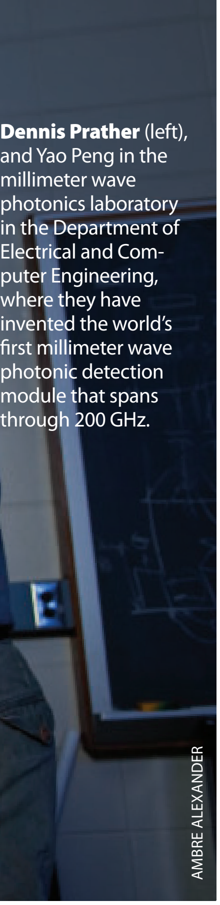
#1 Killer in the Middle East

Improvised explosive devices (IEDs) are the largest cause of casualties to U.S. and NATO troops in the region.

Completely covert

Over the past few decades, imaging in the infrared spectrum has allowed us to see through the darkness or "in the absence of light" because objects at non-zero Kelvin give off radiation (think hot, glowing coals in a fireplace).

By contrast, Prather's system uses passive radiation and requires just 400 watts to operate, about the same energy needed to run a high-end personal computer. It does not illuminate objects; rather it looks for radiation given off from systems that emit heat, using the sky temperature as a reference.



Dennis Prather (left), and Yao Peng in the millimeter wave photonics laboratory in the Department of Electrical and Computer Engineering, where they have invented the world's first millimeter wave photonic detection module that spans through 200 GHz.

This means that while humans see blue sky during the day and black sky at night, millimeter waves always see the absence of millimeter wave radiation, or black. As luck would have it, anything metal on earth also reflects millimeter waves. Since many IEDs are metallic in nature, Prather's device uses millimeter waves to "see" through the sand and other environmental conditions and detect IEDs buried underground.

"This system requires much less power than typical active systems like infrared, and because it never has to illuminate anything, it is entirely covert — a huge advantage for the military," he says.

No false positives

Another benefit of millimeter waves is that they are a great discriminator of false alarms because they use the sky temperature, not radiation, to visualize targets. While IEDs typically look "hot" under infrared, so do rocks and mounds of sand and dirt. When viewed with millimeter waves, only IEDs are visualized.

> "Imaging in the millimeter wave spectrum offers many of the advantages common to infrared imaging, but allows for the ability to see through obscurants, such as blowing sand, fog, dust, smoke and light rain. It also offers the ability to see through certain types of materials...." — Dennis Prather

"You don't see this in optics or infrared at all, which change based on the environmental conditions, making this wavelength a good tool for tracking and discerning IEDs," says Prather. "The tradeoff, however, is that you don't get the same high resolution as in the visible or infrared spectrum, so in that regard, it is not the most optimal solution for target acquisition."

Never blind

When imaging conditions hinder the ability to see in visible and infrared, so-called VIS-IR blind, these technologies lose sight of what they are tracking. The millimeter wave system is never blind, making it advantageous when used in combination with other types of technology.

"It's called image fusion — where you take visible, infrared and millimeter waves and put them together to create a high-quality, information-based image in all conditions," Prather says. "We're just beginning to think about applications on that level."

Next steps

Funded through grants from the U.S. Office of Naval Research (ONR), the Air Force Office of Scientific Research (AFOSR), the Defense Advanced Research Projects Agency (DARPA) and the Army Research Laboratory, Prather's millimeter wave system is now being tested in laboratory scenarios. The current system measures 60 cm x 60 cm x 20 cm and weighs 27.6 pounds. According to Prather, it needs to be smaller — by about 15 cm in depth.

"In the military, SWaP – size, weight and power – is the mantra," explains Prather. "That's what we're working on now, making it small enough to be mounted to a Humvee or secured to an unmanned aerial vehicle (UAV)."

Prather is also working with partners including Lockheed Martin, Heico, Systems Integration Organization and Phase Sensitive Innovations to investigate scalability and manufacturing scenarios that would help transition the technology to industry. — *Karen B. Roberts*

The first-ever demonstration of a photonic millimeter wave imaging system capable of seeing through obscurants and detecting IEDs.

Taking supercomputing to the extremes

Guang Gao and a team of researchers at the University of Delaware are poised to break new ground in the supercomputing landscape. Again.

Gao, Distinguished Professor of Electrical and Computer Engineering, is leading research to improve the speed, efficiency and computational capacity of our nation's extreme-scale supercomputer systems.

The effort is part of a research and development initiative by the Defense Advanced Research Projects Agency (DARPA) to create an innovative, revolutionary new generation of computing systems under the agency's recently announced Ubiquitous High Performance Computing (UHPC) program. Gao and the University of Delaware are members of the Intel Corporation UHPC team.

According to DARPA, which is the research arm of the U.S. Department of Defense, advanced computing is critically important to national security. The UHPC program plans to advance radically new extreme-scale computer architectures and programming models that deliver 100 to 1,000 times more performance, and that are easier to program than current systems. Prototype UHPC systems are expected to be complete by 2018.

Gao and his team at the Computer Architecture and Parallel Systems Laboratory in the UD Department of Electrical and Computer Engineering, are part of the Intel-led UHPC team focused on prototyping revolutionary hardware and software technologies for extreme-scale computing systems.

The UD team is leading the fundamental computer system research on execution models and its impact on system software design. They will work in close collaboration with other principal members of the Intel team from the University of Illinois at Urbana-Champaign, University of California at San Diego, Reservoir Labs Inc., and E.T. International Inc. (ETI).

"This is a very important event for the nation. This project will develop a supercomputer that puts the United States ahead of our competitors. But with that comes a lot of responsibility," says Gao, an expert in computer architecture and parallel systems.

Parallel computing is an important technology employed by supercomputer architectures to use multiple processors (CPUs) to speed up the execution of application programs. Computing performance increases historically have been driven by Moore's Law, which states that "the number of transistors that can be placed on an integrated circuit doubles every two years." Current models have limitations, however, and achieving projected performance gains requires new thinking.

The UHPC program recognizes that "a new model of computation or an execution model must be developed that enables the programmer to perceive the system as a unified and naturally parallel computer system, not as a collection of microprocessors and an interconnection network."

"Professor Gao's involvement in the DARPA Ubiquitous High Performance Computing project demonstrates his leadership in the extreme computing realm. The outstanding collaborative team comprised of Intel and leading universities is certain to ensure that the project outcomes significantly impact the future of high performance computing for many years," says Kenneth Barner, chair of the Department of Electrical and Computer Engineering.

A consummate researcher and educator, Gao and his group's pioneering work on novel computer architecture models and system software, including the compilers that optimize applications for efficient execution, serves as the basis for high-performance parallel supercomputers and is considered to be at the pinnacle in processing capacity, particularly in speed of calculation.

Guang Gao, Distinguished Professor of Electrical and Computer Engineering, at work in his office at UD.

EVAN KRAPE

He has actively participated in numerous research programs in parallel computing architecture and software sponsored by the National Science Foundation, DARPA, the Department of Energy, Department of Defense, and other U.S. and Canadian government agencies and private organizations.

ETI, founded by Gao and his associates as a UD start-up, is a computer technology and software company. ETI specializes in developing and deploying system software solutions and tools for advanced computing architectures and platforms based on new multi-core chip technology. ETI's system software explores large-scale many-core chip technology, with 160 processing cores on a single chip designed by IBM, to power the world's most influential supercomputers.

"We have received tremendous support from our department, college and university administration. Such support brings tremendous inspiration and encouragement to the members of the team in their pursuit of excellence," says Gao.

— *Karen B. Roberts*

Putting education to purpose

Since signing a Cooperative Research and Development Agreement (CRADA) in January 2010, the University of Delaware and the U.S. Army at Aberdeen Proving Ground (APG) have joined forces for research and development opportunities, as well as graduate education, professional development and employment or internship opportunities for the UD community.

David Weir, director of the UD Office of Economic Innovation and Partnerships, notes that workforce development is a high priority for the Army, and it is a natural fit to collaborate with UD, as the University is the closest Category I Research University to APG.

The College of Engineering, which already has a strong commitment to graduate education through teaching and research, is an active partner in developing educational programming to meet APG's growing professional development needs.

Last spring, the Department of Electrical and Computer Engineering (ECE) began supplementing on-campus and distance learning offerings with courses taught on-base to make it easier for APG employees to continue their education.

The first course — advanced engineering electromagnetics — attracted six students, including Janeen Winne, an APG engineer supporting the Army Evaluation Center in non-ballistic survivability.

"Despite recently completing a master's in systems engineering elsewhere, I feel that broadening my technical base is very important," says Winne.

U.S.ARMY

"The most powerful asset this nation has is not its technology, but the people who find new ways of moving our nation forward."

– Maj. Gen. Nickolas Justice
U.S. Army Research, Development and Engineering Command (RDECOM)

"UD's comprehensive program offers classes I have not seen at other universities," Winne notes, "and the knowledge I've gained helps me ensure that systems that are reaching soldiers will survive the complex environments that they face."

Current UD-APG on-base offerings in antenna theory and design and in digital signal processing have seen a three-fold increase in enrollment, with nearly 20 APG employees registered for the 2011 spring semester.

"Local course offerings greatly ease my travel burden and reduce my time away from work," explains Joseph Deroba, an APG electrical engineer and UD alumnus currently pursuing a doctorate in electrical engineering at UD. "Taking courses with my peers, many of whom have similar experience levels and responsibilities, is also a benefit."

Deroba also says having the knowledge to accurately design and model the performance of systems before they are mass produced greatly decreases risks and overall costs to the government.

In addition, new degrees such as the recently added master of science in software engineering, designed at APG's request by faculty from ECE and the Department of Computer and Information Sciences, position students and professionals to meet future job challenges with advanced innovation and problem-solving skills.

"We look forward to offering additional courses and developing mutually beneficial partnerships with increasing numbers of APG employees as they transition completely from the Army's Ft. Monmouth, New Jersey, site," says Michael J. Chajes, dean of engineering.

— Karen B. Roberts

Cyber Security Boot Camp Delaware presented attendees with myriad challenges in hacking to digital forensics. UD's group took home top honors in the "capture-the-flag" style competition that culminated the event.

Students answer call for cyber sleuths

Cyber threats are increasing in complexity, volume and seriousness, as criminals and terrorists become more adept at accessing all kinds of private information from individuals, companies and nations, with little more than a computer.

