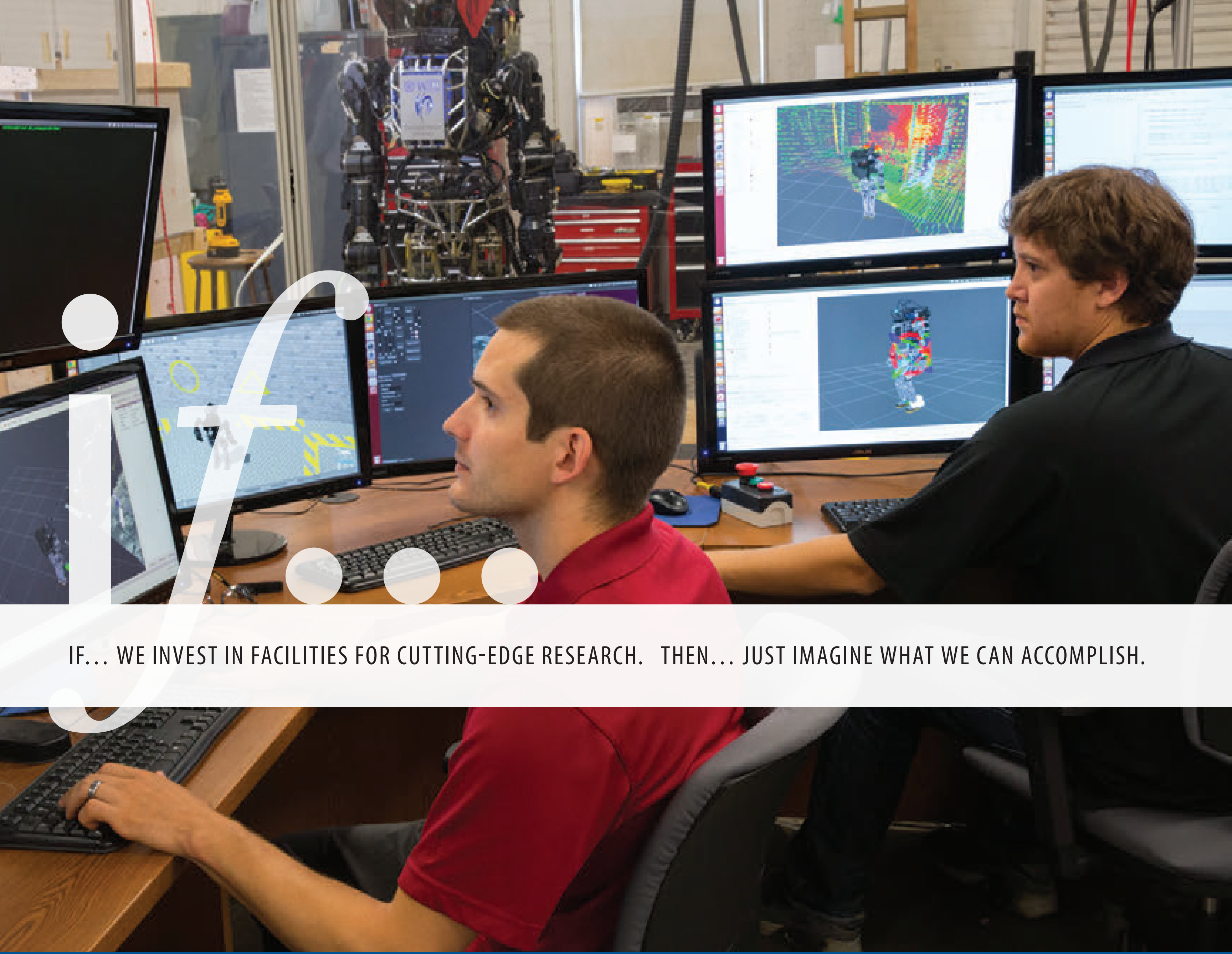
WPI Research

2015 Spring

SAVING THE WORLD, ONE ROBOT AT A TIME

TAŞKIN PADIR BELIEVES ROBOTS WILL REVOLUTIONIZE OUR LIVES, AND HE'S PROVING IT THROUGH HIS INNOVATIVE RESEARCH.

WORCESTER POLYTECHNIC INSTITUTE



IF… WE INVEST IN FACILITIES FOR CUTTING-EDGE RESEARCH. THEN… JUST IMAGINE WHAT WE CAN ACCOMPLISH.

Through the DARPA Robotics Challenge, WPI researchers are exploring how humanoid robots might one day perform the dangerous work of responding to disasters. That's just one way the university's pioneering program in robotics engineering is helping build a world where robots help people in areas as diverse as manufacturing and health care.

WPI was the first university in the nation to offer a bachelor's degree in robotics engineering and the first with BS, MS, and PhD degrees. Through groundbreaking academic programs and research, we are committed to advancing one of the most important emerging areas of technology. Imagine what our impact could be with your support.

if… the campaign to **advance WPI**

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if… The Campaign to Advance WPI — a comprehensive, $200 million fundraising endeavor — is about providing outstanding resources for education and research. The Campaign will supply the facilities to help the university's talented faculty and students address important challenges that matter to society and produce innovations and advances that help build a better world.

if… we imagine a bright future, together we can make it happen.

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2015 Spring

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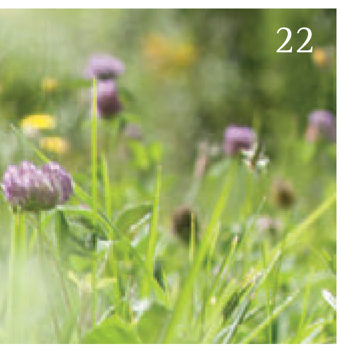

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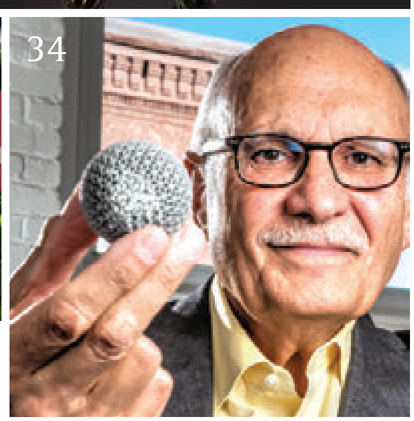

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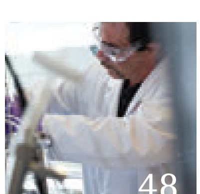

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The symbols above indicate that the stories describe research in Arts and Sciences A, Business B, or Engineering E.

ON THE COVER: WARNER (WPI's Atlas Robot for Nonconventional Emergency Response) is just one of the machines that come to life at WPI through the research of Taşkin Padir. Photo by Patrick O'Connor. Built by Boston Dynamics for the DARPA Robotics Challenge, WARNER recently received a major makeover, which refreshed about 75 percent of his parts. See the back cover for a peek at his new look. Photo by Matthew Burgos. At left, biomedical engineers George Pins, left, and Glenn Gaudette.

KEEP UP WITH RESEARCH AT WPI > Read the latest WPI research news, watch videos about research, and read back issues of this magazine at **wpi.edu/+research**.

A SEAMLESS SPECTRUM OF RESEARCH

Ben Bocko

As WPI celebrates its 150th anniversary in 2015, it is looking back on the events that shaped the university we know today. Two of the most significant developments of the past 50 years—the creation of a radically new approach to undergraduate education and the rise of a robust research enterprise—turn out to be closely connected in a way that says a great deal about the unique strengths of WPI's approach to education and research.

The new method of learning, called the WPI Plan, was a response by WPI's faculty to concerns that the Institute's curriculum had become too rigid and tightly prescribed, depriving students of the freedom to exercise their creativity and innovative spirit, and steering the Institute away from its founding principle of balancing theory with practice. With the passage of the Plan in 1970, the curricular pendulum swung in the other direction with a program built around applied projects, including an interdisciplinary project (the Interactive Qualifying Project or IQP) and a research experience (the Major Qualifying Project or MQP).

The Plan, which places a premium on student-faculty interaction, is demanding of faculty time. So as the university began to ramp up its research efforts in the 1980s, faculty members were naturally concerned that it might prove too difficult to be both an active project advisor and an active researcher. In reality, the existence of the IQP and MQP and the need to find ways to give all WPI undergraduates rigorous and meaningful research challenges provided an opportunity to build a powerful bridge between a faculty member's roles as educator and researcher.

Today, faculty members routinely include undergraduates on their research teams. The research problems that IQP and MQP teams tackle both support and augment the work that graduate researchers undertake. Undergraduate project teams may design and build needed research equipment or instrumentation, conduct experiments that help set the stage for a larger research effort, address questions that grow out of a research program, or explore societal or humanistic dimensions of a scientific or engineering research program.

Welcoming undergraduates into graduate research programs has a number of benefits. Undergraduates gain real-world research experience that not infrequently leads to sharing credit on publications and presentations. Research labs become more productive and gain insights that can open up new areas for exploration. And faculty members engage deeply and meaningfully with undergraduates while also exposing them, in a potent way, to the excitement of research.

Perhaps most important, the marriage of WPI's undergraduate curriculum and research enterprise has made research at WPI an endeavor that seamlessly spans all academic levels, from undergraduate to postdoctorate to faculty. This vertical integration of applied research has helped foster a remarkable culture of innovation and problem solving at WPI, as well as a can-do spirit that sees science, technology, engineering, and mathematics as vehicles for making the world a better place. Many universities strive to achieve this top-to-bottom research culture, but we believe WPI is one of the very few that has truly achieved it.

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notebook

> CAN ROBOTS HELP US RESPOND TO THE EBOLA CRISIS?

ON THIS BRISK NOVEMBER DAY, the canopy of fall leaves stands out against the clear blue sky—as do the two WPI students in yellow biohazard suits and the small yellow robot rolling along beside them. What might look like a scene from a science fiction film is actually a demonstration of a potential new role for robots: helping in the global fight against Ebola.

Strapped to the robot are two carboys connected to a sprayer on a remotely controlled arm. Cameras mounted on the robot let a remote operator scan the robot's surroundings. The robot rolls up to a wooden pallet and douses it with liquid. In a real-world scenario, it might have been helping decontaminate an Ebola clinic.

As the crisis in West Africa highlights both the difficulty of containing infectious disease outbreaks and the risks that doctors and other medical personnel take as they work to keep outbreaks in check, a coalition of academic researchers and government officials has begun exploring whether robots, which have already proven their worth by helping rescue workers deal with disasters as diverse as the 9/11 attacks and the Fukushima nuclear reactor crisis, might help Ebola volunteers do their hazardous work more effectively and safely.

Spurred by a call for support from the White House Office of Science and Technology, robotics researchers at WPI, Texas A&M University, and the University of California at Berkeley recently organized brainstorming meetings that brought together academic researchers, medical responders, robot manufacturers, and government officials to explore possible roles for robots in infectious disease outbreaks.

The meeting at WPI was organized by **Taşkin Padir**, PhD, assistant professor of electrical and computer engineering and robotics engineering. In his presentation, he said the urgency of the Ebola crisis argues for repurposing existing technology, rather than developing untried platforms. He noted that WPI's disinfection robot was actually AERO, a prototype planetary exploration rover.

Other ideas emerging from WPI's robotics engineering laboratories include using tele-operated robots to enable physicians to interact with patients from a distance and "tech tents," medical tents equipped with sensors to monitor patients and to help guide robots that might deliver medicine, food, and water.

In his Autonomous Robot Collaboration (ARC) Lab, **Dmitry Berenson**, PhD, assistant professor of computer science and robotics engineering, has been exploring how Baxter, a low-cost manufacturing robot, might help aid workers remove their protective clothing and goggles without having to touch them. Padir and Berenson recently received National Science Foundation Rapid Response Research awards to further develop the tech tent and robot-assisted clothing removal ideas.

The need to respond quickly to the Ebola crisis argues for repurposing existing robots rather than developing untried platforms, say WPI researchers, who proposed using AERO, top, a prototype planetary exploration robot, to decontaminate treatment facilities, and Baxter, a flexible manufacturing robot, to help aid workers remove contaminated clothing, as Dmitry Berenson demonstrates for a BBC reporter.

As they explore the use of technology to help manage the Ebola outbreak, researchers should be mindful of the psychological risks of placing robots in settings where a human touch is critical, notes **Jeannine Skorinko**, PhD, assistant professor of psychological sciences at WPI, who helped organize the WPI workshop. She says technology that isolates patients from the people caring for them carries the risk of adding to the stigma already attached to people who contract an infectious disease.

In the months ahead, WPI's robotics researchers will continue to develop their technological solutions knowing that even if robots don't end up playing a major role in the current Ebola crisis, the work they are doing and the collaborations they are building will pave the way for solutions that will be ready to roll when the next outbreak occurs.

FIXING A WEAK LINK IN FIREFIGHTING TECHNOLOGY

WHEN BOSTON FIREFIGHTER MICHAEL KENNEDY entered a burning building in the city's Back Bay on a windy March day in 2014, the last thing he was probably worried about was the attack hose he carried. But as he worked, windswept flames burned through the layers of woven cotton and rubber that made up the hose. Kennedy and fellow firefighter Edward Walsh Jr. died in that blaze.

Today, with funds from the Last Call Foundation, established by Kennedy's mother, Kathy Crosby-Bell, to support work on firefighter safety, researchers in WPI's Department of Fire Protection Engineering are working to fix a weak link in the chain of technology used to fight fires. They are taking the first steps toward the development of a fire-resistant attack hose.

"Fire hoses have advanced significantly since the first rubber-lined, cotton-webbed hoses were developed in the 1820s," said **Kathy Notarianni**, PhD, associate professor of fire protection engineering and a principal investigator for the research project. "Today's attack hoses are lightweight, durable, and flexible. But they are not fire resistant."