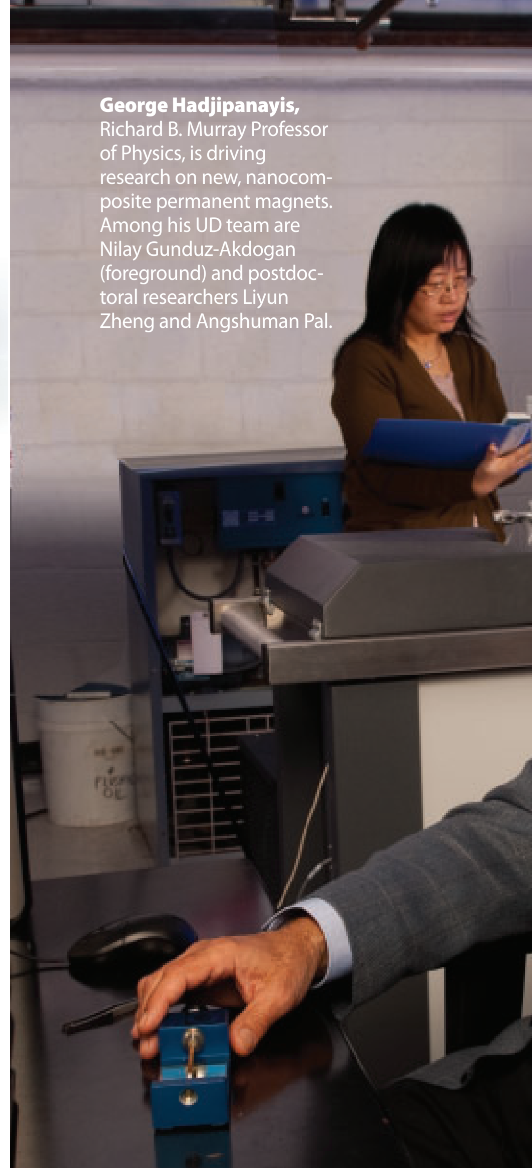
Nine UD students and alumni recently graduated from a first-of-its-kind cyber-training camp held as part of an effort to shore up the nation's capability to protect its information systems. Currently, there is a shortfall of individuals trained in this area.

"These security skills are critical to fighting cyber crime and to securing the systems we use daily, like email, social networking and banking," said Chase Cotton, associate director for cyber security at UD's Center for Information and Communications Sciences. "These same skills are also needed to help the government and military prepare to defend the country in this electronic battlefield."

The Delaware camp, one of only three in the nation, was organized by Wilmington University, UD, Delaware Technical and Community College, the SANS (SysAdmin, Audit, Network, Security) Institute and the Delaware Department of Technology and Information.

— Karen B. Roberts

Coming attraction



George Hadjipanayis, Richard B. Murray Professor of Physics, is driving research on new, nanocomposite permanent magnets. Among his UD team are Nilay Gunduz-Akdogan (foreground) and postdoctoral researchers Liyun Zheng and Angshuman Pal.

If it has a motor, it has a magnet — from cell phones to laptop computers. But the materials used in today's permanent magnets, produced chiefly by China, are dwindling in supply and rising in cost. University of Delaware physicist George Hadjipanayis is leading a multidisciplinary team of scientists aiming to develop the next generation of magnets to pull the U.S. industry back online.

As recently as 25 years ago, the United States ranked first in the production of magnets, George Hadjipanayis says. But then that dominance started to deteriorate.

"Now China is number one, followed by Japan, and then Europe," notes the professor and chair of the Department of Physics and Astronomy at UD. "Today, there is only one company left that makes magnets in the United States."

The strongest permanent magnets are made from neodymium and praseodymium, iron and boron (Nd(Pr)-Fe-B) as Hadjipanayis well knows. He's one of their inventors. In 1983, he published the first journal article on these magnets, which rapidly revolutionized the industry. Today, he says, the demand for such magnets is still growing, at about 15 percent per year.

"Two big areas of usage for the future are power generation and distribution. Hybrid and electric vehicles and wind turbines use lots of magnets," he notes.

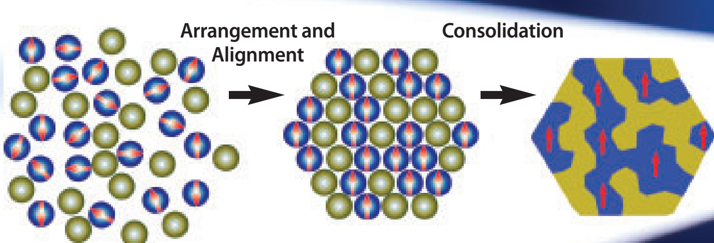
However, reserves of neodymium and dysprosium — two magnetic elements in the rare earth family on the Periodic Table, used in Blackberrys to iPods to Toyota hybrid cars — are projected to last no more than 50 years, he says.

At risk of running out of the elements for its growing population, China, the producer of 97 percent of the world's supply of rare earths, has imposed export quotas and raised prices, along with international concern. Hadjipanayis has participated in recent meetings in Japan, as well as the United States and Europe, focusing on alternative magnet materials.

In 2009, Hadjipanayis won a $4.4 million federal stimulus grant from the U.S. Department of Energy's Advanced Research Projects Agency (ARPA-E) to

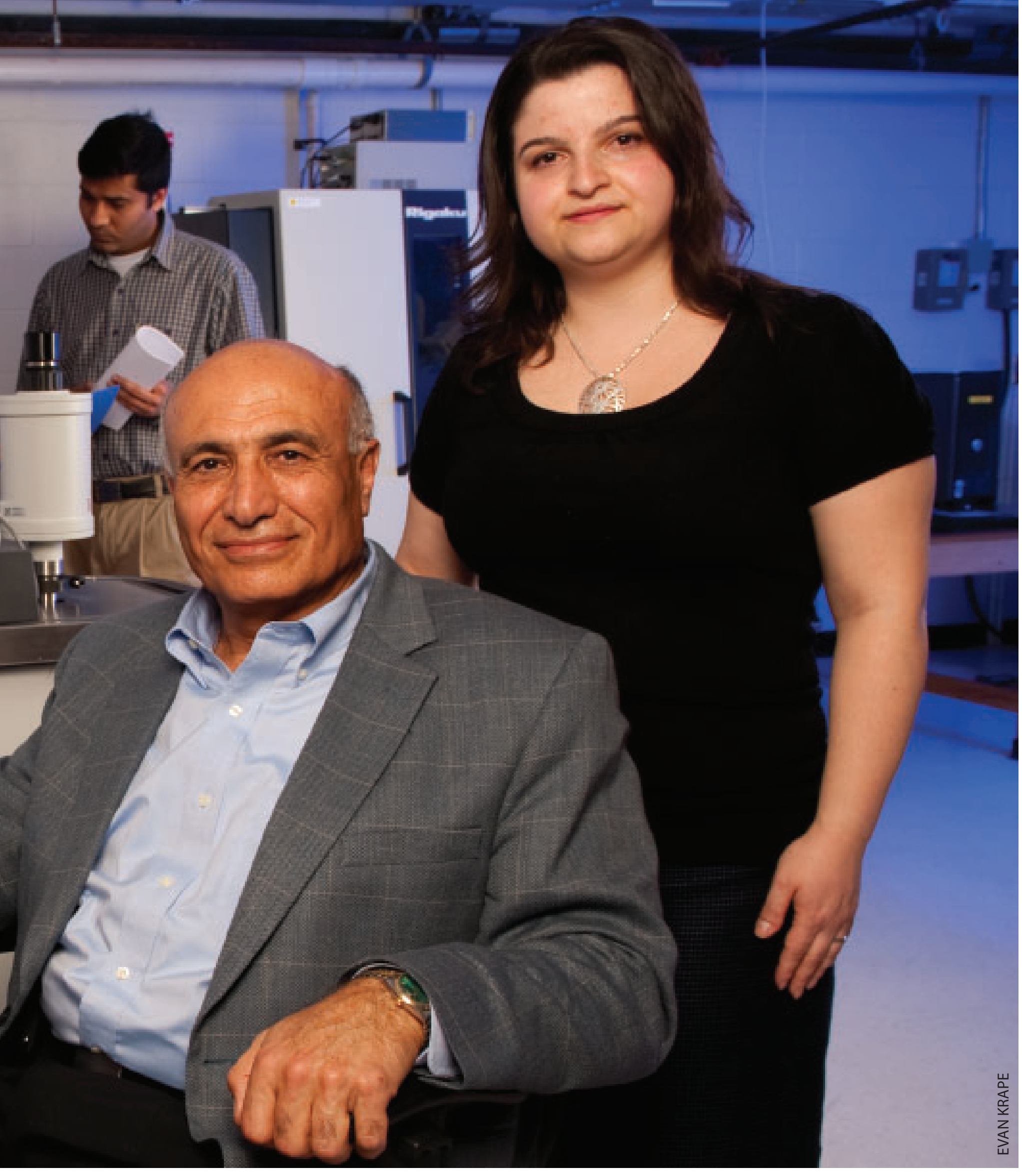
New magnets in the making

Researchers are putting together particles nearly as tiny as atoms to create nanocomposite magnets. At left is the chamber into which samples have been loaded for testing. As shown in the graphic below, specific particle shapes and arrangements are explored in the quest to get the particles' magnetic spins to interact and align, achieving optimal magnet strength.



Inside this bottle are dust-sized particles of neodymium, a rare earth metal used in the magnets that run the motors of smart phones to wind turbines.

EVAN KRAPE



EVAN KRAPE

The strongest permanent magnets are made from neodymium, iron and boron, as Hadjipanayis well knows. He's one of their inventors.

lead a multi-institutional research project to develop advanced magnets that are less dependent on rare earth elements and twice as strong.

Magnet strength is measured in "maximum energy product" (MGOe) units. Today's permanent magnets register between 50–60 MGOe. Hadjipanayis is shooting for over 100 MGOe.

Working with him on the three-year project are chemists, materials scientists, physicists and engineers from the University of Delaware, University of Nebraska, Northeastern University, and Virginia Commonwealth University; the U.S. Department of Energy's Ames Laboratory at Iowa State University; and Electron Energy Corporation in Landisville, Pa.

Bringing back a technology

A primary focus of the team is to create nanocomposite magnets by putting together particles of neodymium as small as 50 nanometers with even tinier particles (10–20 nm) of non-rare earth elements, such as iron or cobalt.

"We're basically making magnets by putting nanoparticles together like atoms to form a solid," Hadjipanayis notes.

Professors Siu-Tat Chui and Karl Unruh in the Department of Physics and Astronomy are his co-investigators on the effort at UD, which also involves five postdoctoral researchers and several graduate and undergraduate students.

The team is assembling the particles in specific arrangements in the quest to get their magnetic spins to interact and align in the same direction, achieving optimal strength. Different particle sizes and shapes, both square and spherical, are being explored.

"It's difficult to make these nanoparticles," Hadjipanayis says. "They are highly reactive and get oxidized right away."

Iron at the size of 10 nanometers, for example, catches fire if not protected properly. To prevent that from happening in their experiments, the team uses surfactants such as oleic acid, a component of olive and vegetable oil, as part of the fabrication process. Karl Unruh is making the iron nanoparticles and colleagues from Northeastern University the iron-cobalt nanoparticles.

The team has pioneered a way to make larger quantities of the nanoparticles for research purposes, producing a slurry of "nanoflakes" with thicknesses smaller than 100 nanometers and with a crystallographic texture. Because of this, when a magnetic field is applied, the nanoflakes pile up "like a shish kebab," Hadjipanayis says. Colleagues at Virginia Commonwealth University are coating the nanoflakes with iron-cobalt to help facilitate assembly and maximize their performance.

It's a step-by-step learning process, but Hadjipanayis sees progress.

"I'm happy we're making things happen," he says.

Over the years, Hadjipanayis has witnessed the downturn in magnet research and development in the U.S., but now the tide may be turning. A rare earth mine in California recently reopened, several industry labs are starting up again, and pockets of academic research and teaching are growing, with the largest group at UD and smaller ones in Texas, Nebraska and Iowa.

"If you lose the technology, it takes time to catch up," he says. "You need to have students, and faculty to train the students, and industries for the students to work in.

"This is very high-risk research," he notes. "It takes time to find new materials, and it takes time to commercialize them. However, GM has reopened its research center, which had been closed since the 1980s, and Ford is hiring. We are going to do our best to resurrect and revive U.S. research and development on permanent magnets." — *Tracey Bryant*

Taking a new field of science out for a spin

John Xiao was fascinated by magnetism as a child. "I thought it was like magic," he says. The attraction has never faded.

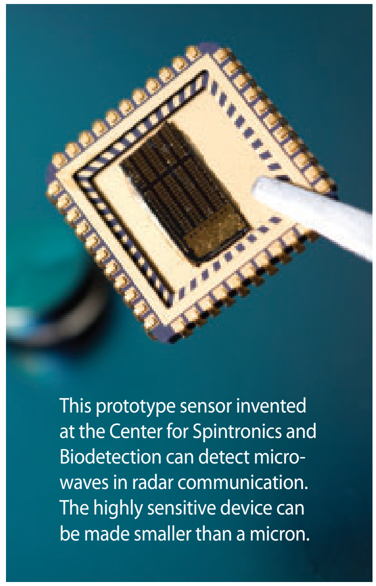
Today, the professor of physics and astronomy directs the Center for Spintronics and Biodetection (CSB) at UD, a growing research collaboration aimed at lassoing the magnet-like "spin" of electrons to encode and process data.

The new field of "spintronics" is expected to transform the electronics industry, yielding cheaper, faster, less power-hogging cell phones, computers and other devices. Xiao's interest lies in harnessing the "spin" to create new sensors so fine — in environmental monitors to medical diagnostic equipment — they can detect particles a thousand times smaller than a human cell.

UD's center, established in 2007 through the U.S. Department of Energy Experimental Program to Stimulate Competitive Research (EPSCoR), involves an interdisciplinary team of scientists from UD, as well as researchers from Brown University in Providence, R.I., and Argonne National Laboratory, one of DOE's largest research centers, located near Chicago.

In addition to Xiao, the principal investigators include professor Edmund Nowak, associate professor Branislav Nikolic and assistant professor Yi Ji in the Department of Physics and Astronomy, and James Kolodzey, the Charles Black Evans Professor of Electrical and Computer Engineering — all at UD — and Souheng Sun, professor of chemistry and engineering at Brown University. Postdoctoral researchers and graduate students from both universities also are involved.

The team has five patents in the pipeline so far, most of them demonstrating spintronics in the microwave regime, which is the UD center's innovation, Xiao says. Their prototype sensor, of particular interest to the military, can detect microwaves through the change in sensor resistance. The sensor can be made smaller than a micron (that's smaller than four one-hundred-thousandths of an inch).



This prototype sensor invented at the Center for Spintronics and Biodetection can detect microwaves in radar communication. The highly sensitive device can be made smaller than a micron.

"Microwaves used in communication are very weak, and our sensor is very sensitive and is able to detect the microwave phase with a circuit that is much simpler than those used in traditional approaches. As such, it is easy to build an array of sensors that can be used to image the microwaves," Xiao says. "With this technique, we are exploring medical applications such as the detection of breast cancer — that is a very exciting aspect of this research."

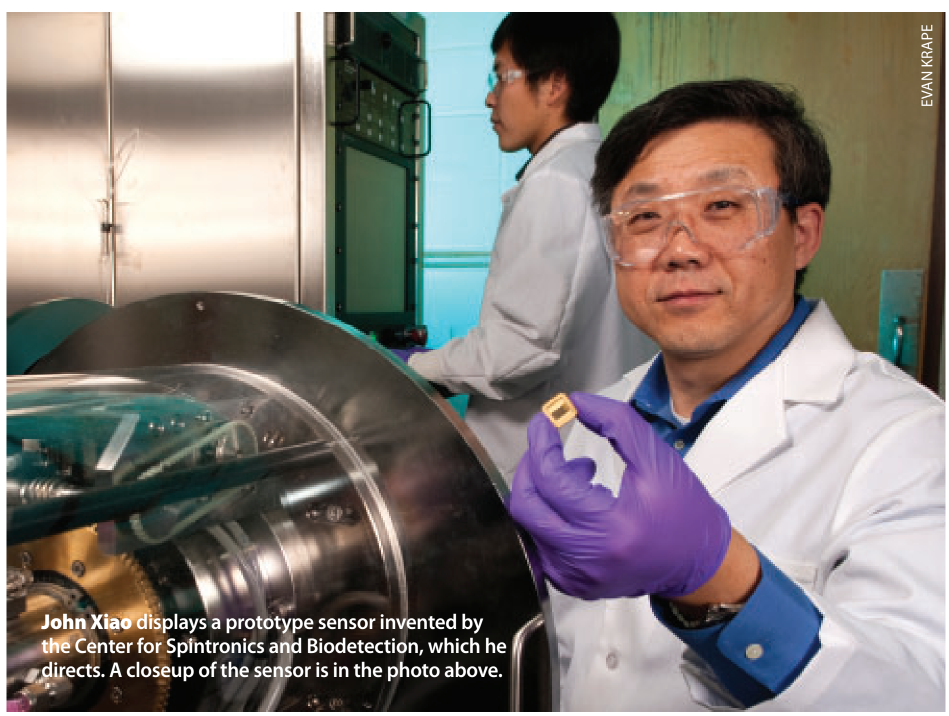
A major goal is to develop a biosensor, patterned much like a DNA chip, that can detect the tiny magnetic field generated by a single nano-sized particle that can then be used to label various biomolecules. Although this approach to biodetection is not new, Xiao says, he and his colleagues are working to perfect the technique, and a prototype biosensor has been developed.

"The goal is to detect as few nanoparticles as possible present," Xiao says. "We can attach DNA to the magnetic particles and 'functionalize' them, linking them, one-to-one, to a biomolecule."

The applications for more sensitive sensors are numerous, Xiao says, from increasing the early diagnosis of cancer, diabetes and other diseases, to detecting harmful viruses as part of antiterrorism programs.

As the work proceeds, each collaborator contributes a critical strength, Xiao says. Brown University researchers are functionalizing the surface of the magnetic particles and know how to attach them to the sensor and to the target biomolecule. The UD researchers are experts at understanding the underlying physics for better sensor design and signal-to-noise ratio, and the feasibility and demonstration of the technology. And colleagues at the Center for Nanoscale Materials at Argonne National Laboratory are helping to fabricate the spintronics devices.

"This is very much a team effort," Xiao says. "Scientists can do something very useful, very helpful, when working together in an interdisciplinary way." — *Tracey Bryant*



EVAN KRAPE

John Xiao displays a prototype sensor invented by the Center for Spintronics and Biodetection, which he directs. A closeup of the sensor is in the photo above.

On the Home Front

Home: Noun \'hōm\ One's place of residence; a familiar or usual setting; congenial environment; the focus of one's domestic origin

EVAN KRAPE

Better lighting for safer streets

Long before sedans and SUVs populated the highways, walkers and bicyclists shared the road with automobiles. The cities — and city streets — were designed to be walkable and safe for all users.

Today, roads are largely designed for cars. Moreover, the streetlights that help drivers see the road in front of them and the cars and signs around them might not sufficiently illuminate the roadway for its other "forgotten" users, such as pedestrians, bicyclists and those waiting for transit.

"The post–World War II proliferation of suburban development has caused developers to ignore the basic planning principles that were the foundation of most communities," says Marcia Scott, an associate policy scientist in the Institute for Public Administration (IPA), whose research examines transportation policy and planning.

Scott is part of a larger research team within IPA examining the issue of pedestrian lighting in unincorporated Delaware communities. The team, led by researcher Theodore Patterson, includes policy scientist Edward O'Donnell and graduate research assistant Ryan Gillespie. Together, they are analyzing best practices of pedestrian lighting in unincorporated areas, with respect to livability, environment, energy efficiency, financing and aesthetics. The team plans to form a working group with key transportation stakeholders and incorporate their input into working paper recommendations.

The researchers are not examining the extent of lighting throughout the state; rather, they are interested in the roles of responsibility and options for pedestrian lighting in unincorporated areas. For instance, if a community outside a city's limit recognizes a need for street lighting, where should they go to request it, and who is responsible for its installation and maintenance?

Preliminary research shows policy differences across Delaware's three counties with respect to requesting lighting in unincorporated areas. Still, until now, no research has examined the effectiveness and outcomes of such policies. And it is Sussex County — which has yet to implement a system for street and pedestrian lighting in unincorporated areas — that is experiencing the largest influx of an aging population who will require well-lit streets.