Notarianni and co-principal investigator **Raymond Ranellone**, research engineer in fire protection engineering, will begin by investigating the current state of the art in fire hose manufacturing. They will examine the materials used to make fire hose and find out how those materials perform when exposed to fire; they will also investigate other materials designed for use in high-temperature environments and conduct burn tests on the most promising to assess their suitability for use in fire hoses. **Nima Rahbar**, assistant professor of civil and environmental engineering, will conduct non-fire testing to characterize the thermo-mechanical properties of current and future fire attack hose materials.

The team will also research codes, standards, and approval processes that govern the manufacture and performance requirements for fire hoses in the United States, as well as the functionality requirements of the fire service. Finally, they will organize a workshop at WPI to vet their findings with a variety of stakeholders, including firefighters and representatives of federal agencies, hose manufacturers, the National Fire Protection Association, and the Last Call Foundation.

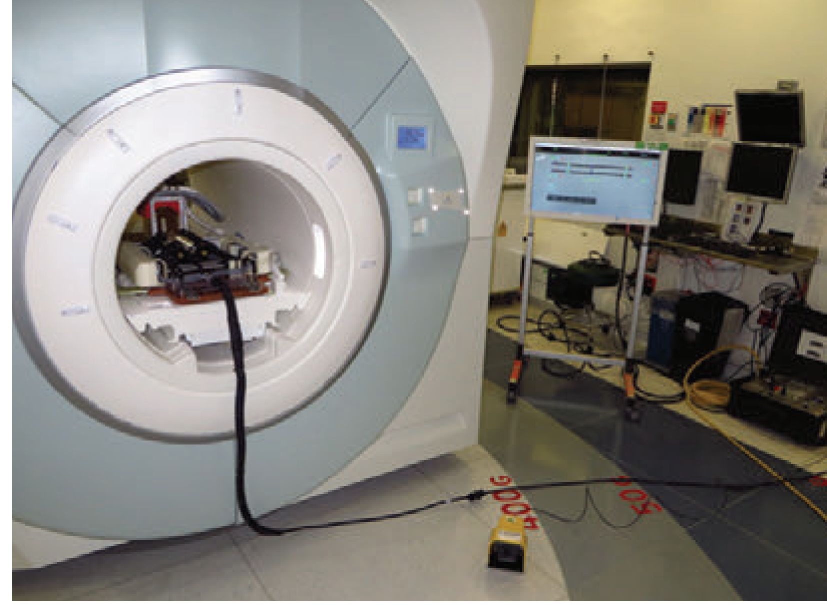
They are working with three undergraduate project teams. One, an interdisciplinary team, is focusing on human, economic, and societal issues, while two major project teams are exploring the response of current and potential hose materials to fire conditions.

Among the tasks to be completed by the undergraduates is a national survey of fire departments to gather data on fire hose burn-through incidents.

"We're confident that this new collaboration will put us on a pathway to developing a fire hose that will lead to improved firefighting practices," said **David Cyganski**, PhD, dean of engineering ad interim. "This effort could impact the safety of firefighters nationally and internationally."

The fire attack hose project is the latest chapter in a multifaceted research effort at WPI, spanning nearly 15 years, that is focused on developing technological solutions to problems that threaten the safety and health of first responders. Other research efforts have produced technology for precisely locating first responders within buildings; monitoring their physiological status; alerting them to the imminent onset of flashover; and, most recently, warning them when they are in the presence of toxic gases in or near the fire ground.

"We're confident that this new collaboration will put us on a pathway to developing a fire hose that will lead to improved firefighting practices. This effort could impact the safety of firefighters nationally and internationally."



ROBOTIC SYSTEM AIMS FOR BETTER CANCER DETECTION

A NOVEL ROBOTIC SYSTEM may help transform the detection of prostate cancer, the last form of cancer still diagnosed with blind needle biopsies. The heart of the system is a specially designed MRI-compatible robot that can work inside the bore of an MRI scanner to help a physician guide a biopsy needle precisely toward a target of interest identified using real-time images. It promises to make prostate cancer biopsies faster, more accurate, less costly, and less discomforting for the patient.

The robotic system was developed by a team of WPI robotics engineers led by **Gregory Fischer**, PhD, associate professor of mechanical engineering and robotics engineering and director of WPI's Automation and Interventional Medicine (AIM) Laboratory. The work has been carried out in collaboration with researchers at Johns Hopkins University, Brigham and Women's Hospital in Boston, and Acoustic MedSystems Inc.

The system is currently being tested as part of a larger clinical research program at Brigham and Women's funded by a Bioengineering Research Partnership award from the National Institutes of Health through the National Cancer Institute. The program aims to replace blind needle biopsies with image-guided technology, notes Clare Tempany, MD, professor of radiology at Harvard Medical School, chair of research radiology at Brigham and Women's, and principal investigator for the research program. "The ultimate goal of our group is to develop enabling technologies that extend the capabilities of physicians to treat their patients."

Most prostate biopsies today are performed with the aid of ultrasound, which can localize the prostate but not readily detect potential cancers. Requiring multiple needle insertions, the biopsies suffer from low sensitivity and often misleading results. In fact, about 35 percent of serious tumors may be missed during initial biopsies.

In the Brigham and Women's program, biopsies are being performed with the aid of real-time MRI imaging—both with and without the MRI-compatible robot. When working without the robot, physicians use a plastic grid to help position the biopsy needle. They first use multimodality MRI scans to generate a plan showing where the needle should be inserted. Then, with the patient in the MRI scanner, the physician directs the needle through most appropriate guide holes in the grid. Additional scans are made periodically to verify the path of the needle and make adjustments, if needed.

Rather than restrict the needle positioning to the choices offered by a grid, the robot manipulates a needle-guide inside the bore of the scanner to help the physician place the needle in the most optimal position as indicated by the real-time images generated by the MRI. "The robot gives the physician a great deal more choice about where to place the biopsy needle," Fischer says. "This technology should permit greater accuracy, and the odds of hitting the target on the first try should be higher."

This "first-in-human" testing of the robotic system is the culmination of more than six years of research and development by Fischer, who, along with Julian Lordachita and colleagues in the Laboratory for Computational Sensing and Robotics (LCSR) at Johns Hopkins University, has pioneered the development of compact, high-precision surgical robots that are expressly designed to work in the environment inside the bore of an MRI scanner, as well as the electronic control systems and software needed to operate the robots with the safety, reliability, and ease of use required of technology designed for the operating room.

To develop robots that can work inside an MRI scanner, Fischer and his team have had to overcome several significant technical challenges. Most important, since the scanner includes a powerful magnet, the robot, including all of its sensors and actuators, must be made from nonferrous materials. The robot used in the prostate cancer trial is built primarily of plastic parts and uses ceramic piezoelectric motors.

Gregory Fischer, second from right, with PhD candidates, from left, Weijian Shang, Nirav Patel, and Gang Li, in the Advanced Multimodality Image-Guided Operating suite at Brigham and Woman's Hospital. Above, the robotic system for prostate biopsies: the robot in place inside the MRI unit; a foot pedal used by the physician to activate the robot; a screen that displays the robot's status; and (black case on floor) the robot control unit.

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VISUALIZING THE DAILY COMMUTE

DATA VISUALIZATIONS can distill massive quantities of information into graphical representations that help bring to light knowledge and insights buried in the data. When they were assigned to choose a data set to visualize as a project, **Michael Barry** and **Brian Card**, master's degree candidates in computer science at WPI, chose publicly available data on the operation of Boston's transit system, the Massachusetts Bay Transit Authority, or the T. The result was an interactive map that a blog on Boston.com called "insanely awesome."

"You've never seen the T like this," the blog said. "A student website takes MBTA travel time, location data, and more to create some stunning data visualizations and maps explaining your commute better than you ever could."

Following a process developed by the late **Matt Ward**, longtime professor of computer science at WPI and a pioneer in multivariate visualization and visual analytics, the students first determined what questions they wanted to answer, ranging from factors that can delay trips to where trains can be found, moment by moment, and how long they take to travel particular routes during rush hour.

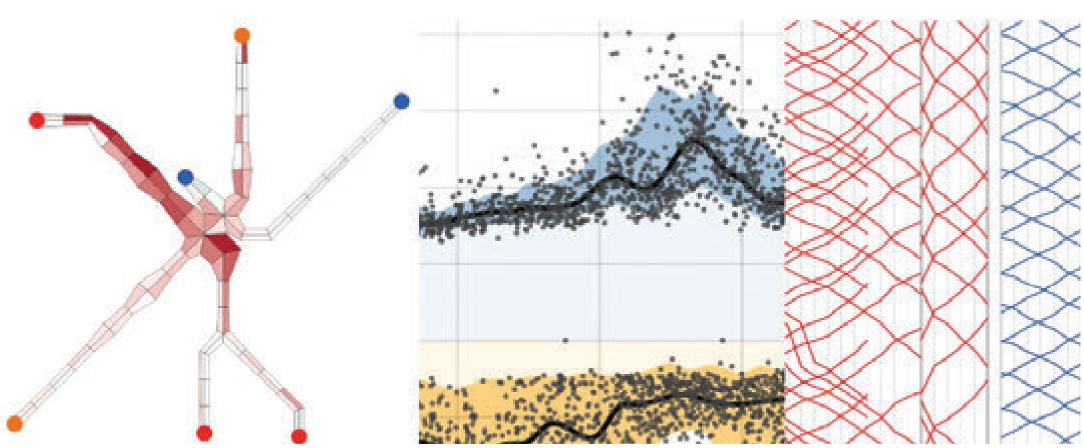
Since Barry and Card work full time as software engineers, their challenge was not how to program an interactive model, but rather how to present its results to make them as intuitive and useful as possible. After exploring various prototype models to find and extract aspects of the data they wanted to showcase in their visualizations, they used the filtered data to create their final model. They used layers of abstractions to create the visualizations, which can be explored at mbtaviz.github.io. They started with simple and intuitive representations of the data and then added abstraction layers that make the visualizations interactive. For example, viewers can control the time of day to see how the state of the transit system changes as the morning commute progresses.

These data visualizations not only have opened the door for future projects for Barry and Card, but they have also had an impact on WPI's new data science graduate program, noted its director, **Elke Rundensteiner**, PhD, professor of computer science. She says she sees the project as a prime example of how data analytics can be useful in the field. "It illustrates the power of visual and computational analytics—especially as it allows us to look in new ways at data that affects all of us directly and that the general public can relate to," she says. "This MBTA data project is particularly exciting since it allows us to interactively explore public data."

Rundensteiner says a new course in data visualization will give students in the data science graduate program (wpi.edu/+datascience) the chance to pursue similar projects. And there will be plenty of students to take that course, she adds. More than 30 students enrolled in the program in its first year (triple the number expected), and applications have been brisk for fall 2015.

—Carmen Blandino

"A student website takes MBTA travel time, location data, and more to create some stunning data visualizations and maps explaining your commute better than you ever could."



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A sample of graphics from the MBTA visualization. From left, instantaneous congestion and delays on the T; the duration of the trip between the Kendall/MIT and South Station stops (grey curve) and the wait time between trains (yellow); the locations of Red and Blue Line trains, minute by minute, during the morning.

ATTACKING CANCER BY LURING TUMOR CELLS INTO A TRAP

IMAGINE A DEVICE that can lure tumor cells to their death. That's the idea behind an innovation first developed by **Anjana Jain**, PhD, assistant professor of biomedical engineering at WPI, while she was a postdoctoral fellow in the laboratory of Ravi Bellamkonda, PhD, chair of the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University.

The device, which Jain is continuing to research in her laboratory in WPI's Life Sciences and Bioengineering Center, uses tiny fibers engineered to mimic the surfaces of blood vessels and axons. One end of a fiber bundle is implanted near a brain tumor, while the other is placed in a vessel filled with a drug that kills only cancer cells. The tumor cells, which are prone to migrate, travel up the fibers like passengers on an escalator until they reach the drug and are killed, leaving healthy brain tissue unaffected. Jain calls it the "brain tumor trap."

"With growing incidences of cancer, there is a great need for therapeutic strategies to treat aggressive, inoperable brain tumors," Jain says.

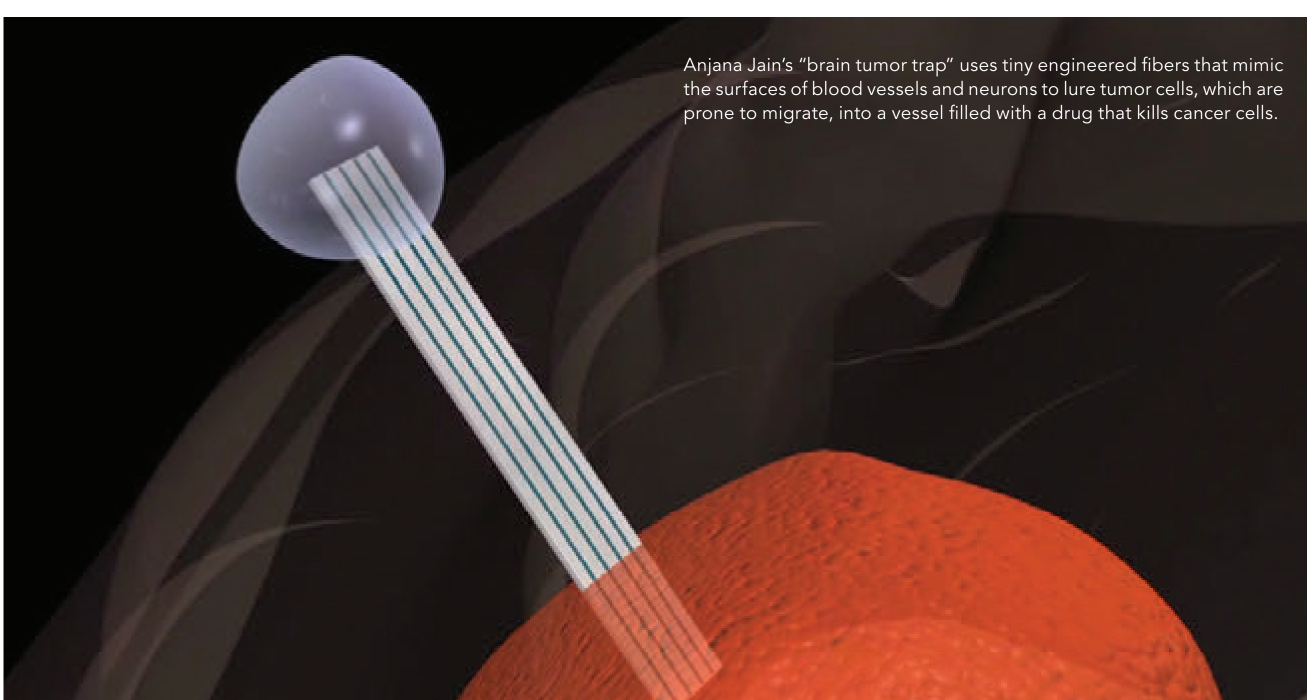
Results from early tests with the new device were published in March 2014 by the journal *Nature Materials* in a paper titled "Guiding intracortical brain tumor cells to an extracortical cytotoxic hydrogel using aligned polymeric nanofibers." Professor Bellamkonda, co-inventor of the brain tumor trap device, is the senior author of the paper.