Funded by the Delaware Department of Transportation, the study builds off previous research that examined the safety, security and maintenance of multi-modal facilities in the state.

"Our goal is to bring awareness of the need to develop pedestrian lighting policies in unincorporated communities in Delaware that address design, safety, cost and maintenance issues but also promote walkability and a pedestrian-friendly environment," says Scott. "Lighting is an important issue for road safety, and our hope is that mothers with strollers and grandfathers with canes will be able to walk in their communities on safe, well-lit sidewalks and pedestrian pathways." — *Artika Rangan*

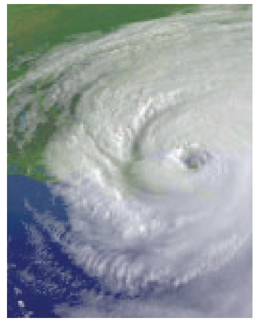
"Our goal is to bring awareness of the need to develop pedestrian lighting policies...."

— Marcia Scott

Advanced roofing materials offer disaster resistance with an environmental twist

The earthquake that devastated Haiti in 2010 rendered more than 1 million homeless and collapsed or severely damaged 250,000 residences and 30,000 commercial buildings, according to Haitian government estimates.

National Hurricane Center reports estimate the property damage caused by Hurricane Katrina along the Gulf coast in 2005 at $81 billion.



A prevailing question following such disasters is can this type of damage be prevented?

At the University of Delaware, Tripp Shenton and Richard Wool have been a driving force behind the development of advanced roofing materials designed to withstand such natural catastrophes.

> "It is low cost, energy efficient, made from renewable resources and contains fabulous engineering properties that impart disaster resistance in an efficient and environmentally friendly way."
> — Richard Wool

Shenton is a civil engineer with more than 25 years' expertise in structural health monitoring and condition assessment of civil infrastructure. Eight years ago, he began collaborating with Wool, a chemical engineer and materials scientist who develops novel composites using green, renewable materials.

"I've always been interested in using alternative materials for civil infrastructure applications," explains Shenton, chair of UD's Department of Civil and Environmental Engineering. "Civil engineers are not building rocket ships, but talking with Richard sparked the idea of developing a better, safer roofing system for low-rise construction using renewable materials."

In conventional construction, an average neighborhood roof is built from rafters, trusses, sheathing, tar paper and shingles. Under high winds, these materials easily "peel off," creating holes that impair structural stability to the roof and ultimately to the home, and can lead to structural collapse, says Shenton. Even small holes present large problems because they pressurize the interior of the home, opening the structure to wind and water damage.

"Houses deconstruct in high velocity wind due to pressure drop," adds Wool. "The roof acts like an airplane wing, which uses the pressure drop to guide the aircraft. While the drop is only about one psi (pounds per square inch), it is the equivalent of hanging a Volkswagen bus off of each 4' x 8' board on your roof."

Superior structural stability, renewable resources

To address this problem, Shenton and Wool conceived the idea of replacing the common patchwork of individual roofing components with a monolithic panel that acts as one large structural unit and expands in high winds.

Their design, funded through grants from the National Science Foundation, is called a "sandwich structure." The outer layers (Wool calls this "the bread") are made from recycled paper infused with a biobased resin made from thin, high-performance composites. The interior layer (or "meat") is 12 inches of synthetic based foam core, which offers inherent insulation. The "sandwich" is bonded with bioresins that act as an impermeable weather coating, provide superior structural integrity and improved disaster resistance, and resist holes, cracks or fissures that can degrade the roof.

When installed, the all-natural composite roof system works together with the floor and the vertical walls to transfer the loads coming at it from the weather to preserve the building envelope and reduce the loss of life and property damage due to hurricanes and earthquakes.

The soy-based natural-fiber composites are environmentally friendly and inexpensive relative to petroleum-based composites. The resins are derived from a plentiful U.S. crop — the soybean — while the natural fibers are byproducts of seasonal crops that otherwise would become waste.

Because the monolithic roof system can be mass produced in a factory and assembled at the site, the potential exists to also reduce construction site injuries.

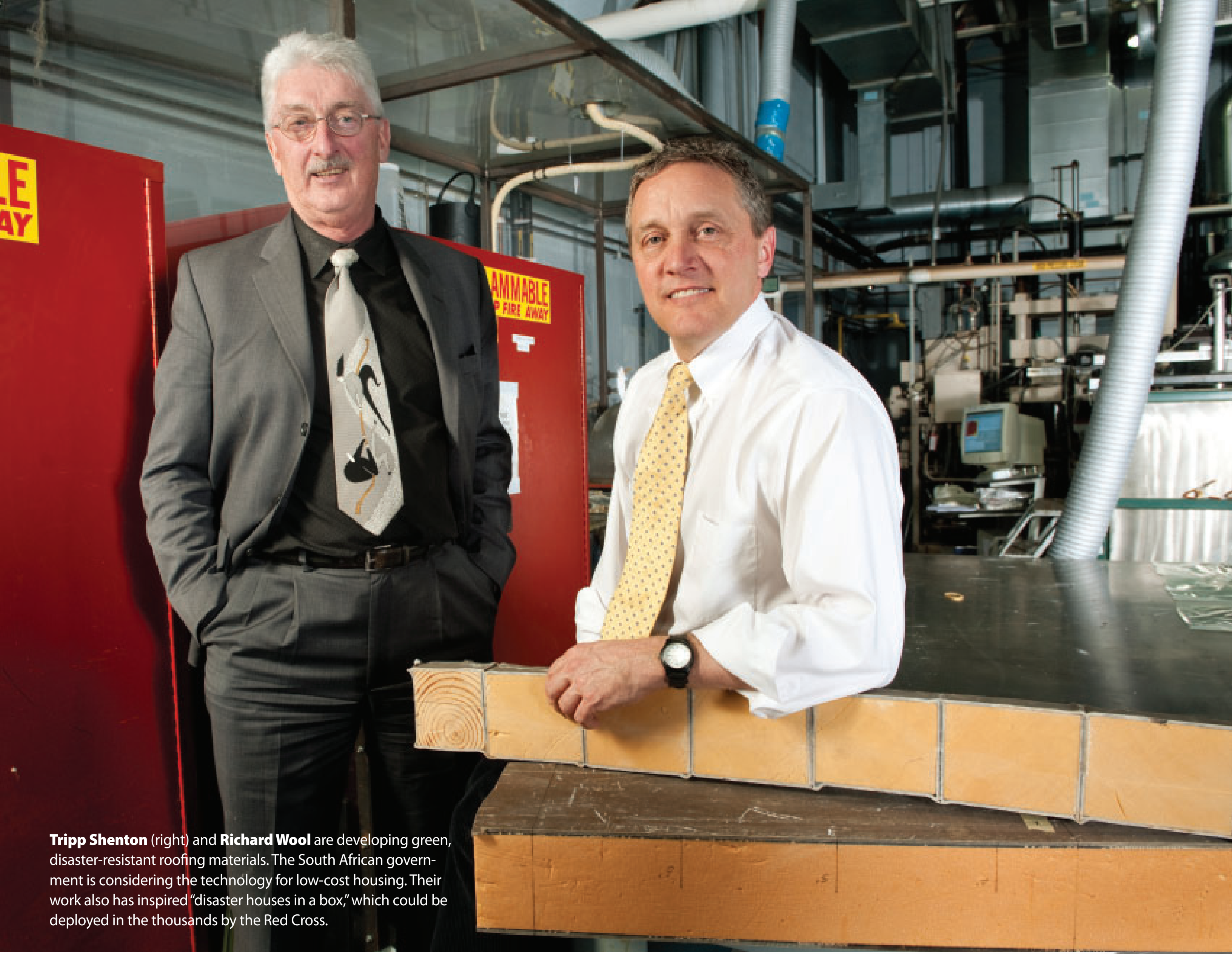
"This particular design offers a much needed four-way punch. It is low-cost, energy efficient, made from renewable resources and contains fabulous engineering properties that impart disaster resistance in an efficient and environmentally friendly way," says Wool. He is currently working to commercialize a biobased foam made from soybean for added energy efficiency.

A New York architect has used a modified version of the UD system to design "disaster houses in a box," which could be rapidly deployed in the thousands by the Red Cross to provide relief from future earthquakes, tsunami, floods, hurricanes and other natural disasters.

UD green engineering students have examined the design for Haiti reconstruction projects, an option Wool says is being considered for the future by Catholic Relief Services in Baltimore, Md.

From a global warming perspective, the hurricane-resistant design is highly energy efficient and, if combined with solar energy, could make an important contribution to our global energy, according to Wool. Because it is made with biobased materials, carbon trading benefits also exist.

EVAN KRAPE



Tripp Shenton (right) and **Richard Wool** are developing green, disaster-resistant roofing materials. The South African government is considering the technology for low-cost housing. Their work also has inspired "disaster houses in a box," which could be deployed in the thousands by the Red Cross.

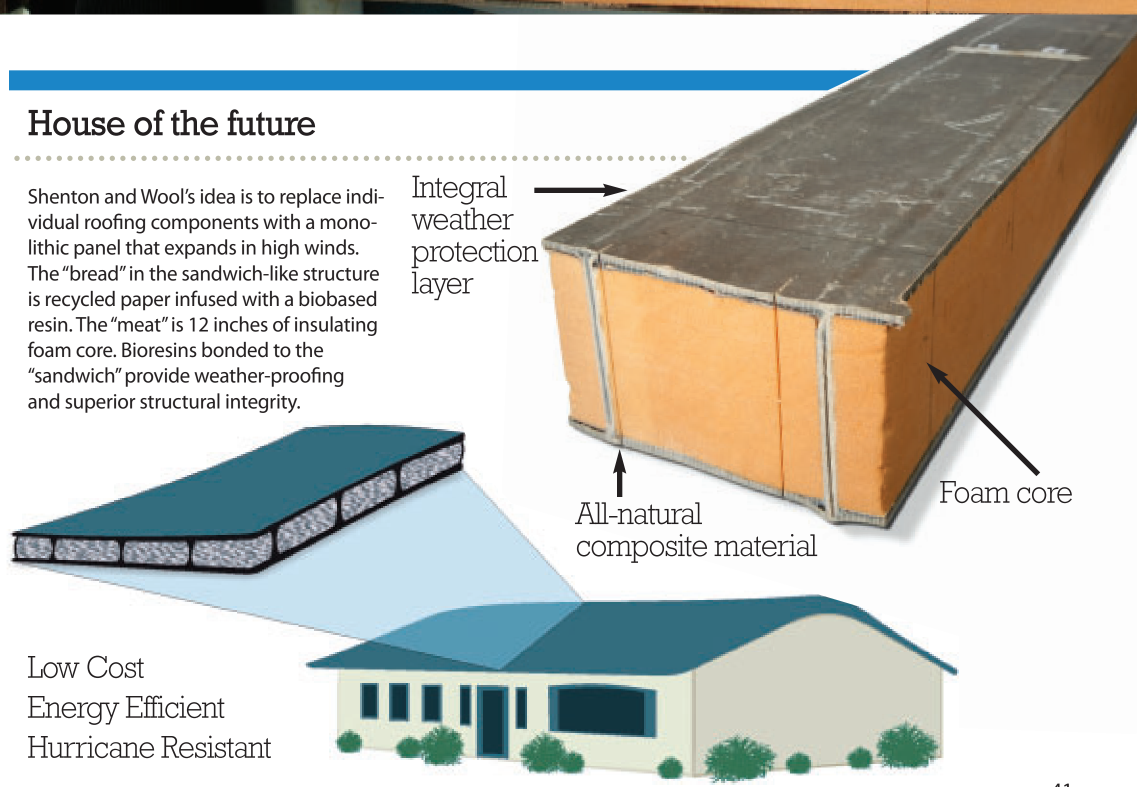
These attributes attracted the attention of the South African government, which recently signed a "memorandum of understanding" with UD to explore this technology to build 2.2 million low-cost township houses in South Africa.

With patents on the materials, Wool is currently working with industry partners, including UD startup Crey Bioresins Inc. and Dixie Chemical Company Inc. in Pasadena, Texas, to license and commercialize the technology in the Gulf States and elsewhere.

"It is a revolutionary technology, one that is almost before its time because the infrastructure is not yet there to produce it," concludes Wool. — *Karen B. Roberts*

House of the future

Shenton and Wool's idea is to replace individual roofing components with a monolithic panel that expands in high winds. The "bread" in the sandwich-like structure is recycled paper infused with a biobased resin. The "meat" is 12 inches of insulating foam core. Bioresins bonded to the "sandwich" provide weather-proofing and superior structural integrity.



KATHY F. ATKINSON

The psychology of bullying

When it comes to understanding bullying, "we make a lot of assumptions that aren't based on data," says UD psychologist Julie Hubbard, whose scholarship aims to build a stronger empirical foundation that could lead to new and more successful evidence-based programs for bullying.

Although school-based bullying prevention programs already exist, findings suggest they are not particularly effective. Thus, Hubbard, an associate professor of psychology, believes that more basic research is needed to understand why children bully and how to develop effective programs to combat bullying.

Her area of research examines peer relations, aggression and emotion regulation in 6- to 12-year olds, the age at which the peer world starts becoming more important. She has studied peer rejection, anger management and social-cognitive processes in children and found the need to refine one key question in this population: "What more do we need to learn about aggressive children to be able to develop more effective interventions for them?"

Hubbard has specifically focused on two types of aggression — reactive and proactive — in an effort to better answer this question.

Defined as defensive, retaliatory, and in response to real or perceived provocation, reactive aggression is driven by anger. Proactive aggression, on the other hand, is deliberate and purposefully goal-oriented. Think: the kid who fights back versus the kid picking the fight. Hubbard considers bullying to be a particular type of proactive aggression.

While there have been numerous theories and speculations that proactive aggression is characterized by lack of physiological arousal and anger, there have been far fewer studies to examine the difference, physiologically and emotionally, in these children in the moment that they engage in episodes of proactive or reactive aggression.

In the first empirical support of the theory suggesting proactive aggression is literally "cold-blooded," Hubbard and her colleagues developed tools to measure physiological arousal and anger expression and found that proactive aggression is displayed when children are particularly calm and unprovoked. Reactive aggression, they found, tends to be "hot-tempered," driven by anger, and marked by physiologic changes such as increased heart rates and perspiration.

The research team studied reactive and proactive aggression in 36 fourth- and fifth-grade boys and girls who were engaged in a simulated drawing contest project. To measure reactive aggression, the students were asked to prepare drawings on the computer, which were then critiqued, criticized and spoiled by a "virtual peer" in another room. The students were later given the opportunity to comment on their peer's picture and spoil it if he or she chose to do so.

To measure proactive aggression, the invisible virtual peer did not comment on the children's drawings; instead, the students were "competing" with the peer and given the opportunity to spoil the virtual peer's picture in order to win an attractive prize.

"The reactive tasks involved peer provocation but no instrumental gain from aggression, whereas the proactive task involved no peer provocation but clear instrumental gain from aggression," Hubbard explains.

The researchers observed and measured the students' behavioral aggression (the extent to which the child spoiled the peer's picture), their verbal aggression, facial expressions, and physiological arousal (through heart rate and skin conductance reactivity monitors).

The children in the reactive task who were most likely to spoil their peers' pictures were the ones with increased heart rates and skin conductance reactivity, a stark contrast to the children in the proactive task, who were most likely to sabotage the peer's pictures if they exhibited decreased heart rates and skin conductance reactivity.

The finds are revealing, but the "real trick," according to Hubbard, is how to turn these findings into interventions.

"If we know that children's physiology differs when they are engaging in acts of reactive and proactive aggression, then perhaps we need to do a better job of developing interventions that separately target reactive and proactive aggressive episodes in children," Hubbard says.

"My hope is that, over time, we can develop the next generations of interventions that are better because they are based in data, not hypothesis." — *Artika Rangan*

Keeping flu out of the coop

For the record

Flu can be fatal for chickens and turkeys

Is a "perfect storm" brewing for an avian flu outbreak in Delaware? UD is part of a poultry health network working to protect the state's $3.2-billion poultry industry from the disease.

Waterfowl — ducks, geese, swans and shorebirds — commonly get avian flu, but they don't get sick. However, they become natural carriers of the disease as they migrate along the world's flyways, including the Middle Atlantic Flyway, where Delaware is a prime pitstop.

For chickens and turkeys, the flu can be fatal.

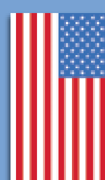
"Much like people do when they get influenza, chickens and turkeys become listless, cough and suffer other respiratory distress," says Jack Gelb, chairman of UD's Department of Animal and Food Sciences and director of the Avian Biosciences Center. "Avian influenza is a highly contagious disease, and if the virus is particularly virulent, high bird mortalities will occur."

Poultry powers Delaware's economy in a big way. Delaware farmers sent over 231 million broiler chickens to market in 2009, according to Delmarva Poultry Industry Inc., a regional trade association. A study released earlier this year by the UD Department of Food and Resource Economics estimates the poultry industry's value at $3.2 billion — it is the single largest contributor to the state's $8-billion agricultural industry.

Waterfowl defecate as they fly overhead or waddle on land, putting poultry flocks potentially at risk if a farmer accidentally gets feces from a flu-infected bird on a shoe or equipment and walks inside a poultry house. And that's just one of a number of scenarios, Gelb says. Birds bought at live markets, backyard flocks and the threat of bioterrorism also concern the triumvarite of industry, government, and university partners working to monitor poultry health.

In 2004, the H7N2 strain of avian influenza struck three farms on Delmarva and was quickly brought under control through the teamwork of state governments in Delaware and Maryland, the Delmarva poultry industry, and the University of Delaware and the University of Maryland. The U.S. Department of Agriculture (USDA) hailed the response as a "national model."

Although the highly pathogenic H5N1 avian influenza has not caused problems in the United States, that virulent strain has impacted poultry in Asia, Africa, Europe and the Middle East. Some people living in close contact with infected flocks in those countries have gotten sick and died. Health officials are wary that the virus could mutate to infect humans and create a pandemic, as humans have no immunity to the disease.



A national model

An outbreak of the low-pathogenic H7N2 avian flu caused a scare on the Delmarva Peninsula in 2004, but was tamped down quickly and limited to three farms — a feat attributed to rapid diagnosis, quarantine, proper dead bird composting and decontamination.

This efficient response and control — credited to the teamwork of state government, poultry growers, the Delmarva Poultry Industry Inc., and the University of Delaware and the University of Maryland — has been hailed as a "national model" by the U.S. Department of Agriculture (USDA).

UD researchers continue to share the approach with colleagues in the U.S. and abroad via technical assistance programs in Romania, Bulgaria, Turkey and India. The Emergency Poultry Disease Response Certificate Program (ag.udel.edu/abc/epdr.html) is an internationally recognized short course offered annually on campus.

In 2010, UD tested nearly 4,000 samples as part of the USDA and poultry industry program that screens every commercial broiler flock prior to marketing to ensure they are influenza-free.

Additionally, UD's Avian Biosciences Center has tested more than 10,000 samples from live and dead wild migratory birds as part of an early warning and detection program that has been in place since 2005, led by the Delaware Department of Natural Resources and Environmental Control, with support from USDA and the Department of the Interior.

JON COX

Help prevent poultry disease

Rising food costs, a dimmed economy, and the desire for locally grown food have sparked a backyard gardening movement in the United States, and an increasing number of cities are now allowing chickens to be grown within city limits.

According to the University of Delaware's Avian Biosciences Center, biosecurity is especially critical for owners of backyard flocks since these birds sometimes are raised outside and may come in contact with wild birds and migratory waterfowl. Restricting access to your property and birds minimizes the risk of avian influenza infection.

If you have come in contact with wild fowl or other birds, the experts recommend that you bathe and change your clothes and footwear before caring for your flock. Hunters must be particularly aware of where they have been and how they may interact with domestic poultry.

Know the warning signs of disease, and report any sick birds to your state department of agriculture or the USDA's toll-free hotline at 1-886-536-7593.

Avian influenza a moving target

UD's Avian Biosciences Center in the College of Agriculture and Natural Resources encompasses two major laboratories and teams of scientists and extension agents working on a comprehensive program of poultry disease research, surveillance and outreach. Gelb oversees the program.

Lasher Laboratory, at the Georgetown campus, serves as the primary poultry diagnostic lab in Delaware. Technicians there utilize the real-time reverse transcription polymerase chain reaction (rRT-PCR), a fast, highly sensitive DNA test for avian influenza. The lab provides comprehensive diagnostic services to commercial poultry producers — a representative sample of birds from every farm flock in Delaware is tested before being sent to market. The testing also is available to small non-commercial hobby and backyard flocks.