In this study Jain and the team at Georgia Tech worked with glioblastoma multiforme (GBM), which accounts for nearly half of all human brain tumors. Aggressive and invasive, GBM often develops in parts of the brain that make it inoperable. Even in cases where the primary tumor can be removed, some of the cancer has usually spread to other locations. With the best current treatments, the five-year survival rate for patients with GBM is less than 25 percent.

Typically, GBM and other cancers spread by secreting enzymes that break down neighboring healthy tissue. In the brain, they tend to migrate along blood vessels and axons. It's a process that requires a significant amount of energy from the tumor cells. "So our idea was to give the tumor cells a path of least resistance," Jain says, "one that resembles natural structures in the brain, but does not require the cancer cells to expend any more energy."

Early results show the new device works exactly as designed, providing tumor cells a tempting path that leads to a dead end. With the device in place, the size of brain tumors was significantly reduced in rats, says Jain, who notes that this potentially game-changing technology could be applied to other types of cancers, not just brain tumors.

Jain says her interest in cancer therapeutics began during her graduate research on spinal cord regeneration. In that work she and the team at Georgia Tech were developing biomaterials to serve as scaffolds to promote the growth of axons into a defect to replace missing or injured tissues. "The signaling pathways we were trying to activate to repair the spinal cord were the same pathways researchers would like to inactivate for glioblastomas," Jain says. "Moving into cancer applications was a natural progression, one that held great interest because of the human toll of the disease."



Anjana Jain's "brain tumor trap" uses tiny engineered fibers that mimic the surfaces of blood vessels and neurons to lure tumor cells, which are prone to migrate, into a vessel filled with a drug that kills cancer cells.

STEMMING BONE STRENGTH LOSS IN PARALYZED PATIENTS

DEPENDING ON WHICH ORGANIZATION does the counting, somewhere between 300,000 and 1.2 million Americans have suffered spinal-cord injuries resulting in paralysis. It's long been known that such injuries leave people vulnerable to the loss of mass and strength in the leg bones. But a new study by a WPI research team has shown that bones lose mechanical strength faster and more significantly than previously believed, putting them at greater risk for fractures from minor stresses.

"It's not just a question of how much bone mass is lost, but where that loss is occurring," notes **Karen Troy,** PhD, assistant professor of biomedical engineering at WPI and senior author on the paper. "We found that bone loss occurred sooner in mechanically important areas and significantly increased the risk of fracture."

The study, "Reduction in Proximal Femoral Strength in Patients with Acute Spinal Cord Injury," was published as the featured cover story in the September 2014 issue of the *Journal of Bone and Mineral Research*. "Our results suggest that physicians need to begin therapies for spinal cord injury patients sooner to maintain bone mass and strength," Troy says. "While our focus was patients with paralysis, the study also provides guidance to physicians treating patients with osteoporosis, who should now think beyond the standard bone density test when they assess the risks of hip and other fractures."

Healthy bones continually adapt to mechanical forces by forming new bone and resorbing existing bone. But when bones stop carrying loads, they begin to lose mass and weaken. In patients with spinal cord injuries, even minor impacts or stresses can result in fractures. "Their bones are so fragile that just the act of rolling over in bed can snap their knee or leg," Troy says.

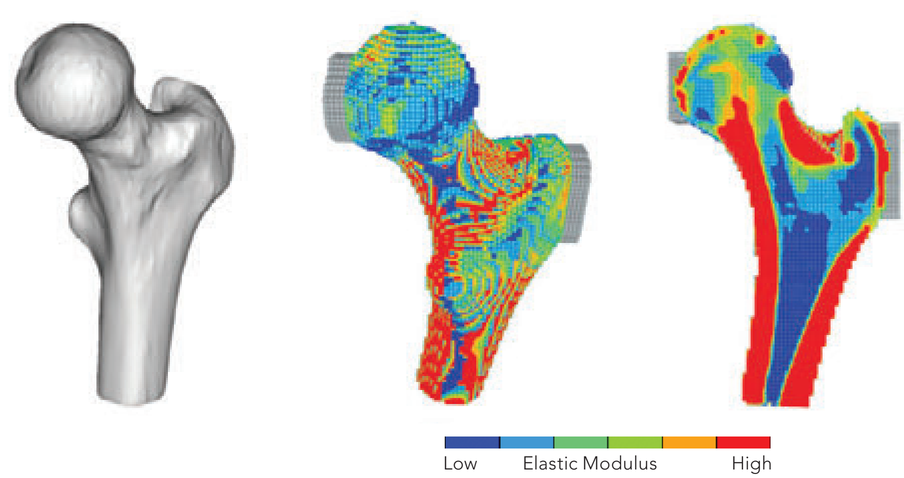
In the study, Troy and her co-authors, Brent Edwards at the University of Calgary and Thomas Schnitzer at Northwestern University, studied 13 spinal cord injury patients treated at the Rehabilitation Institute of Chicago. To document the change in bone mass over time, the team took CT scans and DXA bone mineral density scans of the patients' legs at regular intervals for about four months. They fed that data into sophisticated computer models that could predict how the amount and distribution of bone loss would affect the ability of the leg bones to stand up to mechanical loads and movements.

They found that the patients lost 2 percent of their leg bone mass each month, but that was equivalent to nearly a 7 percent loss in leg bone strength. "In just three and a half months, reductions in strength for some patients were on the order of that predicted for lifetime declines owing to aging," the authors wrote.

The study points to the need to begin therapies early to maintain bone mass and strength, Troy says, both to prevent injuries and to assure that patients remain eligible for treatments and technologies that are currently in development. "In 10 or 15 years, with advances in tissue regeneration to repair the spinal cord, and with exoskeleton assist devices, many of these people will have the opportunity to get back on their feet, if their bones are strong enough to carry the load. It's very difficult to restore bone mass once it's lost, so the better approach is to prevent the loss in the first place."

Troy says the study also has implication for the 54 million people in the United States who have low bone density or osteoporosis. With the three-fold difference the researchers observed between bone mechanical strength and bone density, physicians may want to reconsider how they evaluate bone loss and fracture risk and how they treat patients. "Bone mineral density is important, but it doesn't tell the whole story," she says.

From left, a three-dimensional reconstruction of a femur compiled from CT scans, and 3-D and 2-D planer-cut views of a femur from Karen Troy's study of mechanical strength in leg bones of individuals with paralysis. The images show the spatial distribution of elastic moduli, or the bones' resistance to mechanical loads. Red areas are stiffer and blue areas are less stiff. Troy showed that the bones in paralyzed individuals lose mechanical strength faster than previously believed. The images were featured on the cover of the *Journal of Bone Mineral Research*.



NSF AWARDS HELP TRANSLATE INNOVATIONS INTO IMPACT

AWARDS THROUGH THE NATIONAL SCIENCE FOUNDATION'S INNOVATION CORPS (I-CORPS) are designed to help NSF-funded researchers take results that show immediate prospects for real-world application and economic benefits out of the laboratory and into the commercial marketplace. The awards provide funding for researchers (each funded team has a technology and an entrepreneurial lead) to participate in national business development workshops and to then get out into the field to talk with a minimum of 100 prospective customers and partners about the real-world potential of their technology. Here are the stories of two recent I-Corps award-winning teams:

A Fishy Approach to Fighting Infections

Over the eons they've spent swimming in bacteria-laden waters, fish have developed an effective first line of defense against infections. Antimicrobial peptides (AMPs) located in their gills can trap and kill pathogens before they can reach the bloodstream. **Terri Camesano**, PhD, professor of chemical engineering and dean of graduate studies, wondered whether these same molecules might help protect people from infections caused by bacteria that can dwell on catheters, orthopedic implants, and other invasive medical devices—infections that strike millions of Americans each year.

In her laboratory, Camesano and her research team attached AMPs to silicon and gold surfaces and found that the bound peptides killed 82 percent of *E. coli* exposed to them. More recently, they have explored the mechanisms AMPs use to disrupt bacterial cell membranes, as they reported in 2014 in the journal *Colloids and Surfaces B: Biointerfaces*. Building on these successes, the team continued to refine the technology until it seemed ready for commercial applications as an antimicrobial coating. Working with Frank Hoy, Paul Beswick Professor of Entrepreneurship and Innovation in WPI's Foisie School of Business, the entrepreneurial lead for the iCorps award, Camesano put the new technology before a host of potential commercial partners.

While their initial focus was orthopedic implants, they learned that surgeons and device manufacturers were more interested in developing coatings for bloodstream and urinary catheters, which have higher rates of infections. "We are continuing the customer discovery process to help further develop our ideas and commercialization plan," Camesano says. "We've also applied for follow up funding from NSF and we are exploring forming our own start-up."

Terri Camesano is seeking to attach antimicrobial peptides found in the gills of fish to the surfaces of catheters to protect patients from infections.

New Life for Lithium Ion Batteries

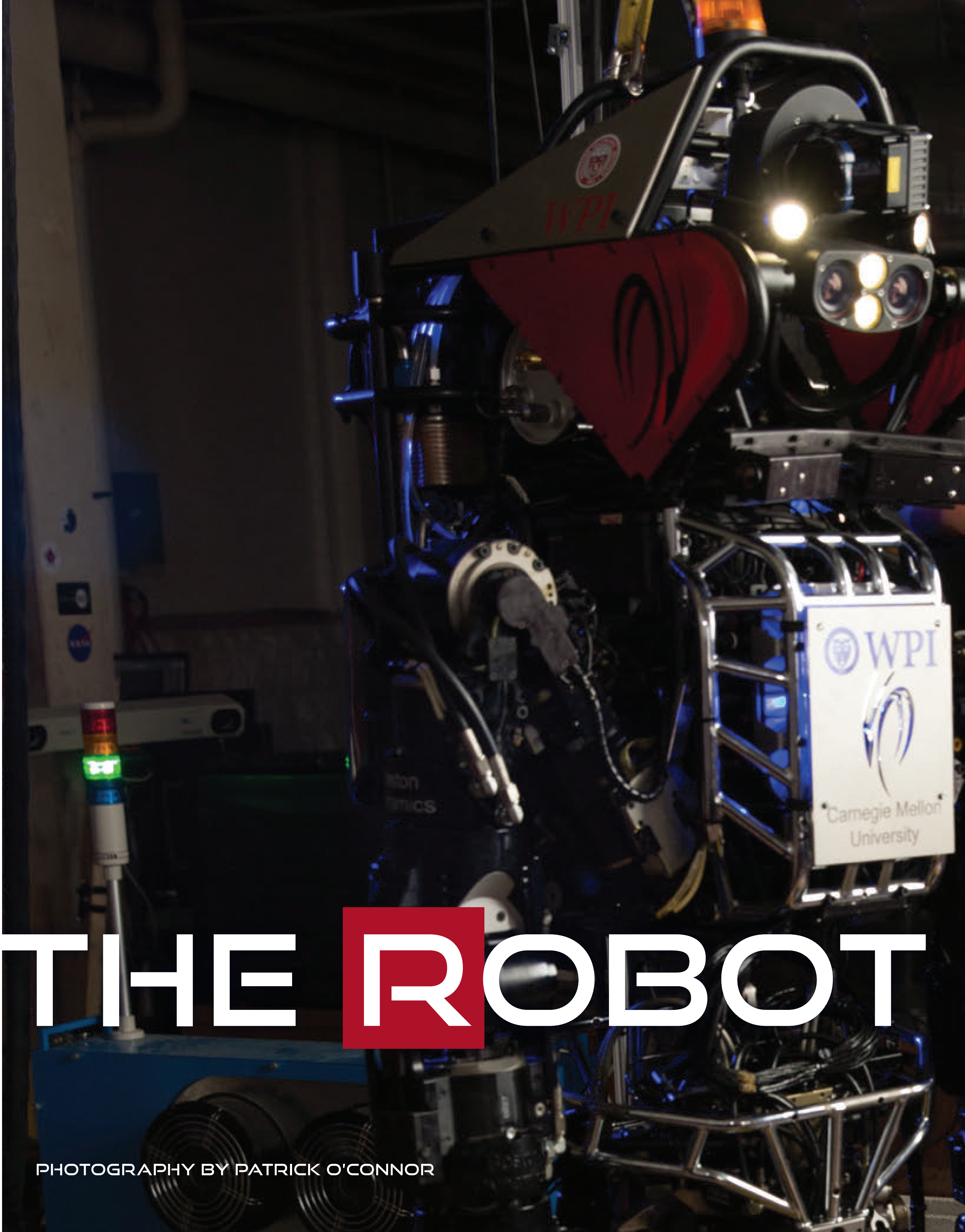
Rechargeable lithium ion batteries, used widely in consumer electronics, power tools, medical devices, and electric cars, account for about 60 percent of worldwide sales of portable batteries. But in the United States, only about 5 percent of these batteries ever get recycled. The widely varying chemistries of the materials used to produce the batteries' cathodes make developing recycling processes difficult, notes **Yan Wang**, PhD, assistant professor of mechanical engineering and director of WPI's Electrochemical Energy Laboratory.