At the Charles C. Allen Laboratory, a federally certified biocontainment facility on UD's main campus in Newark, research yields new discoveries relating to avian influenza and other infectious poultry diseases. Among multiple safeguards, the high-tech laboratory's biocontainment rooms are maintained under "negative pressure," meaning that air continually is drawn into the rooms, and no air can escape without passing through a series of HEPA filters capable of trapping viruses.

The world-class facility, one of only a handful in existence, focuses on epidemiology, pathogenesis (the tracking down of a disease's origin) and vaccine development. Among the projects under way there, Gelb and Brian Ladman, an associate scientist and part-time doctoral student in animal science, are working to uncover how avian influenza evolves from a low-pathogenic to a high-pathogenic virus. The research is supported by the USDA's Avian Influenza Coordinated Agricultural Project.

Jack Gelb, director of UD's Avian Biosciences Center (standing), and research associate **Brian Ladman** inject chicken eggs with avian influenza virus. The scientists are working to uncover how avian influenza evolves.

KATHY F. ATKINSON

What's in a name, what's in a strain?

So what does H5N1 mean in the influenza world?

There are three types of influenza viruses — A, B and C. The H5N1 avian influenza is an A virus.

Only influenza-A viruses are classified by subtypes based on two primary proteins on their surface: hemagglutinin (H) and neuraminidase (N). The numbers in the name reflect a genetic change in the virus.

Influenza-A subtypes are classified by strains, which are further classified as low pathogenic or high pathogenic. To date, only H5 and H7 subtypes have shown the potential to shift from low to high pathogenic.

It seems that the only constant about influenza viruses, whether in chickens, humans or other species, is that they are always changing.

That's why the need for new human vaccines is re-evaluated each year based on the flu viruses in circulation, and why health officials recommend that you get a new flu shot each year. To learn more, visit the Centers for Disease Control (CDC) website at **www.cdc.gov.**

The scientists attempted to adapt low-pathogenic viruses to different poultry species to see how the avian influenza viral populations change depending on the host — whether a duck, chicken, turkey or quail. The virus was adapted by infecting each species ten times. Then using the powerful tool of "deep sequencing" at the Delaware Biotechnology Institute, which decoded tens of millions of gene sequences in a single computing run over several days, the researchers sought to identify "snips," single nucleotide polymorphisms (SNPs), which are "single letter" variations in DNA sequence within the genome.

"We found some pretty interesting changes in the low pathogenicity populations of the adapted viruses in chickens, where it had taken a step toward becoming a high-pathogenic virus," Ladman says.

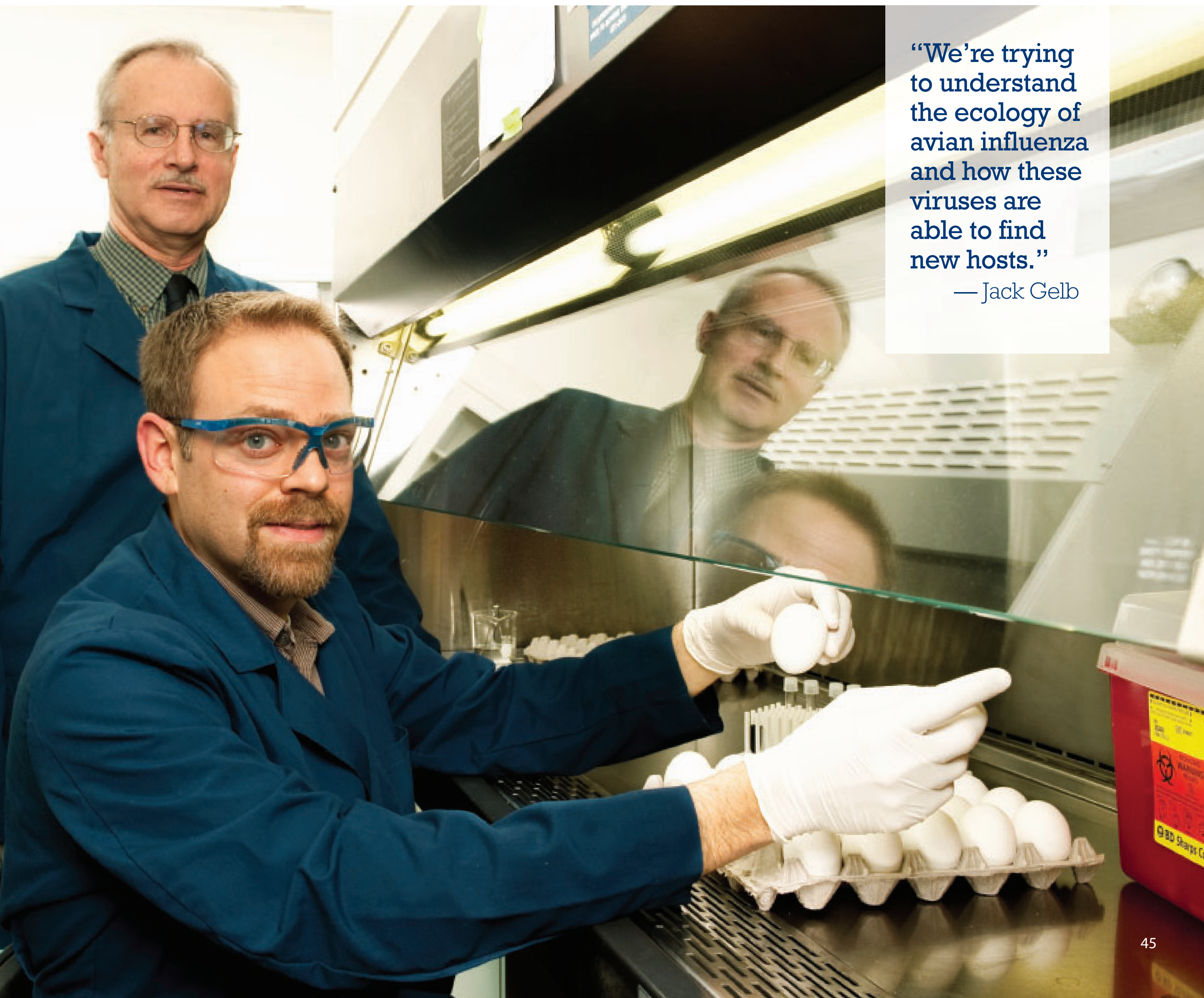
UD's Charles C. Allen Laboratory is a Biosafety Level-3 facility for poultry disease research.

The telltale sign, Ladman says, was a mutated amino acid occurring at the cleavage site of hemagglutinin (H), a key surface protein the virus uses to infect its hosts.

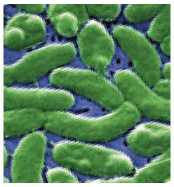
Ladman is now analyzing the viral genetic data across the four poultry species to determine how unique this mutation is, and when it first occurs in chickens. The answers may help illuminate the inner workings of influenza and help researchers predict if and when a low pathogenicity form of the virus might mutate to the virulent high-path form.

"Flu is everywhere — it's found naturally in certain wild animals and humans hosts all the time and should not be a concern," Gelb notes. "We're trying to understand the ecology of avian influenza and how these viruses are able to find new hosts."

— Tracey Bryant



"We're trying to understand the ecology of avian influenza and how these viruses are able to find new hosts."
— Jack Gelb



"Bugs" gone bad

Aquatic pathogens on upswing

Microbiologist E. Fidelma Boyd wants to know how and why some members of *Vibrio,* a family of aquatic bacteria, cause illness and others do not.

Ultimately, her research could help advance new methods of screening seafood and drinking water for pathogenic *Vibrio,* and new ways to fight bacterial infection.

Boyd, an associate professor in the Department of Biological Sciences at UD, became intrigued by *Vibrio* years ago as a college student back home in Ireland. Salmon farms along Ireland's west coast were experiencing problems with bacterial infection, and that is where her studies began.

"These bacteria are natural inhabitants of the aquatic ecosystem, where they play important roles, such as breaking down chitin, a component of the shells of crabs and other sea life," Boyd remarks. "They are incidental human pathogens. However, there is concern about new pathogenic strains that can cause high mortality rates, particularly in individuals whose immune systems are already compromised."

Currently, Boyd is focusing on three species: *Vibrio cholerae, Vibrio parahaemolyticus,* and *Vibrio vulnificus.* Under the microscope, all look like curved capsules with a single flagellum, or tail. But genetically, each species possesses unique attributes that Boyd is investigating in the quest to understand how harmless microorganisms evolve to become harmful, even lethal.

Using the computer-intensive tools of genome sequencing and bioinformatics, she and her research group are illuminating these bacterial relatives at the molecular level. They are comparing the suite of genes of pathogenic and non-pathogenic isolates within each species and across the three species — as well as analyzing environmental factors — to find out what makes some microscopic "bugs" go bad.

Of particular interest to Boyd, the recent recipient of a prestigious National Science Foundation Early Career Development Award, is horizontal gene transfer, the delivery of genetic material from one species to another through the environment rather than from one species to its offspring.

Vibrio cholerae

Vibrio cholerae infects an estimated 3 million people annually, causing severe diarrhea and vomiting. According to the Centers for Disease Control, over 100,000 people die from the disease every year.

Pathogenic *V. cholerae* was confirmed in India in 1817 and began winding around the world in wave after wave of cholera pandemics. In fall 2010, it emerged in Haiti, causing the island nation's first cholera outbreak in at least a century.

Scientists previously pinpointed *Vibrio* Pathogenicity Island-1 (VPI-1) within the *V. cholerae* genome, where major virulence factors are encoded. Boyd and her group discovered a second pathogenicity island, VPI-2, harboring genes that break down sialic acid, an abundant amino-sugar on human mucous membranes. This unique trait allows the bacterium to use the compound as a food and energy source.

Additionally, Boyd and doctoral student Salvador Almagro-Moreno have identified three genes in VPI-2 that enhance the bacterium's survival in the human gut.

Boyd's group is examining how these island regions are acquired and integrated into the bacterial genome. Along with undergraduate student researcher Michael Napolitano, they have shown that some of these islands are new additions to the genome and others are much older.