With support from the National Science Foundation and WPI's Center for Resource Recovery and Recycling (CR^3), Wang has developed a new process that will work with any cathode chemistry, opening the door not only to widespread recycling, but to closed-loop manufacturing and recycling operations where recovered materials are reused to make new batteries. In tests in the lab, Wang and his team have been able to recycle up to 90 percent of the cathode materials, while also recovering other valuable metals.

Yan Wang has developed a new flexible method for recycling the materials in lithium-ion batteries that is attracting interest from battery and car makers.

In Wang's process, for which patents are now pending, the batteries are first shredded and the resulting particles are roughly separated into component materials. The cathode materials are then dissolved in acid and treated to remove impurities. By adjusting the chemistry of the resulting solution, Wang is able to precipitate out cathode precursor materials that have specific combinations of elements (nickel, cobalt, and manganese are commonly used in lithium ion battery cathodes) in the proper ratios to produce the desired cathode material. An economic analysis has shown that a recycler could net more than $1,000 per ton of used batteries by using the process.

Working with entrepreneurial lead Eric Gratz, a research assistant professor in the CR^3, Wang has garnered interest in licensing the new technology and in forming joint ventures from several companies, including a large battery material manufacturer and a major car maker. He says he is also exploring the option of a spin-off company.



THE ROBOT

PHOTOGRAPHY BY PATRICK O'CONNOR

TAŞKIN PADIR BELIEVES ROBOTS WILL REVOLUTIONIZE EVERY ASPECT OF OUR LIVES.

AND WHEN THEY DO, HE AND THE ROBOTICS ENGINEERING PROGRAM HE'S HELPED BUILD AT WPI WILL BE A BIG PART OF THEIR SUCCESS.

WHISPERER

BY ANDREW CLARK

From R2-D2 to the Terminator to RoboCop, robots seemed to be everywhere when Taşkin Padir, PhD, was a teenager in Turkey in the 1980s. But though robotics loomed large on the big screen, it wasn't yet a booming field within engineering.

Still, it caught Padir's interest as he worked toward his bachelor of science degree in electrical and electronics engineering at Middle East Technical University in the early 1990s. It was hard to resist a field that combined engineering with nearly every discipline imaginable, he says, not to mention one that seemed poised to change the world in a big way.

"To me, robotics seemed to be a means to apply engineering expertise to all kinds of exciting, practical applications to benefit society," he says.

Twenty years after falling in love with robots, Padir is an assistant professor of electrical and computer engineering and robotics engineering at WPI and the director of the Robotics and Intelligent Vehicles Research (RIVeR) Laboratory. As one of the first hires for the school's groundbreaking Robotics Engineering Program (WPI was the first university in the nation to offer a bachelor's degree in robotics engineering and the first with BS, MS, and PhD programs), Padir has been an invaluable cornerstone for the program's development. In the six years since joining the faculty full-time, he has garnered a number of awards for his work with robots, particularly for the products of his collaborations with students.

"There is never a dull day," he says. "It's always entertaining and challenging."

A GROWING FIELD

The landscape of the robotics world has been evolving rapidly since Padir's undergraduate days. What once was a relatively sleepy subset of engineering has become its own discipline. And once found primarily in factories, robots themselves are becoming ubiquitous, notes Michael Gennert, PhD, professor of computer science and founding director of the Robotics Engineering Program. "You have robots exploring the surface of Mars," he says. "There are robots for security and defense purposes, for hostage situations, and for defusing IEDs. New companies focused on robotics are starting up every month."

"Robotics technologies have become a part of our everyday lives," Padir says. "They provide new means for transportation in the form of self-driving cars. They are revolutionizing the healthcare system, not only in hospitals, but also in our homes. This becomes challenging, because we need to come up with systems that can work reliably in all these different environments."

As one of the principal building blocks of the Robotics Engineering Program, Padir sometimes seems to be everywhere at once. The program, founded in 2007, was still in its formative stages when Gennert decided to try to make a splash with one of his first hires. Padir, he says, was just the candidate he was looking for.

"He's meant everything," Gennert says.

One of Padir's inimitable qualities is his sheer versatility, Gennert says. He has the background to teach virtually any course in the program's curriculum, from introductory to advanced classes. Gennert also has high praise for Padir's accomplishments as a scholar and a researcher, which have been supported by NASA, the National Science Foundation (NSF), and the Air Force Research Laboratories, among other agencies and companies. And then there is his uncanny ability to work with — and inspire — others.

"He really is the complete package," says Gennert. "He cares deeply about his students. He understands robotics extremely well, from software to systems. And he brings a diverse background to his projects."

Since Padir arrived, the robotics engineering faculty has grown to 12 members, all located in their home departments of Computer Science, Electrical and Computer Engineering, and Mechanical Engineering. It's an impressive achievement, especially when considering how young the field is. But as Gennert notes, given the ever-evolving role of robots in everyday life, programs like WPI's are likely to go from hard-to-find to commonplace.

"THERE IS NEVER A DULL DAY. IT'S ALWAYS ENTERTAINING AND CHALLENGING."

MAKING AN IMPACT

Among the many emerging roles for robots, one of the most intriguing is disaster response. In 2013, in reaction to the Fukushima nuclear power plant accident of 2011 and the limited role that robots were able to play in bringing the crippled reactors under control, the Defense Advanced Research Projects Agency created the DARPA Robotics Challenge. The competition's aim is to spur the development of humanoid robots capable of responding to natural and manmade disasters in settings designed for human workers. DARPA hopes that in the future, robots will be able do the dirty work of bringing order out of chaos at sites that have been rendered too hazardous for people.

DARPA established multiple paths for research teams interested in competing. For one, the Virtual Robotics Challenge, teams did not need an actual robot. Instead, they programmed a virtual version of Atlas, a humanoid robot developed by Boston Dynamics, preparing it to perform a number of tasks (from turning a valve to driving a vehicle) on a virtual obstacle course. Padir and Gennert organized a team of graduate students that placed second, out of 26 teams, in the national contest. The prize: the loan of an actual Atlas (valued at $2 million) and funds to prepare it to take part in the next phase of the challenge.

That phase brought 17 teams and their robots, sponsored by university, government, and corporate labs around the world, to a Florida racetrack in December 2013 to carry out tasks similar to those in the virtual challenge. WPI's robot, dubbed WARNER (WPI's Atlas Robot for Nonconventional Emergency Response), placed seventh. That qualified it to move on to the competition's next phase in the spring of 2015.

WPI DARPA Robotics Challenge team member Felipe Polido '11, '14 (MS), left, and team leader Matt DeDonato '09, '13 (MS), program the team's entry, WARNER (WPI's Atlas Robot for Nonconventional Emergency Response), which can be seen in the background. WARNER is just one of the robots that Taşkin Padir is using in his research to demonstrate how robots can solve a multitude of societal problems and change the world for the better.

At 6'2" and weighing in at 330-pounds, WARNER bears a striking resemblance to an NFL lineman. But the robot's strength, supplied by electric motors and 26 hydraulically actuated joints, plus its brainpower, supplied by computers and an array of cameras and sensors, are better suited to saving lives than to flattening quarterbacks. Still, training the robot to drive a Polaris Ranger XP 900 utility vehicle (WARNER covered 250 feet in six minutes, the best time at the Florida showdown) or to climb a ladder or wield a fire hose took thousands of hours of work by a team of computer scientists and robotics engineers.

While WARNER may be the most popular robot at WPI (he even has his own Twitter handle, @WPI_WARNER), Padir and the undergraduate and graduate students he works with in the RIVeR Lab have designed and built a host of other robotic systems, including Oryx 1.0 and 2.0, "planetary rovers" that won NASA's Revolutionary Aerospace Systems Concepts–Academic Linkage (RASC-AL) Exploration Robo-Ops Competition at the Johnson Space Center in Houston two years in a row. They also developed AERO (Autonomous Exploration Rover), which in 2013 and 2014 took part in the Sample Return Robot Challenge, a NASA Centennial Challenge designed and run by WPI.

Two other current research projects are aimed at using robots to assist particular populations. With a five-year, $125,000 award from the NSF, Padir is helping develop personal assistant robots for people with age-related disabilities. He and his co-principal investigator, associate professor of psychology Jeanine Skorinko, PhD, are exploring ways to introduce these robot helpers without engendering discrimination against the elderly.

Padir is also leading a RIVeR Lab team developing a smart wheelchair named Anna, which is designed to help individuals who are functionally "locked-in," unable to move or communicate, despite having full cognitive capabilities. The chair and its robotic arm can currently be controlled with voice commands or eye or facial movements. Padir and colleagues at Northeastern University are working on a body/brain computer interface they hope will enable users to control the chair and the arm with their thoughts. "For

"I ENJOY THE INTERACTION AND THE EXCHANGE OF IDEAS. ONE OF THE MOST EXCITING ASPECTS IS BRAINSTORMING WITH THE STUDENTS."

Left, Padir and PhD candidate Dmitry Sinyukov with Anna, a semi-autonomous wheelchair that is the focus of research on technologies designed to help physically locked-in individuals be more self-sufficient. The robot can respond to facial movements and voice commands delivered through Google Glass. Right, Padir, PhD candidate Velin Dimitrov, and Marisa Warner '15 work on AERO (Autonomous Exploration Rover), developed initially to compete in the NASA-sponsored and WPI-organized Sample Return Robot Centennial Challenge.

the millions of people affected by conditions like ALS," Padir says, "technologies resulting from our research could be life changers."

There is nothing quite like creating innovative technology that benefits others, Padir says. But he adds that the most enjoyable aspect of robotics is the teamwork required to complete a project. There are about 50 students associated with the RIVeR lab, including seven PhD candidates and 12 master's students. Beyond the lab, the cross-disciplinary nature of robotics also allows Padir to work with faculty throughout the university.

"I enjoy the interaction and the exchange of ideas," he says. "One of the most exciting aspects is brainstorming with the students."

Padir's unparalleled ability to work with students — along with his contributions to the robotics engineering field — has earned him recognition both on campus and beyond. In 2010 he won the inaugural Rho Beta Epsilon Award for Excellence in Robotics Education. Just a year later he was awarded WPI's Romeo L. Moruzzi Young Faculty Award for Innovation in Undergraduate Education.

As the Robotics Engineering Program enters its eighth year, Padir says he believes WPI is the ideal place to grow this ever-evolving field. That has a lot to do, he says, with the way the program embodies the WPI spirit. "I always think of the WPI motto: Theory and Practice. With the robotics program, we are always striving to merge the theoretical side with practical applications." Re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When you set out to take a life-saving discovery from benchtop to marketplace, you'd better be prepared for detours.

The Long and Winding Road

BY JOAN KILLOUGH-MILLER

WPI researchers are known for taking on real-world problems, which means the discoveries and innovations they create in the lab often have potential value in the marketplace. But when scientists and engineers decide to take the leap and become entrepreneurs, they can encounter unexpected twists, turns, and detours on the road to commercialization. Navigating such an uncertain path requires creative pivots in strategy. And it's not uncommon for the product that makes it to market to be significantly different from the inventor's original vision. That, in a nutshell, is the story of two WPI biomedical engineers with innovative medical technology and a dream of saving lives. Buckle your seatbelts as we retrace their eye-opening journey.

ILLUSTRATION BY GWEN KERAVAL

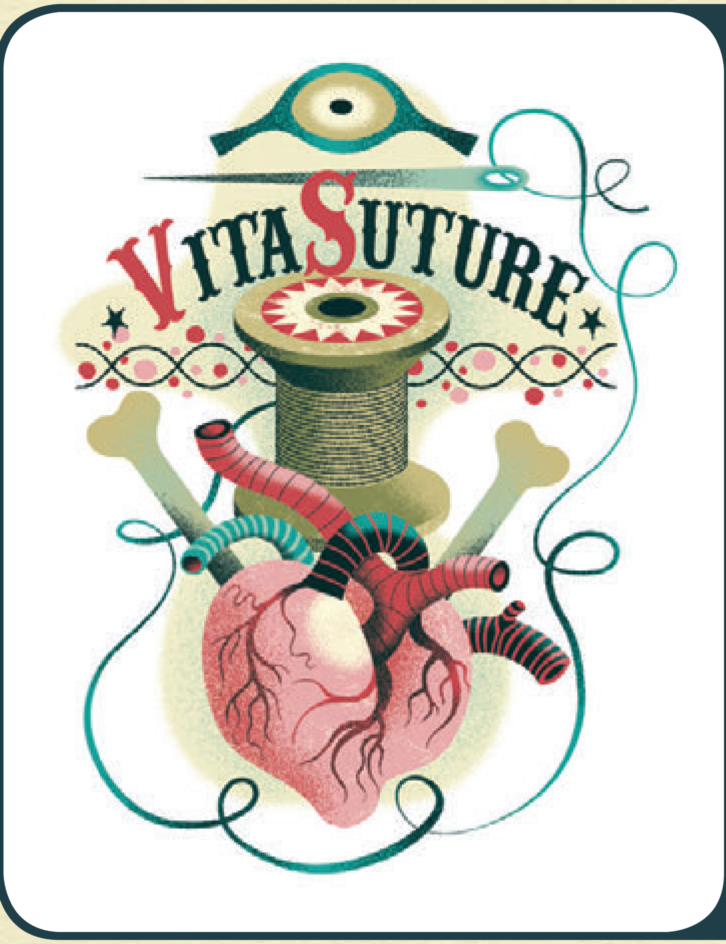
IT SOUNDED LIKE A PERFECT PLAN

VitaThreads, a spin-off founded in 2012 by Glenn Gaudette, PhD, and George Pins, PhD, both associate professors of biomedical engineering, started as a perfect partnership of people and ideas. Pins patented microthreads made from fibrin and other biological polymers that have the ability to stimulate the repair of injured tissue. Gaudette, who explores methods for regenerating damaged heart muscle using stem cells, had begun experimenting with the use of the microthreads to deliver stem cells to the heart. With Pins and Marsha Rolle, PhD, associate professor of biomedical engineering, he came up with the notion of growing human mesenchymal stem cells (hMSCs) directly on the threads and stitching them into the myocardium. The idea seemed to offer new hope to heart attack victims.

Subsequent experiments showed that the threads could deliver stem cells where they're needed and get them to stay put. Stem cell therapy holds great promise for promoting tissue regeneration. But in the heart, the "delivery dilemma" is a significant obstacle. Other means of introducing the cells — such as injecting them intramuscularly or sewing seeded "patches" over the damaged area — are risky and unreliable. Only about 10 percent of the stem cells embed, and few of those survive. But in animal studies, about 60 percent of the cells delivered via microthread sutures took hold.

Despite that success, the heart would prove to be the wrong place for this small, inexperienced company to start its journey. "The heart is a risky organ," Gaudette says, "and this is still a relatively invasive procedure. If you mess

"The heart is a risky organ and this is still a relatively invasive procedure.



SUPPORTING SPINOFF

Inventors don't stand alone at WPI. The spinoff of VitaThreads got a leg up from two initiatives designed to help university researchers become entrepreneurs.

The Tech Advisors Network (TAN) serves as a virtual incubator that connects aspiring entrepreneurs with experienced advisors who are alumni and friends of WPI. VitaThreads was advised by a dream team that included four alumni trustees, another alumnus with extensive technology marketing experience, and team captain Dave Mahoney, a serial entrepreneur and angel investor.

Mark Rice, PhD, professor in the Robert Foisie School of Business, says VitaThreads was among the inaugural cohort of companies to apply for TAN assistance, and its presentation attracted an outstanding advising team that offered specific expertise on the regulatory up in the heart, it can be a life or death matter." The researchers reached out to VitaThread's board of directors and its CEO Harry Wotton '94 — a successful biomedical entrepreneur — as well as the team assembled to help guide them by WPI's Tech Advisors Network (see sidebar). Their advice? Come up with an initial application with a lower risk barrier.

Gaudette recalls, "At the time, a friend of ours had ruptured his Achilles tendon. He had to stay off it for six months. That's a long healing process, and function is not always fully restored. That got us thinking about a new tack."

In previous work, Pins had demonstrated that the microthreads, all by themselves, could be bundled into cables and used as scaffolds to accelerate the repair of ligaments and tendons. His initial target was the knee's ACL (anterior cruciate ligament). Adding stem cells would enhance the threads' benefits, Pins and Gaudette theorized, since they'd promote the growth of new connective tissue. While animal studies were quite promising, the researchers hit a roadblock when they started exploring the potential for human trials. "The regulatory hurdles for using stem cells in humans are not trivial," Gaudette says.

When they presented their concept to their FDA regulatory advisor, his curt reaction cut to bone: "Love the sutures," he said, "but if you want to get through approvals quickly, lose the stem cells." He advised them to strip their medical miracle down to their MVP — minimum viable product — a business strategy that involves rolling out the most basic form of a technology and leaving more

If you mess up in the heart, it can be a life or death matter." —Glenn Gaudette

approval process, networking, attracting financing, and determining an initial market. "They all brought something to the table that we needed to hear," says Gaudette, from advice on determining how much office space to rent, to a rundown of important questions to ask when selecting a patent attorney.

VitaThreads was also a pilot program for WPI's Accelerator Fund, which offers early-stage investments in promising research ventures hatched from the TAN incubator. This seed funding can bridge the gap until a company is in a position to seek outside venture capital.

"We don't just hand over the money," says Todd Keiller, WPI's director of intellectual property and innovation. "Projects must have clear commercial outcomes and must pass milestones at various stages." An independent committee, composed of TAN members, makes the investment decisions. Successful applications receive up to $100,000 (typical investments are expected to be between $30,000 and $40,000) in the form of a convertible note that must be repaid or converted to equity in the company.

With a modest $20 million research base, Keiller says, WPI outperforms larger institutions in the number of start-ups, invention disclosures, patents, and licensing. "We're spinning out as many companies as Tufts and, for our size, we maintain a higher rate of IP disclosures than Harvard. We're running four to five times the national average.

"I attribute it to WPI's project-based curriculum. Our students are entrepreneurial, which makes our faculty more entrepreneurial. And it's all over the board. I've handled IP disclosures from faculty members in music and biomedical engineering, and everything in between."

advanced features for later. For VitaThreads, the MVP was the unadorned microthread suture. The group that had been advising Gaudette and Pins suggested they shoot for an equally simple initial application: stitching up skin.

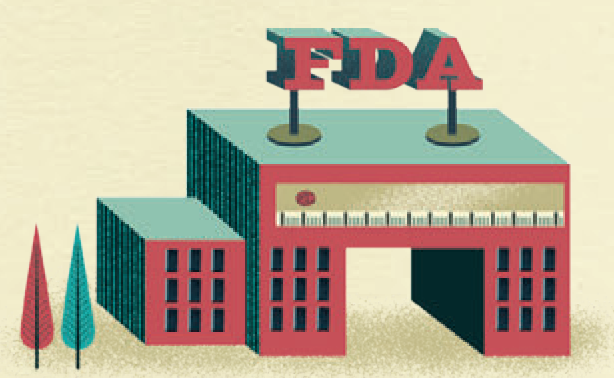
The blow hit Gaudette the hardest. “Compared to operating on a beating, contracting heart, repairing a tendon is basically just sewing a rope together,” he says. “It’s still interesting, but to go from that to stitching up skin…,” he pauses, the disappointment audible in his voice. “I’m a cardiac guy; I cut through the skin to get to the heart. When I’m done, I let my students close up.”

“He’s gone from repairing Lamborghinis to fixing lawnmowers,” Pins teases.

Accepting the realities of the regulatory landscape, VitaThreads settled on its first application. Instead of enabling surgeons to save the lives of heart attack victims or helping athletes heal faster from devastating injuries, their product, now known as the VitaSuture Wound Management System (VWMS), would help plastic surgeons complete face lifts, nose jobs, and eyelid revisions with a much-reduced chance of high-visibility scars. With more than seven million reconstructive and elective facial surgeries performed annually in the United States, it is a sizable market.

In July 2014, the company reported on the results of its pre-clinical in vivo studies. When used with a rat skin incisional model, the sutures were completely absorbed within 14 days, about half the time required for conventional absorbable sutures, and with reduced inflammation. For human patients, those results promised faster recovery with fewer complications and a better cosmetic outcome.

“By establishing ourselves in the fibrin suture market, we’ve achieved a position with the FDA. We’ve started with a small leap of faith, rather than a large one. Now, everything we do to improve our invention will be taking baby steps, rather than making a giant leap from here to there.” —George Pins



THE ROAD FORWARD

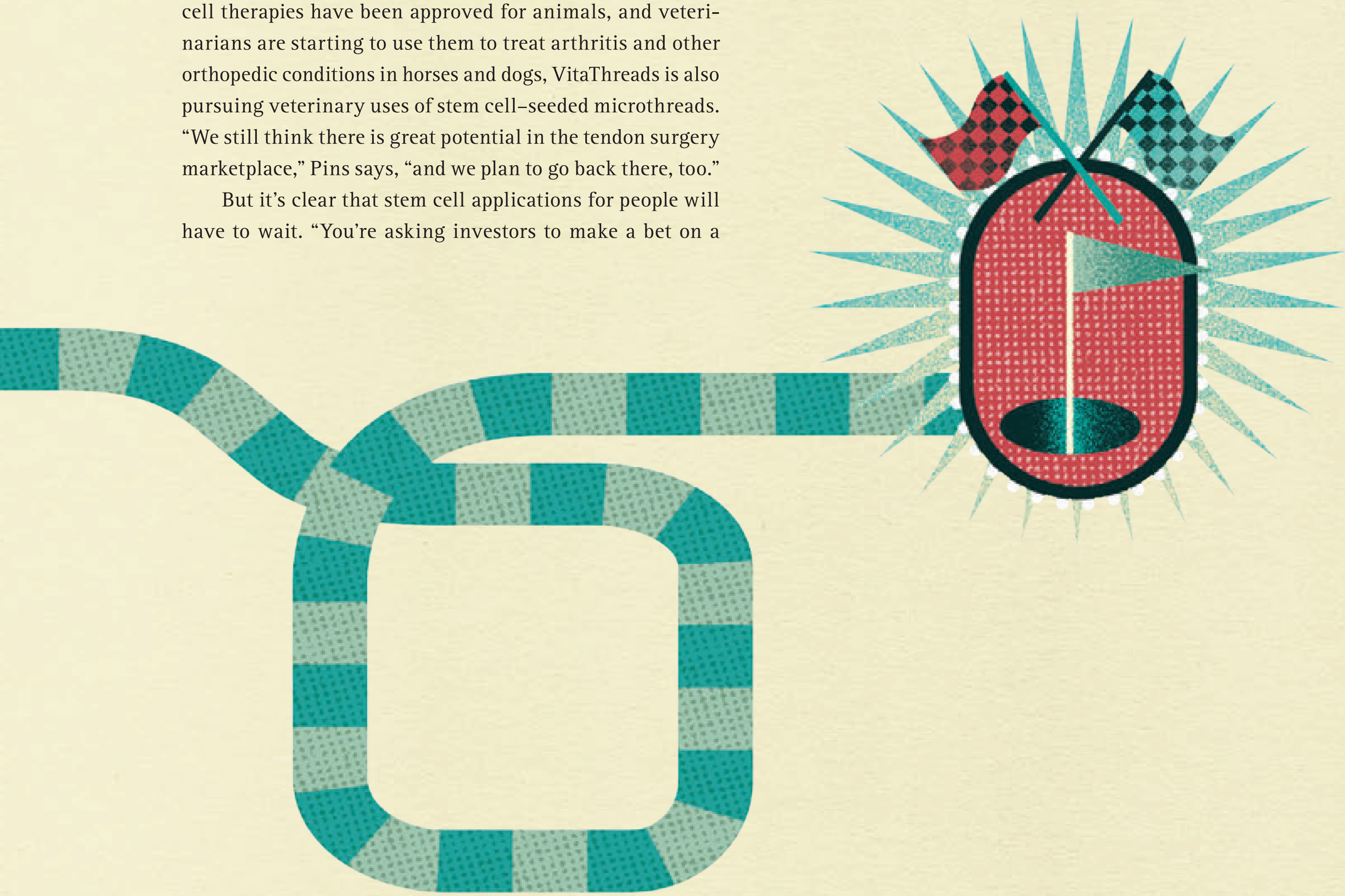
Pins says he sees VitaThreads' first product as a beachhead from which to advance to more complex offerings. "By establishing ourselves in the fibrin suture market, we've achieved a position with the FDA," he says. "We've started with a small leap of faith, rather than a large one. Now everything we do to improve our invention will be taking baby steps, rather than making a giant leap from here to there."

The next steps may include coating the threads with pharmaceutical agents to deliver targeted treatments, and adding anti-scarring agents to the skin sutures. Since stem cell therapies have been approved for animals, and veterinarians are starting to use them to treat arthritis and other orthopedic conditions in horses and dogs, VitaThreads is also pursuing veterinary uses of stem cell–seeded microthreads. "We still think there is great potential in the tendon surgery marketplace," Pins says, "and we plan to go back there, too."

But it's clear that stem cell applications for people will have to wait. "You're asking investors to make a bet on a bet," Gaudette says. "They would be gambling not only that your company is going to be successful, but that the stem cell therapy is going to successfully clear the FDA hurdles."

Still, both researchers say they believe they will eventually realize their original vision for VitaThreads. "Once the FDA approves our fibrin sutures, then getting their approval to add stem cells will be easier than if we had tried to get the combination from the start," Pins says.

"We know there's a big need for stem cell therapy," says Gaudette, "and the heart is where we really want to be. We see this as the best strategy to get there." Re




PHOTOGRAPHY BY PATRICK O'CONNOR

Better by Nature

BY MICHAEL COHEN

Nature is a master materials designer. Millions of years of relentless adaptation have evolved myriad high-performance materials that help living organisms thrive. Three researchers in WPI's Civil and Environmental Engineering Department are studying natural materials to adapt elements of their design, or leverage their natural properties, to make materials that are stronger, more durable, and more sustainable.

Naturally Tough

The blues, greens, and purples of the abalone shell held by assistant professor **Nima Rahbar**, PhD, shimmer like an iridescent glaze on fragile china. But appearances can be deceiving.

"This will resist a shark bite," he says. "It's a fantastic material: light, strong, and incredibly tough."

Fascinated by biology from an early age, Rahbar is a materials scientist who seeks innovation by studying natural forms at the nanoscale. "The beauty of nature is that it optimizes for everything, all at the same time," he says. "If we can learn why these substances are so beautifully tough, then we can apply that knowledge to create better, high-performance materials."

Toughness is key for Rahbar. He is interested in the ability of a material to resist cracking, or to localize the impact of a small crack so it doesn't spread and cause the whole system to fail. Glass, he notes, is strong but not tough. A sheet of glass can carry a stable, heavy load. But introduce one crack, and the sheet will shatter.

In search of natural toughness, Rahbar studies unit cells, which are the smallest repeating forms that give a material its structure. An individual brick, for example, is the unit cell of a masonry wall. During his doctoral work at Princeton University, he studied dentoenamel junction, the material that connects enamel to dentin in the core of a tooth. He adapted elements of dentoenamel junction's design to create a more durable ceramic material for dental crowns.

At WPI since 2012, Rahbar has established the Bio-inspired Material Design Lab where he and his students use mechanical tests and computational tools to characterize biologic materials with the aim of developing new materials that leverage beneficial natural properties.

Enter the abalone. The inner lining of its shell (and that of many other mollusks) is called nacre, or mother of pearl, and it's the source of the shell's toughness. At the nanoscale, the unit cells of nacre look remarkably like bricks in a wall, with rectangular ceramic plates stacked onto thin layers of a protein that functions like mortar. "Nacre is 95 percent ceramic, but the five percent of protein is very important," Rahbar says. "With the protein, nacre becomes 3,000 times tougher than the ceramic alone."