Vibrio parahaemolyticus

While cholera has been around for centuries, a pandemic strain of *Vibrio parahaemolyticus* emerged only in the last few decades. Now, it is the leading cause of seafood-borne gastroenteritis worldwide, most frequently associated with the consumption of raw or undercooked seafood, particularly oysters and crabs.

Abundant in the warm waters of the U.S. Gulf Coast particularly in summer, *V. parahaemolyticus* has expanded its range to the Pacific Northwest likely due to climate change, according to Boyd, who is involved in a U.S. Department of Agriculture food biosafety study of the organism with Michelle Parent, assistant professor of medical technology, and Gary Richards at the USDA Agricultural Research Service (ARS) facility in Dover, Del.

"If a person eats fish or shellfish contaminated with *V. parahaemolyticus,* the organism can double its numbers in as few as 10 minutes," Boyd says.

The team has found four pathogenicity islands specific to the pandemic strain and used the information to create a PCR assay to rapidly detect it. Boyd and doctoral student Brian Whitaker discovered a cluster of genes that enhances the ability of *V. parahaemolyticus* to grow in seawater of fluctuating salinity, as high as 10 percent salt content.

"This ability also seems to enhance the organism's capacity to withstand other environmental stresses such as pH and temperature perturbations," Boyd notes.

Vibrio vulnificus

Vibrio vulnificus, found in marine sediments, oysters and other sea life, is causing increasing cases of wound infection and

E. Fidelma Boyd is leading research on emerging strains of aquatic bacteria that can cause high human mortalities.

EVAN KRAPE

septicemia. It is the leading cause of death due to consumption of contaminated seafood in the U.S., and also afflicts fish.

The UD team discovered a number of unique properties about this opportunistic pathogen such as the ability to both catabolize and synthesize sialic acid, which is being investigated with visiting researcher Joseph Kingston from Mysore, India.

With collaborators at Washington University in St. Louis, Boyd and doctoral student J. B. Lubin are comparing the genomes of clinical and environmental isolates of *V. vulnificus.* They have discovered that, depending on the strain, *V. vulnificus* will produce different types of sialic acid and decorate different areas with it, such as its outer capsule or its flagellum.

A pathogenic cell attempts to masquerade as a host cell so that it will not be recognized as an invader, which would trigger an immune response, Boyd explains.

"An influenza virus always changes its outer coat so that it's not recognized anymore. This is a marker we've started looking at in *Vibrio* species." — *Tracey Bryant*

Seafood Safety:

WHAT YOU CAN DO

Doris Hicks knows seafood. In her 30 years as the Delaware Sea Grant College Program's seafood technology specialist, she has worked to promote safe and healthy seafood among members of industry as well as the public. She has developed safe seafood training programs for everyone from school food service workers to health care providers. Most recently, she worked with a national seafood alliance to revise training manuals for seafood processors ahead of changes to the FDA's fish and fishery products hazard prevention guidelines.

Her signature public outreach events are seafood contests such as the crab cake and chowder cook-offs that draw hundreds of hungry visitors to UD's annual Coast Day. Whether you're ready to get competitive or just making dinner, Hicks has helpful tips to offer (see right) for the next time you purchase and store seafood.

Get Hicks' and Delaware Sea Grant's complete guide to safe seafood handling at www.deseagrant.org. — *Elizabeth Boyle*

Doris Hicks teaches safe seafood handling practices to industry, schools and the public.

TIPS

- **Seafood is highly perishable. If you're buying it at the supermarket, make it one of your last purchases. No matter the time of year, if your trip home from the store is more than an hour, pack the seafood in a cooler.**
- **Whole fish should have bright, clear eyes that are often protruding, bright red or pink gills, firm yet elastic flesh, and shiny skin. Your purchase should feel cold, not cool, to the touch. And it should smell like a sea breeze, not "fishy."**
- **The word "fresh" refers to seafood that has not been frozen. Yet "frozen" does not have a bad connotation, so base your purchase on product quality. Products labeled "fresh frozen" indicate the seafood was frozen while it was fresh, in many instances within hours of harvest. If fishery products were frozen and thawed for retail sale, they should be labeled "previously frozen."**
- **When your fresh seafood purchase arrives home, store it in the coldest part of your refrigerator at a temperature as close to 32° Fahrenheit as possible. Use fish within two days after purchase; shelf life varies with the species. When in doubt, throw it out.**
- **Commercially frozen seafood should go in the coldest part of your freezer, at a temperature as close to -20° Fahrenheit as possible. You can store pre-frozen seafood in the freezer for 6 to 12 months depending on the type of fish.**

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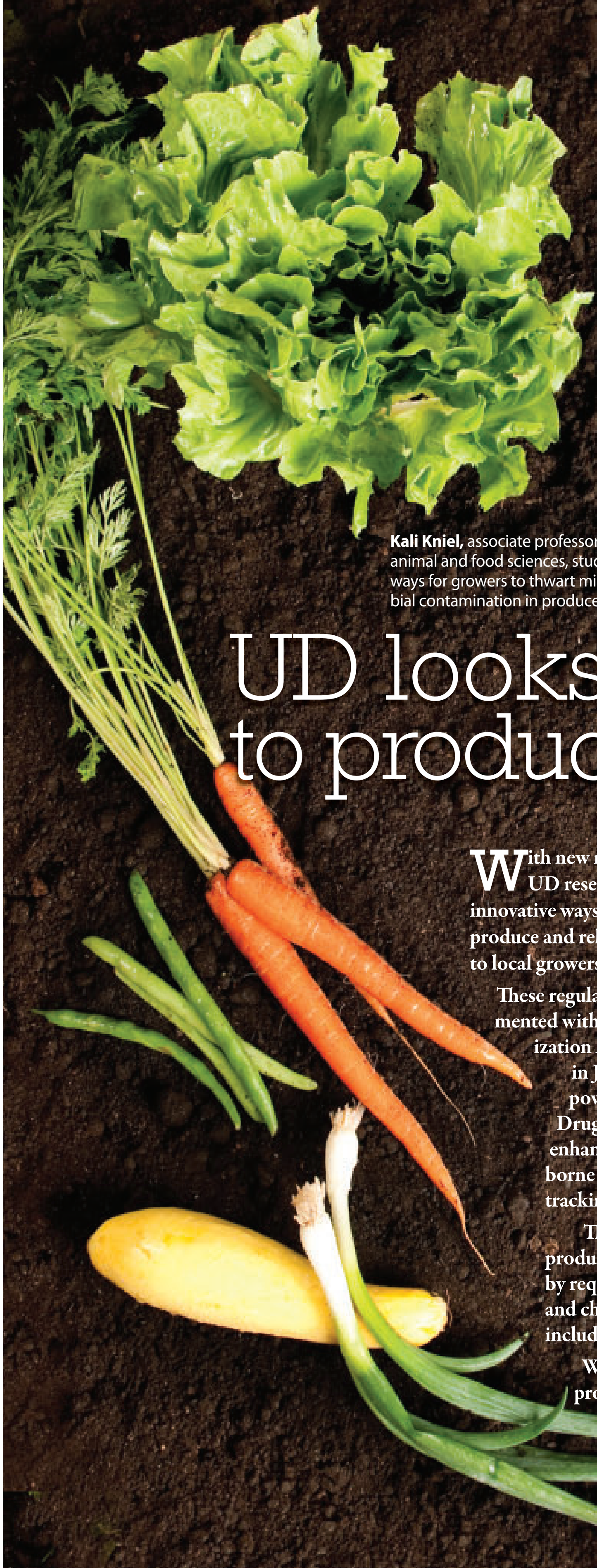


AMBRE ALEXANDER

Kali Kniel, associate professor of animal and food sciences, studies ways for growers to thwart microbial contamination in produce.

UD looks to produce safer produce

With new regulations for food safety, UD researchers are studying innovative ways to ensure healthy produce and relaying this information to local growers.

These regulations have been implemented with the Food Safety Modernization Act, signed into law in January 2010, giving more power to the U.S. Food and Drug Administration and enhancing the nation's foodborne illness surveillance and tracking capabilities.

The act will impact produce growers and packers by requiring federal audits and checks on safety practices, including environmental testing.

With outbreaks from fresh produce increasing almost 300 percent over the past 11 years, studying leafy greens is especially important to UD professors and students.

"Leafy greens are commonly consumed in their raw state without processing to reduce or eliminate viral and bacterial pathogens," says Kali Kniel, associate professor of animal and food sciences. "Therefore, managing how crops are safely grown and harvested is crucial to minimizing microbial contamination."

She points out that the well-publicized outbreaks associated with leafy greens, combined with the increase in consumption and risk of contamination during growth, make lettuce and spinach excellent plants to study in the laboratory.

Kniel explains that there are two key stages where viral and bacterial contamination to produce can occur.

The first is in the pre-harvest stage, with produce being contaminated from soil, feces, irrigation water, land-applied manures and animals.

The second chance for produce contamination comes in the post-harvest

EVAN KRAPE

stage, from harvesting equipment, transport containers and humans.

At UD, students and professors are looking at ways to gain a better understanding of the pre- and post-harvest stage of bacterial and viral contamination.

With regard to pre-harvest contamination, Jie Wei, a postdoctoral researcher in the Department of Animal and Food Sciences, is studying the survival and transmission of viruses in compost and land-applied manures and biosolids.

Kyle LeStrange, a master's student in the College of Agriculture and Natural Resources, is working on the survival and virulence properties of avian pathogenic *E. coli* strains in poultry and fresh leafy greens.

Both Wei and LeStrange, in collaboration with Manan Sharma, at the USDA's Agricultural Research Service (ARS) in Beltsville, Md., and Sima Yaron, at Technion University in Israel, are studying how microbial transmission is affected by irrigation methods.

Adrienne Shearer, a research associate in animal and food sciences, is focusing on post-harvest contamination, working on the interaction of norovirus, a non-enveloped virus that causes gastroenteritis, and its survival in bacterial biofilms on stainless steel and on lettuce leaves.

This research will show how norovirus may survive in drains or on kitchen or bathroom surfaces for extensive periods. Finding out how norovirus survives is crucial. The microbe repeatedly has caused disease on cruise ships, even after extensive cleaning, by hiding in biofilms and evading disinfectants.