Fracture testing of the nacre and computational modeling of the data has drawn Rahbar's attention to tiny protrusions on the surface of the ceramic plates. "We believe these columns are very important, mechanically," he says.

Rahbar's team is in the early stages of creating new ceramic polymers that incorporate the unit cell properties of nacre. One potential application is the development of lighter bullet-proof vests and body armor. "I believe the best way to solve many of our materials problems is to look at what nature has done, and learn from those lessons," he says.

Cinnamon Concrete

A framed print of the Appian Way hangs on the wall behind the desk of assistant professor **Aaron Sakulich**, PhD. He rescued it from the attic of Kaven Hall when he came to WPI in 2012 because the iconic Roman roadway reflects Sakulich's interests in archeology and enduring infrastructure.

"So much of the infrastructure in our country is falling down around our ankles," Sakulich says. "If we just rebuild with the same materials, we'll have this trouble again in 50 years."

The durability of the concrete in Roman bridges, buildings, and aqueducts is legendary, Sakulich says. But the ancient structures have survived nearly 2,000 years primarily because of what they don't contain: rebar.

Steel reinforcement bars (rebar) are indispensable in modern concrete, as they dramatically extend the material's strength and design capabilities. But they also embed an Achilles heel. Eventually, rebar corrodes. As rust builds up it exerts pressure on the concrete that leads to cracking. "Once that first crack happens, it's only a matter of time before you get chunks falling off," Sakulich said.

Sakulich is exploring ways to extend the life of modern concrete by preventing rebar corrosion. Of particular interest is cinnamaldehyde, which gives cinnamon its aroma and flavor. Sakulich became interested in cinnamaldehyde because it is known to be a natural corrosion inhibitor.

Adding cinnamaldehyde to wet concrete doesn't work, as it prevents the material from curing properly. So Sakulich engineered a time-release delivery system. Pea-sized bits of porous clay are soaked in cinnamaldehyde then mixed into the concrete. The clay holds the cinnamaldehyde by capillary action long enough for the concrete to cure.

In the lab, Sakulich's team fabricates small concrete cylinders with a length of rebar in the center; he calls them concrete lollipops. Some lollipops are made with conventional concrete and others with cinnamaldehyde soaked pellets in the mix. The lollipops are suspended in a salt bath and surrounded by electrodes that deliver a steady charge that drives chlorine ions into the concrete.

"The system accelerates weathering and corrosion," he says. "What would take 25 years in the field, we can simulate in a couple of days."

The results are encouraging. Conventional concrete lollipops crumble after three to four days, while several cinnamon concrete lollipops have lasted for months. "We have confirmed that cinnamaldehyde is diffusing through the concrete and forming a protective layer on the rebar," Sakulich says.

Important questions remain — such as whether the cinnamaldehyde layer weakens the bond between the rebar and the concrete, or if the cinnamon oil will leach out of the concrete over time and cause surface problems. "We have more work to do," Sakulich says. "But the students love the project it because it makes the lab smell like Christmas."

"The big environmental impact of infrastructure comes from all the detours, traffic jams, and disruption caused by rebuilding roads and bridges," Sakulich says. "If we can extend even one maintenance cycle by 10 or 15 years, that's a big positive impact."

"The system accelerates weathering and corrosion. What would take 25 years in the field, we can simulate in a couple of days."

—AARON SAKULICH

Sustainable Cement

To lay the foundation for a more sustainably built environment, Mingjiang Tao, PhD, studies the chemistry and physics of foundations already in place — the ubiquitous materials used in concrete, asphalt binders, and soil stabilizers.

"Portland cement is the most widely used construction material in the world," he says. "It consumes a vast amount of natural resources, it's caustic, and it's energy-intensive to make. I believe we can do better."

Named after stone first quarried on the Isle of Portland in the south of England, Portland cement is the glue that holds most concrete mixtures together. It is made from raw materials found in abundance around the world. "When you consider the energy used for mining, heating, grinding, and finishing the product, the greenhouse gas emissions are one to one," Tao says. "Making one ton of Portland cement generates one ton of atmospheric carbon dioxide."

Tao, an associate professor who joined WPI in 2007, applies the tools of engineering and materials science to characterize the essential properties of Portland cement and other cementitious materials. His approach is to meet the global construction needs in a more sustainable way by developing natural or reclaimed materials for use as cement alternatives.

He is currently focusing on a novel geopolymer based on aluminate and silicate that can be synthesized from rice husks or from industrial waste products like fly ash generated by coal-burning power plants and municipal trash incinerators. "We wouldn't need to mine raw materials," he says. "There is enough industrial waste and natural, renewable sources available today globally to make this geopolymer on a large scale."

> "There is enough industrial waste and natural, renewable sources available today globally to make this geopolymer on a large scale." —MINGJIANG TAO

So far, Tao has demonstrated that the geopolymer has similar mechanical properties and can achieve comparable strength to Portland cement. It's also far more fire resistant and tolerant of acid rain than Portland cement. Tao's geopolymer can also be used as a more effective soil stabilizer.

Currently, soils are often mixed with Portland cement, lime, or similar materials and compacted to stabilize an area for construction. In many areas of the world, however, the soil is rich in sulfates, which react with calcium present in the stabilizers and expand, gradually damaging structures built upon it. "The damage done worldwide from soil expansion is probably more than all the damage done by earthquakes, storms, and other natural disasters combined," Tao says.

Tao's team has recently completed a proof-of-concept study using the novel geopolymer for concrete mixtures and soil stabilization. The early results are promising, he says, and he is planning the next steps for product development.

As Tao moves his innovations further along the path from the laboratory to the field, he will continue to be attuned to the lessons he can glean from the natural world around him. For like Rahbar and Sakulich, he has learned that sometimes the most advanced, appropriate, and sustainable materials are the ones that have been there all along, just waiting to be rediscovered. Re

Leading Through Example

BY KATE SILVER

Women researchers at WPI say they feel supported as they pursue careers and advancement. A program that matches young women faculty members with experienced mentors is an important part of that support.

PHOTOGRAPHY BY PATRICK O'CONNOR

Historian Jennifer Rudolph, right, has been a mentor to Jennifer deWinter, who teaches writing and rhetoric, since 2009. Their relationship has helped both women grow professionally even as it became the basis for a close friendship.

> "For women faculty members, particularly in the STEM disciplines, mentoring is critical." —Kristin Tichenor

It's no secret that women are in the minority in academia. According to a 2006 report on gender equity indicators by the American Association of University Professors (the only detailed report on the topic), 38 percent of college and university faculty members in the United States are women. At WPI — as at many technological universities — the imbalance is greater, with male faculty members outnumbering women by nearly three to one.

For this reason, the university has taken steps to create a welcoming and supportive environment for its female faculty. In 2012 Provost Eric Overström formed the Task Force on the Recruitment and Retention of Female Faculty to find out how WPI can hire more female faculty members and better support them as they rise through the ranks and seek leadership positions.

According to the task force co-chairs, Karen Kashmanian Oates, Peterson Family Dean of Arts and Sciences, and Kristin Tichenor, senior vice president, the first task at hand was to identify what WPI is currently doing well and what more can be done to enhance the professional development and long-term success of women in STEM (science, technology, engineering, and mathematics) disciplines.

Among WPI's most potent tools for achieving those aims, the task force found, is the mentoring of younger female faculty members by female colleagues who've already navigated the path to success in academics, research, and service.

SUPPORT FOR WOMEN FACULTY AT WPI:

What the Survey Says

Among the results of a recent Collaborative on Academic Careers in Higher Education (COACHE) survey of the WPI faculty:

- More than 90 percent of women faculty members said they'd been mentored by someone in their department.
- Women faculty members, much more than men, say their colleagues support their work/life balance.
- Women faculty member were in the top percentile, among all universities surveyed, in their rating of "recognition from colleagues."
- About 85 percent of women faculty members (vs. about 80 percent of men) say they have mentored other faculty members at WPI.
- When faculty members were asked to list the best aspects of WPI, women (but not men) placed "support of colleagues" among their top two.

Common Ground

Jennifer Rudolph and Jennifer deWinter say it's difficult to pinpoint when their relationship evolved from mentorship to close friendship. "My family goes to her family's house for Thanksgiving every year, now," deWinter says.

DeWinter, PhD, assistant professor of writing and rhetoric and an associated faculty member in WPI's Interactive Media and Game Development Program, joined the Department of Humanities and Arts in 2009 and was paired with Rudolph, PhD, associate professor of Asian history and associate department head. While their areas of specialization were different, the two related to one another on their shared interest in Asia (DeWinter had done work in Japan and Rudolph had conducted research in China). They also connected as friends. "She's personable. I think that gets undervalued in matching up mentors," says deWinter. "We had a good time."

They began talking on the phone several times a week. "We would always be brainstorming back and forth ways to address issues, ways to present material to the department or to the faculty," says deWinter. "When I had to put together my tenure materials, she came down and helped me photocopy and collect everything and organize it into binders."

Rudolph adds that she has, in turn, learned a great deal from deWinter, and the two have collaborated on grants and projects, spoken on panels, and presented at conferences as a team. As a historian, Rudolph says that she's accustomed to working solo on projects, but she's learned new work styles and ways of collaborating from deWinter, who is in a more collaborative field. "The result is almost always much richer than if we're doing it individually," says Rudolph.

As women professors in the humanities and arts at a school where STEM studies and men are in the majority, they've also shared a challenge. "Together, I think we've been able to pull together lots of work and create initiatives that integrate humanities and arts more completely into the WPI core," Rudolph says. "You can feel sidelined easily in humanities and arts at a STEM school. But you don't have to be."

Terri Camesano, left, recalling how she benefitted from having a mentor during her early years at WPI, has worked hard to share what she has learned with Anjana Jain, who joined the faculty in 2011.

The value of mentoring for female faculty was reinforced by the findings of a recent in-depth survey of the WPI faculty by the Collaborative on Academic Careers in Higher Education (COACHE), which is based at the Harvard Graduate School of Education. The COACHE survey was undertaken in 2013 at the recommendation of the Task Force. The results showed that women faculty at WPI feel supported, that the majority (more than 90 percent) said they've received mentoring from within their departments, and that when faculty members were asked to list the best aspects of WPI, women placed "support of colleagues" among their top two.

"For women faculty members, particularly in the STEM disciplines," Tichenor says, "mentoring is critical. Considering how underrepresented women are within these academic disciplines, especially within leadership roles, getting advice from a veteran colleague of the same gender can make all the difference."

Engineering a Path

When Terri Camesano, PhD, thinks back to 2000, the year she arrived at WPI, she recalls how helpful it was to have the school match her with a mentor. A professor of chemical engineering who was recently appointed dean of graduate studies, Camesano has worked hard to pass those same lessons on to her own mentee, Anjana Jain, PhD, an assistant professor of biomedical engineering who joined the faculty in 2011.

Jain, who was given a choice of three mentors, said she selected Camesano because she had a strong reputation in teaching and research, and because she was outside of Jain's department. "Everyone in my department is great," she says. "They tell me, 'You know we can mentor you, come and ask us questions any time you want.' But it has been really nice having a different perspective, from someone I normally would not hear from."

> "When I hire someone, I know this is a person I could potentially work with for the next 20 years." —Diane Strong

She says that from the start Camesano was incredibly helpful. She taught her about WPI's culture, introduced her to colleagues, and shared tips on applying for grants. Most important, she served as a role model. "There are not a lot of women in engineering who've decided to go into academia," Jain says, "so it was really important for me to get to know someone who's done that and also had success balancing her personal and professional lives."

Although their formal year as mentor and mentee is over, Camesano and Jain still talk regularly. Today, Camesano is the one with most of the questions. "When I was named dean of graduate studies, it became really important for me to keep up with the needs of the junior faculty coming in," she says. "Anjana is there for me when I need advice."

• • •

Because of the proven value of mentoring, all new faculty members at WPI are offered the chance to be paired with a mentor through the New Faculty Mentoring Program, based in the Morgan Teaching and Learning Center. During the 2013–14 academic year, 80 percent of WPI's newly hired tenure track assistant professors participated. Since the program's inception in 1997, 76 percent of new female tenure-track assistant professors have signed up, versus 66 percent for male tenure-track assistant professors.

Chrysanthe Demetry '88, PhD, associate professor of mechanical engineering and director of the Morgan Teaching and Learning Center, coordinates the mentoring program. She says she seeks to match faculty members according to their goals, whether that's grant writing, navigating the tenure and promotion process, balancing teaching and research, or all of the above.

The feedback she gets on the program is positive. "Fairly regularly, I hear that it lessens anxiety for new faculty members, builds their confidence, helps them maintain a positive outlook, and helps build connections and community, especially across departments," she says.

Lasting Impact

Diane Strong, a professor in the Robert A. Foisie School of Business and director of the Management Information Systems Program, knows how important it is to make the school a welcoming place for new faculty. Strong has been at WPI since 1995. "When I hire someone, I know this is a person I could potentially work with for the next 20 years," she says. "Of course I'm going to try to make sure they're successful."

She does that, in part, by serving as a mentor for women like Bengisu Tulu, PhD, assistant professor of information technology in the School of Business. Strong served on the search committee that hired Tulu in 2006. Both women work in the same field and have overlapping research interests in healthcare and information technologies. It proved to be a mutually beneficial relationship, as Tulu, having just received her PhD, was up to date on the latest research in healthcare, while Strong had more than a decade of experience at WPI to share. "This is where mentoring works really well," says Strong.

Tulu says that Strong answered her day-to-day questions about the university and provided valuable advice on striving for a work/life balance. They also complemented one another when it came to research and applying for grants.

"Early on, she put me on certain grants because I had expertise in that area," Tulu says. "Diane, as a principal investigator with a long track record of obtaining and leading grants, brought credibility to the applications, while my background boosted the team's expertise. So it helped both of us." That experience, says Tulu, helped her build her resume enough to get her own grants. "That was a tremendous help," she says.

Today, nearly 10 years after meeting, the two women still work together and talk daily, although the mentor/mentee dynamic has faded. "It's equalized," says Strong. "Even though she's more junior, there are things she knows that I don't know. Today, we work together as colleagues."

• • •

Karen Oates says that as a scientist and a dean at a technically focused university she is acutely aware of the challenges women faculty members in science and engineering face as they seek to rise through the ranks to positions of leadership in academia. In collaboration with the deans of science at Clarkson University and Michigan Technological University, she has applied for a grant through the National Science Foundation's ADVANCE program, which funds innovations aimed at increasing the participation and advancement of women in academic science and engineering careers. Oates notes that a group of women faculty members has established a WPI chapter of AWIS (the Association for Women in Science), which, as part of its mission, advocates for the needs of women scientists and engineers.

All of these efforts are aimed, over the long term, at building lasting relationships that help retain and advance talented women faculty members, benefitting them, the mentors who help them, and the university. And when it all comes together, the results can be remarkable.

Diane Strong, left, and Bengisu Tulu are colleagues in the Foisie School of Business. Strong, who served as Tulu's mentor when she joined the faculty in 2006, says mentorship can be mutually beneficial. She gained from Tulu's up-to-date knowledge of healthcare and information technology while Tulu participated in grants led by Strong, which helped jump-start her own research program.

Surrounded by a traditionally cast metal part, Diran Apelian, director of WPI's Metal Processing Institute, holds an intricate metal object made, layer by layer, using additive manufacturing.

IT ALL ADDS UP

BY ALEXANDER GELFAND

The next frontier in manufacturing is making metal parts, layer by layer, with 3-D printing. Researchers at WPI are addressing the challenges of additive manufacturing and taking this technology in exciting new directions.

Additive manufacturing, also known as 3-D printing, is nothing new. Designers in industries ranging from transportation to toy manufacturing use three-dimensional polymer printers to rapidly prototype new products, while hobbyists and researchers have used similar equipment to produce everything from musical instruments to mandibular jaw implants.

But the next step in additive manufacturing will take the technology into a new, more complicated, and far more challenging realm: printing three-dimensional objects with metal. WPI faculty members and students in materials science and engineering are helping define the boundaries of this new frontier as they draw upon their extensive expertise in metals processing, manufacturing, materials characterization, and performance evaluation to help launch what could be the next industrial revolution.

According to **Diran Apelian**, PhD, Alcoa-Howmet Professor of Mechanical Engineering and director of WPI's Metal Processing Institute (MPI), 3-D polymer printers are not unlike common inkjet printers. Instead of depositing liquid ink on paper, they lay down layer upon layer of heated, viscous polymers to build up 3-D objects based on CAD (computer-aided design) files.

Additive manufacturing with metal works in much the same way, except that rather than melting powdered polymers, the highly sophisticated "printers" typically use lasers or electron beams to heat metallic powders or wires to high temperatures, depositing layers of fused metal (see diagram, p. 39). Cold spray, another emerging additive manufacturing technology, accelerates metallic powders to supersonic speeds, causing them to fuse on contact with any substrate in their path.

PLUSES AND MINUSES

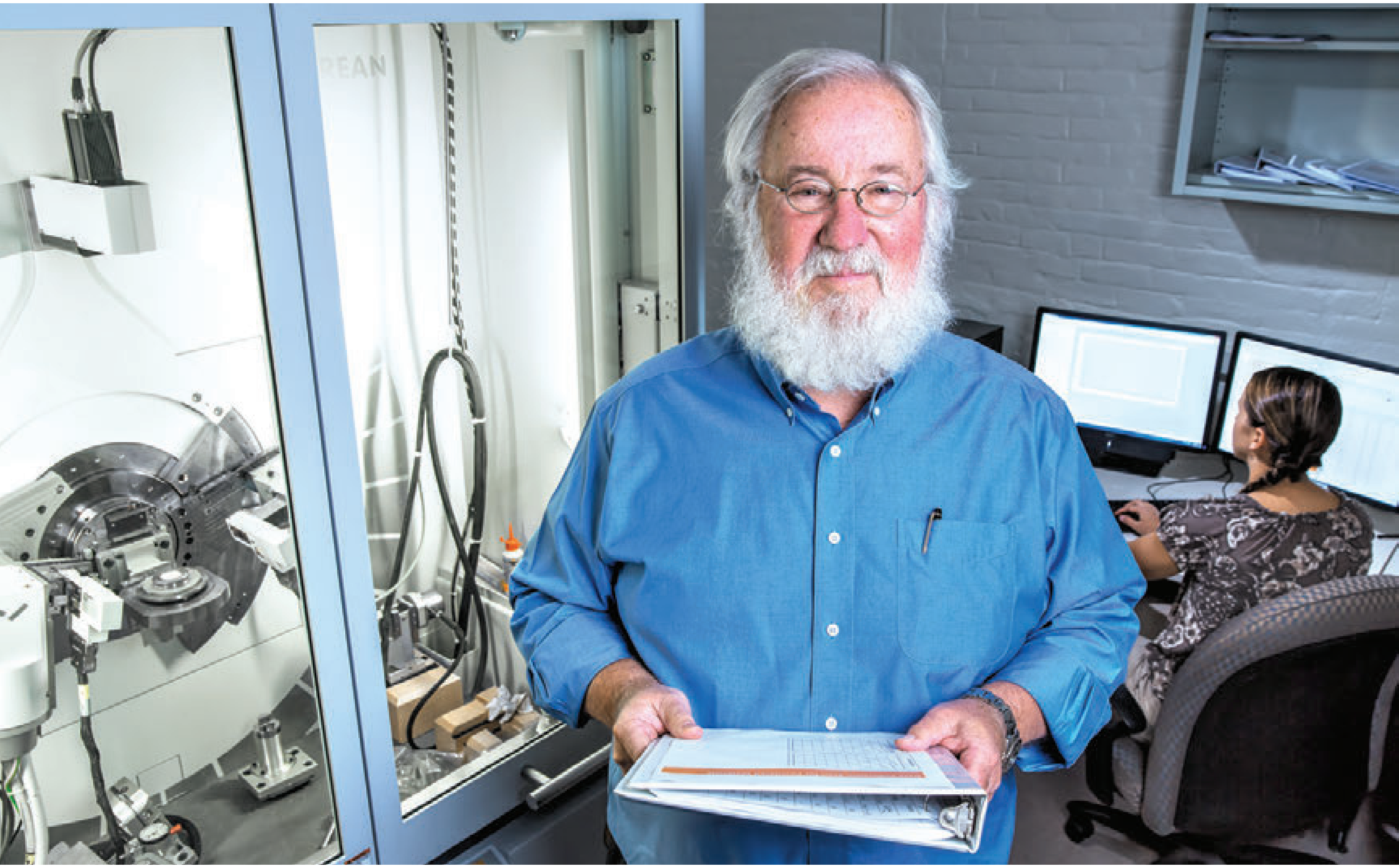
Additive manufacturing has a number of benefits. **Diana Lados**, PhD, associate professor of mechanical engineering and director of WPI's Integrative Materials Design Center (iMdc), says the technique can produce parts more quickly and fabricate far more complex geometries than conventional casting and forging methods, all while consuming less energy and generating less waste. And **Richard Sisson**, PhD, George F. Fuller Professor of Mechanical Engineering and director of WPI's Manufacturing and Materials Science and Engineering programs, notes that while large parts that must be produced by the thousands, such as automobile engine blocks, will likely always be made from big forgings, additive manufacturing is a superior method to produce small runs of parts that can be extremely expensive to manufacture by conventional means.

Forging a single replacement part for a jet engine, for example, can take months and cost upwards of $100,000, while simply making the die to cast a transmission case can cost more than a million dollars — a fact that helps explain why so many of the corporations that lend their expertise and support to MPI and iMdc have shown a keen interest in additive manufacturing. The technology also allows for individually customized parts, a feature of considerable interest to the biomedical industry. Imagine, for example,

Diana Lados in the lab where she and her students (clockwise, from left, PhD candidates Joshua Morales, Anthony Spangenberger, and Yuwei Zhai) test additively manufactured parts, like the 3-D printed sample Lados is holding.

a knee or hip implant that can be tailored to a patient's anatomy, rather than chosen from a narrow range of standard sizes, as is the case currently.

But much work remains before additive manufacturing with metals can become commonplace. For one thing, researchers need to better understand the distinctive microstructures they see in parts made by different additive manufacturing processes. They also need to determine how those unique microstructures give rise to different properties, and how those properties affect performance. Only then will they be able to predict how a particular material will behave under specific operating conditions.

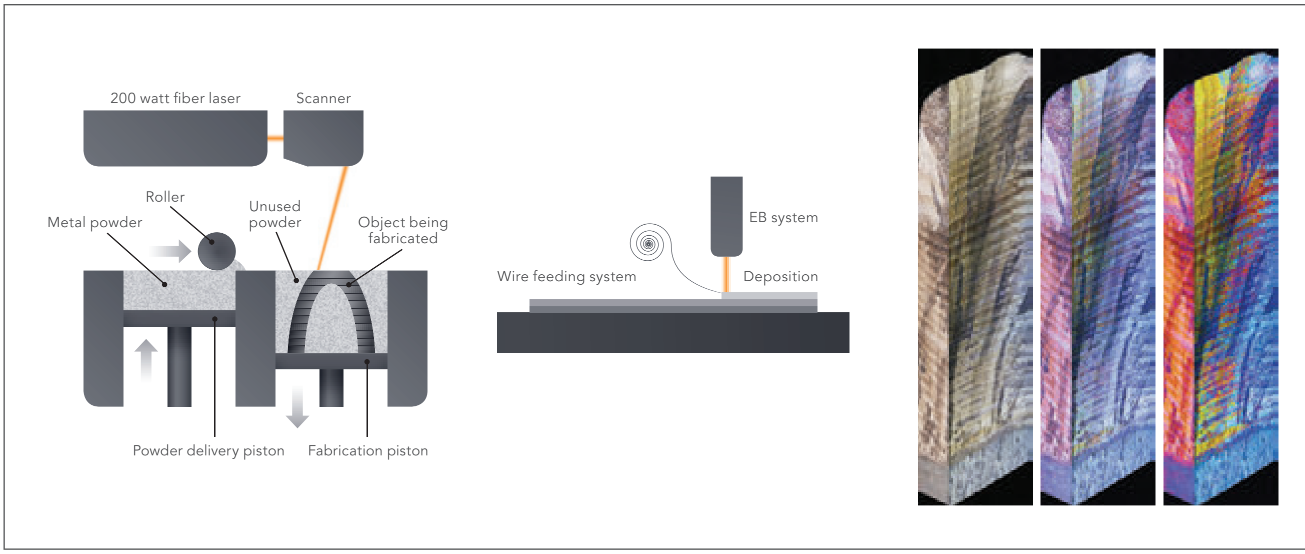


Richard Sisson directs a multi-year project funded by the U.S. Army aimed at understanding and predicting the properties of parts made with cold spray, a "borderline" additive manufacturing tool. With PhD candidate Baillie McNally, he analyzes parts using sophisticated instruments, including this x–ray diffractometer, which can reveal the nanoscale properties of metals by bouncing x-rays off of their surfaces.

THE DEVIL IN THE DETAILS

There's a lot to consider — from the way in which the powder or wire was originally manufactured to the manner in which it is heated and subseqently cooled. And the properties themselves range from strength and ductility to fatigue life to corrosion resistance and porosity, any of which could be important to a specific application. Porosity, for example, is crucial to manufacturing bone implants that can be soaked in antibiotics or used as matrices for growing cells; but without knowing more about how porosity evolves in a specific additive manufacturing process, it's difficult to know exactly how to model and predict it. Add to this the fact that every layer that's laid down affects the ones below it, and you have a very complicated picture.

For the past several years, Rick Sisson has been developing databases and computational models to understand and predict the properties and performance of materials created with cold spray, which he calls a "borderline additive" process because it is currently used primarily to coat and repair existing parts rather than build new ones from scratch. (Funding for his research comes from a multiyear, multimillion dollar agreement with the U.S. Army Research Laboratory, which now commonly uses cold spray to repair magnesium gearboxes in its helicopters and would like to use additive manufacturing to produce entire replacement parts for its vehicles in the field.) But even though 3-D metal printing employs many of the same alloys as cold spray, the fact that they are processed in completely different ways



Additive manufacturing builds up metal parts layer by layer. There are a number of methods that can be used to deposit the layers. In direct metal laser sintering (left), a laser melts layers of powered metal. With electron beam freeform fabrication (middle), a wire is melted using an electron beam. The deposited layers can be seen clearly in the sample at right (from the materials testing lab of Diana Lados) of a titanium-aluminum alloy deposited with laser-engineered net shaping, in which metal powers are melted by a high-powered laser.

means that the parts will behave differently. So Sisson and his colleagues are now undertaking precisely the same work with respect to additive manufacturing processes like powder- and wire-based printing. "Our goal in life is to develop the models to understand the properties, and therefore the performance, of these materials," he says.

UNIQUE WAYS TO FAIL

Diana Lados is working to better understand the unique characteristics and behavior of additively manufactured metal components, especially as the technology makes inroads in high-integrity applications. Since 2011, she and her iMdc collaborators have been developing experimental methods, property databases, and computational tools to help additively manufacture and repair critical structural components for the transportation industry. Among other things, that has meant investigating how various alloys made with additive manufacturing processes fatigue or crack under repeated loading — a phenomenon that Lados has studied extensively in conventionally manufactured and cold-sprayed metal components for the aerospace and automotive industries. (Fatigue is the leading cause of mechanical failure in metals, she says, so understanding how it occurs — and maximizing the resistance of structural materials to it — is vital to the broad implementation of this technology.)