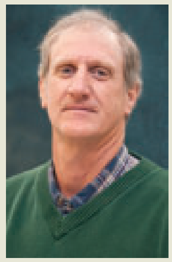
In her study of pre- and post-harvest contamination, doctoral student Kirsten Hirneisen is investigating whether enteric viruses can enter plant tissue through the root. This research is being done by placing green onions and spinach plants in virus-contaminated soil and virus-contaminated hydroponic systems. After initial contamination, the foods are processed by ultraviolet light or high pressure.

The findings indicate that when grown in the hydroponic systems, both the roots and edible portions of the plants were found to be positive for virus presence, whereas they were not detected in the soil-grown produce, indicating that the current methods of onion and spinach production make it hard for viruses to internalize through the root into the edible tissues of the plant. Processing methods were able to inactivate the pathogens.

With all the new changes that face produce growers around the nation, learning more about the contaminating viruses that plague them is a must.

Kniel said that the new food safety regulations "make it even more important that we understand the science behind microbial survival in the environment and use this information to recommend effective testing and food safety management strategies."

— Adam Thomas



Gordon Johnson

UD Extension educates farmers about good agricultural practices

With the increasing concerns about microbial safety of fresh produce, University of Delaware Cooperative Extension specialists and educators are helping local farmers learn about Good Agricultural Practices (GAP) and Good Handling Practices (GHP) through a certification training program geared at teaching farmers how to reduce the risk of produce being contaminated with harmful pathogens.

The four main areas of focus for the GAP training are water safety; manure, compost, and biosolid use; worker hygiene and personal practices; and field sanitation. The GAP/GHP certification training also includes information on training farm workers, third-party audits and developing a food safety plan for the operation.

Concerning manures, the focus is on eliminating runoff from livestock production areas, eliminating contamination by imposing long time intervals between manure application and produce growing periods, and composting manure to reduce or eliminate pathogens. Water safety is another important issue for farmers, particularly those who use ponds or streams for irrigation, which can be contaminated by microorganisms in stormwater runoff. The focus is on regular water testing and treatment systems for surface irrigation water.

On-farm research is being conducted on water safety for produce farms. According to Gordon Johnson, extension specialist and assistant professor of plant and soil sciences, in 2010, a survey was conducted to quantify microbial loading in surface water sources used for irrigation on produce farms throughout the state at bi-weekly periods throughout the growing season. A water treatment system using chlorine tablets also was installed at the irrigation pump on one farm, and the effectiveness of this system for reducing waterborne pathogens will be evaluated in 2011.

Worker hygiene involves simple steps such as hand washing and wearing clean clothes, and field sanitation involves making sure that the tools, equipment and containers used for harvesting and transporting a product are clean and free of pathogens.

In GHP training, the focus is on packing area, sales area and transport sanitation; worker hygiene; and water quality, with regard to the washing of fruits and vegetables.

UD Cooperative Extension agents and specialists have held classes in the three Extension offices in New Castle, Kent and Sussex counties, and they also have traveled to farms to consult with those that required third-party audits, examinations to assist farmers in adopting the best GAP and GHP possible.

Entering the third year of operation, a total of 16 training sessions throughout the state have reached 311 growers and farm workers in Delaware. In total, 156 participants completed the GAP/GHP training and received certification.

The group conducted a six-month post-program survey, and of those who have completed the program, 90 percent of respondents replied that they were better able to manage risks relating to farm food safety, and 95 percent were more apt at understanding their role in preventing foodborne illness.

The GAP/GHP professionals involved in the program include Extension specialists Gordon Johnson, and Sue Snider, professor of animal and food sciences. County-based staff include agricultural agents Phillip Sylvester, Corey Whaley and Tracey Wootten, and family and consumer science educators Maria Pippidis, Kathleen Splane and Ann Camasso. *— Adam Thomas* first person

DANIELLE QUIGLEY

Future Food

As the dean of the College of Agriculture and Natural Resources at the University of Delaware, Robin Morgan is cultivating a vibrant community of students, faculty, staff, and friends and partners united around a shared passion for the natural world. One of her key concerns is the safety of America's food supply.

by Robin Morgan

For many decades, the United States has benefited from an extraordinarily successful production agriculture system, and Americans have become accustomed to having a wide variety of inexpensive food available to them anytime and anywhere.

Across the globe, many also enjoyed the plenty, but others have lived in poverty, suffering from malnutrition and cycles of food scarcity depending on climate conditions, political situations, economics, and lack of education. This is particularly acute for those who cannot produce their own food but depend on distribution networks to provide products grown in other places.

Now, to complicate the problem, demographers project that by 2050, the world's population will approach 10 billion people. Our nation already has examples of urban decay, some small and scattered, and others vast and undeniable. Indeed, even in America, access to fresh and nutritious food can no longer be taken for granted.

Production agriculture in America is vulnerable. Fewer and fewer people understand what it takes to produce and provide the food they enjoy. The impact of agricultural practices on the environment is undeniable, and efforts to find achievable and effective solutions that couple efficient production agriculture with sound environmental stewardship are threatened by special interest groups unwilling to compromise and determined to blame production agriculture for all of the world's water, air, and soil quality issues, period. Ever-stringent regulatory compliance issues confound the situation.

If these trends continue, the United States will increasingly import food from production agriculture networks that are emerging in various parts of the world such as Brazil and China. American agribusiness will move offshore following precedents established in other manufacturing sectors.

It is not difficult to imagine a day when this country will depend on foreign sources for many of our food products. If we do not recognize and rectify this problem, the security of America's food supply could become increasingly vulnerable to trade policy, politics, and world climate fluctuations, and we will compete with other geographies to acquire safe and sufficient food for our people.

Food safety has always been an important issue but has received increased attention in recent years as epidemiology has advanced and communication networks became capable of spreading information at lightning speed.

Assuring that clean water and safe food are available to everyone, every day, and everywhere is at the foundation of basic human rights, social justice, and world civilization. —*Robin Morgan*

Food safety impacts the very foundation of human health, and contamination of food products with microbial pathogens, pesticide residues, or toxic chemicals must be prevented. While all of these issues are relevant for our domestic food supply, they escalate in the context of foreign-produced food. In a world where terrorism threatens, food and water are recognized as Achilles' heels. Without question, food security and food safety have emerged as major societal issues.

Food safety begins at the point of food production. Healthy plants and animals promise the greatest potential for providing safe food. Diseased, immune-compromised, stressed animals or drought-intolerant, nutrient-starved, pest-laden plants are sources of potentially unsafe food products. Food safety continues at the point of processing, packaging, and distribution. And finally, food safety ultimately depends on consumer practices.

Solutions to food safety and security challenges, like those to other complex problems, will be multi-faceted. Investments in science and technology are essential if we intend to improve animal husbandry and plant production practices. Relevant research must continue to advance and be put into practice. Technologies to preserve food quality, extend shelf-life, and efficiently monitor the integrity of food supply chains are needed and will provide new opportunities for innovative business entrepreneurs. Food industries must have food safety as a fundamental core value of their business strategies. Consumer awareness of basic nutritional principles and safe handling procedures for food and water must be continually preached and renewed. Ultimately, success depends on renewing the relationship between those who produce food and those who consume it. Simply put, farmers must be profitable, respected, and appreciated if we expect them to stay in business.

At the University of Delaware College of Agriculture and Natural Resources, food safety and security are major strategic priorities that provide opportunities to partner with colleagues in academia, government, and the private sector. Our faculty members and students are conducting research on the safety of fresh fruits and vegetables and poultry products that may harbor or be contaminated with pathogens such as avian influenza virus or pathogenic types of *E. coli, Salmonella* species, *Listeria* monocytogenes, parasitic protozoa, and enteric viruses. We are building programs in zoonotic medicine that interface animal health, food safety, and public health. We offer resources for K-12 educators to provide instruction and improve food safety awareness, and via Cooperative Extension, UD offers extensive food safety training to the public.

Humans are 60 percent water, and everybody eats. Assuring that clean water and safe food are available to everyone, every day, and everywhere is at the foundation of basic human rights, social justice, and world civilization. The stakes are high, marginal impacts will not suffice, and the time to seek solutions is now.

EVAN KRAPE

THE *Nobel Prize*

Richard Heck, Willis F. Harrington Professor Emeritus at UD, won the 2010 Nobel Prize in Chemistry. Test your knowledge of science's most prestigious prize, and Prof. Heck's winning contributions.

THE NOBEL MEDAL FOR CHEMISTRY

The medal depicts Nature in the form of a goddess resembling Isis, emerging from the clouds and holding a cornucopia. The veil covering her face is held up by the Genius of Science.

The inscription, taken from Virgil's *Aeneid*, reads: *Inventas vitam juvat excoluisse per artes*. Loosely translated, it means: *"And they who bettered life on earth by their newly found mastery."*

1 The Nobel Prize was established by Alfred Nobel. Who was he?

A. Austrian philosopher
B. Inventor of dynamite
C. Scandinavian king

2 When was the first Nobel Prize awarded?

A. 1780 **B.** 1865 **C.** 1901

3 How many individuals have received the Nobel Prize in Chemistry?

A. 502 **B.** 159 **C.** 300

4 Who was the first woman to win the Nobel Prize in Chemistry?

A. Margaret Sanger
B. Rosalind Franklin
C. Marie Curie

5 Where was UD Nobel Laureate Richard Heck born?

A. Delaware
B. Massachusetts
C. Oregon

6 What does a Nobel Laureate traditionally receive?

A. Laurel wreath
B. 21-gun salute
C. Medal

7 Which major area of science among those listed did Heck's discoveries revolutionize?

A. Pharmaceutical science
B. Anthropology
C. Food science

8 Nobel Prizes are awarded in six areas. Can you identify the correct one below?

A. Economics
B. Mathematics
C. Computer science

9 Where did Richard Heck receive the 2010 Nobel Prize in Chemistry?

A. Oslo
B. Stockholm
C. Copenhagen

10 Heck got carbon molecules to link up through a chemical reaction activated by what element?

A. palladium **B.** oxygen **C.** iron

ANSWER KEY

1-B; 2-C; 3-B; 4-C; 5-B; 6-C; 7-A; 8-A; 9-B; 10-A

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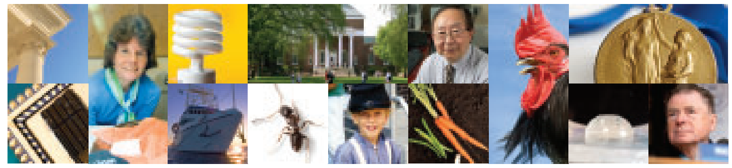

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