Lados's research has shown that the rapid cooling and reheating of layers as they are deposited during additive manufacturing creates what she calls "micro-heat affected zones" between the layers, which results in non-uniform microstructures and stress distributions. Because of these zones, additively manufactured materials have different properties and failure mechanisms than conventionally manufactured materials.

In other research, Lados is exploring ways to optimize existing laser- and electron beam–based additive manufacturing processes and heat treatments used primarily for titanium and nickel alloys, while also attempting to expand the capabilities of additive manufacturing to a wider range of lightweight structural materials. This includes new studies on additive processing methods for aluminum and magnesium alloys undertaken in collaboration with scientists at Benét Laboratories and Oak Ridge National Laboratory, both iMdc members.

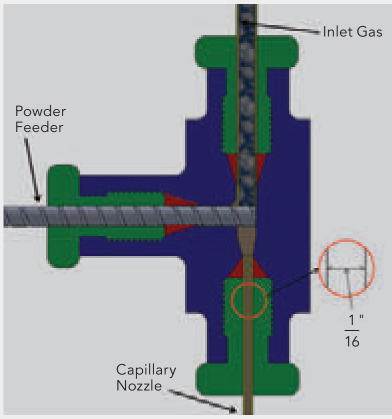
She is also hopeful that additive manufacturing will open up entirely new vistas in materials science; for example, engineers could take advantage of additive manufacturing's unique layering approach to develop new alloys, as well as composite and gradient materials whose composition, microstructures, and properties change across their volume. "The more people understand this technology," she says, "the more versatile it becomes."

DRAWING A FINE LINE

"When people talk about the size limitations of additive manufacturing," says Jianyu Liang, "they are usually referring to the difficulty of using the technology to make really big parts. But there are also limitations in going small."

Liang is working with Ryan Mocadlo '13, a PhD candidate and a U.S. Department of Education GAANN (Graduate Assistance in Areas of National Need) fellow, to develop a new way to use cold spray (the additive manufacturing technology that accelerates metal powders to supersonic speeds to fuse them with a substrate) to make parts at the scale of microns, well below the size of parts typically produced with additive manufacturing.

The key is starting with powders that have particle sizes much smaller than those currently used in cold spray guns, which typically range between 5 and 20 microns. In early work, Liang and Mocadlo have found it difficult to accurately control the feeding of the powders into the supersonic gas stream, resulting in unacceptable variability in the uniformity of the deposited metal. They are currently experimenting with a novel feeding method and trying to learn more about the aerodynamics of the fine metal powders as they speed toward their target.



< A cross-section of a novel cold spray device being developed by Jianyu Liang and Ryan Mocadlo. Extremely small metal powders will be accelerated by gases through the capillary nozzle to produce parts at the scale of microns.

Liang says the U.S. Army Research Laboratory, which is funding her research, is closely following her results. "The Army would like to be able to make very small parts and devices in the field," she says, "so they are very interested in this work."

SMOOTHING ROUGH EDGES

The way additively manufactured parts are processed after they are produced can also affect their properties and their vulnerability to fatigue and cracking, notes **Jianyu Liang**, PhD, associate professor of mechanical engineering. Liang notes that all metal parts, whether made through conventional or additive processes, have rough surfaces that contain burrs or pits that can become initiation points for cracking. Because of the intricate shapes of additively manufactured parts, Liang, whose research expertise includes the nanoscale characterization of materials and electrodeposition, is investigating electrochemical techniques for smoothing and polishing their surfaces. An electrochemical bath will reach even the tiniest nooks that more conventional surface finishing methods like sanding and grinding can't touch. She says she has been engaged in conversations with the Army and Alcoa (which is investing in additive manufacturing) about this approach to surface finishing.

Current techniques for additively manufacturing with metals are not without their limitations. Metallic powder particles, for example, tend to be covered in oxides, and oxides do a great job of initiating the kind of cracks that Lados would like to prevent. Wire-based systems, like the one that Sisson plans to purchase with some of his Army funding, aren't susceptible to that particular flaw, but they do suffer from other problems associated with large cast microstructures and welds. And any method that relies on heating alloys to high temperatures can result in unwanted evaporation.

GOING WITH THE FLOW

Those drawbacks led Apelian to consider an altogether novel approach. Rather than processing wires and powders, both of which are initially manufactured from liquid metal, why not, he asked himself, go back to the source and use liquid metal itself?

Alas, while liquid metal flows well, controlling its viscosity — and the precision with which it is deposited — is no easy task. So in collaboration with researchers at Lawrence Livermore Laboratory and one of the corporate

Jianyu Liang explores electrochemical finishing techniques that can reduce the vulnerability of additively manufactured parts to fatigue and cracking, and uses the scanning electron microscope to observe the effects of those methods. Behind her are, from left, PhD candidates Andelle Kudzal, Yinjie Cen, Yangzi Xu (sitting), and Ryan Mocadlo.

members of MPI, Apelian has turned his attention to thixotropic metals that remain semisolid across a range of temperatures. Pure aluminum, for example, melts at 660 degrees Celsius, whereas an alloy of aluminum and copper might be partially liquid and partially solid from 500 to 750 degrees. The precise temperature within that range determines what fraction of the material is liquid or solid, while the amount of shear applied to it, and the rate at which that shear is applied, controls its viscosity. By manipulating both temperature and shear, therefore, Apelian hopes to achieve the kind of precision required to additively manufacture complex metal components.

There are many ways of improving existing processes, however, and Apelian has more than one iron in the fire. Together with doctoral candidate Aaron Birt, for example, he has been using high-powered lasers to increase the precision of the cold spray deposition process in order to enhance its additive-manufacturing capabilities. And he is also working on a possible collaboration with an MPI member to investigate laser cladding, an additive manufacturing process that can employ either wires or powders.

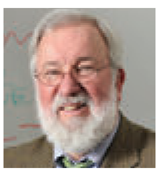
“There’s not going to be one silver bullet here,” Apelian says. But with this much ammunition, that hardly seems necessary. Re

highlights

MAJOR RESEARCH AWARDS

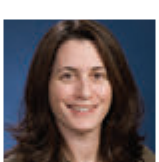
Here is a small sample of the many notable awards from federal agencies, corporations, and other entities that have supported research at WPI in recent months.

BETTER ALLOYS FOR MILITARY VEHICLES



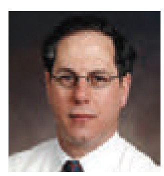
WPI is the lead institution on a $7.4 million, multi-university award from the U.S. Army that will support the development of new metallurgical methods and new lightweight alloys to help the military build more effective and durable vehicles and systems. The technologies and processes developed as part of the research will also have applications in the aircraft, automotive, and electronics industries. The project is led by principal investigator **Richard Sisson**, PhD, George F. Fuller Professor of Mechanical Engineering and director of WPI's Materials Science and Engineering Program; co-principal investigators are **Diran Apelian**, PhD, Alcoa-Howmet Professor of Mechanical Engineering and director of the Metal Processing Institute, **Marion Emmert**, PhD, assistant professor of chemistry and biochemistry, **Jianyu Liang**, PhD, associate professor of mechanical engineering, **Makhlouf Makhlouf**, PhD, professor of mechanical engineering and director of the Advanced Casting Research Center, and **Yan Wang**, PhD, assistant professor of mechanical engineering.

AN APP TO HELP MANAGE OBESITY AND STRESS



Stress and obesity, tightly interconnected in their impact on our health, can increase the risk of cardiovascular disease. Therefore, greater attention to stress in lifestyle interventions could help significantly reduce cardiovascular disease risk in obese adults. With a three-year, $2 million R01 award from the National Institutes of Health (NIH), **Bengisu Tulu**, PhD, associate professor in WPI's Foisie School of Business and principal investigator for WPI, and Sherry Pagoto, PhD, associate professor of medicine and principal investigator for the University of Massachusetts Medical School, will develop and test the RELAX Application Suite, a mobile- and web-based intervention companion designed to monitor patient behavior and stress indicators and deliver stress interventions in between doctor visits. **Emmanuel Agu**, PhD, associate professor of computer science, and **Justin Wang**, PhD, assistant professor in the Foisie School of Business, are co-investigators from WPI. Edwin Boudreaux, PhD, director of research in the Department of Emergency Medicine, James Carmody, PhD, associate professor of medicine, and Yunsheng Ma, PhD, associate professor of medicine, are co-investigators from UMass Medical.

PREPARING TO MOVE ON IN THE DARPA CHALLENGE

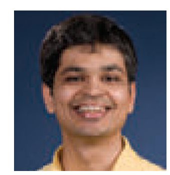


The DARPA Robotics Challenge is a national competition designed to accelerate research on humanoid robots that may one day be able work in hazardous environments to respond to natural and man-made disasters. Having excelled in an early phase of the competition, a WPI research team was granted use of an Atlas humanoid robot made for DARPA by Boston Dynamics (see p. 13). The team programmed that robot to perform a host of tasks, from driving a vehicle to cutting through a wall, and placed well against 17 international teams in a showdown in Florida in 2013. Now, with a $1.5 million award from DARPA, the team is preparing for the next round of the competition, in June 2015, when the competing robots will be required to perform more complex sequences of tasks. **Michael Gennert**, PhD, professor of computer science and director of WPI's Robotics Engineering Program, is the principal investigator; **Taşkin Padir**, PhD, assistant professor of electrical and computer engineering, is the co-principal investigator.

CASTING LIGHT ON ZINC'S JOURNEY INTO THE CELL

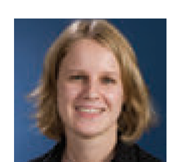
Robert Dempski, PhD, assistant professor of chemistry and biochemistry, has received a $1.4 million R01 single PI award from the NIH to conduct a pioneering investigation of a protein that transports zinc across cellular membranes. Little is known about the molecular mechanisms involved in the protein's selective binding to zinc cations and the movement of the protein/metal combination from the extracellular domain into the intracellular space. The study has important medical implications, as mutations of zinc transporter proteins are associated with a number of diseases, including acrodermatitis enteropathica, a childhood disorder that can be fatal if untreated, and solid tissue tumors, including pancreatic cancer.

CAN BURNING OIL HELP SAVE THE ARCTIC?



As oil companies search for new sources of crude, their gaze is falling increasingly on the Arctic, a region believed to have vast reserves. But the prospect of Arctic drilling also raises the specter of oil spills in this remote, ecologically sensitive area. Burning the spilled oil could be the best way to remove it, but little is known about how oil ignites and burns in frigid conditions. Building on earlier research sponsored by the U.S. Department of the Interior (DOI), **Ali Rangwala**, PhD, associate professor of fire protection engineering, has received two new DOI awards totaling more than $1.3 million to conduct pioneering studies to better understand how cold and ice affect such parameters as ignition, flame spread, burning rate, and heat release of oil.

HELPING NON-EXPERTS TEACH ROBOTS NEW SKILLS

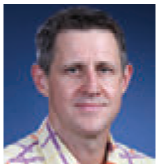


With a three-year, $502,000 Young Investigator Award from the Office of Naval Research, **Sonia Chernova**, PhD, assistant professor of computer science and robotics engineering, will extend her groundbreaking work aimed at developing methods by which non-experts can teach high-level tasks to robots without the need for programming. As robots are increasingly used in military applications, it will be imperative that personnel without special training be able to teach robots new skills on the fly in response to changing field conditions. Using long-term user studies conducted over the web, Chernova and her team will seek to develop a novel learning framework that combines supervised learning and reinforcement learning to enable robots programmed with only a library of primitive skills to learn from a combination of user demonstrations, corrections, guidance, and rewards. The Young Investigator Award is for untenured faculty who "who show exceptional promise for doing creative research."

THWARTING ATTACKS WITH CENTRALIZED CONTROL

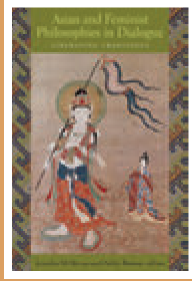
With a three-year, $454,000 award from the NSF, **Craig Shue**, PhD, assistant professor of computer science, will develop a centralized access control system designed to make enterprise computer systems and networks more secure. To protect their data from hackers, many organizations organize their computers into "risk pools" to minimize the chances that a threat directed against one group will jump to others. But this arrangement also makes it difficult for network administrators to monitor traffic within these groups or to determine, when an attack does happen, where it originated. Shue's system will place monitoring software on each computer that will make the risk pools more transparent and provide the central network control system with the information it needs to intelligently monitor and control traffic.

ENGINEERING LEAK-RESISTANT HEART VALVES



Replacement heart valves grown through tissue engineering have the potential to out-perform mechanical valves or bioprosthetic valves, and are also able to repair themselves and grow along with a patient. But, currently, these valves have a tendency to contract, and shrinkage of the leaflets, the flaps that close to prevent blood from flowing in the wrong direction, causes the valves to leak. With a three-year, $451,000 award from the NIH, **Kristen Billiar**, PhD, professor of biomedical engineering, will attempt to develop engineered valves that don't contract by experimenting with a new way of growing the valves under mechanical and biochemical conditions (including low mechanical tension) that mimic those experienced by embryonic heart valves.

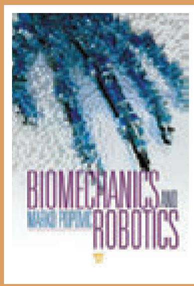
NEW BOOKS BY WPI FACULTY



ASIAN AND FEMINIST PHILOSOPHIES IN DIALOGUE: LIBERATING TRADITIONS

Edited by Jennifer McWeeny and Ashby Butnor
Columbia University Press, 2014

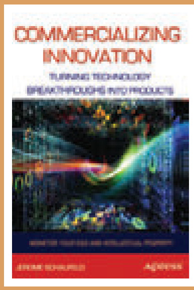
One of the first anthologies to embody the practice of feminist comparative philosophy, this collection, co-edited by **McWeeny**, associate professor of philosophy, creatively engages with global, cultural, and gender differences within the realms of scholarly inquiry and theory construction. In the essays, international scholars put Asian traditions into conversation with contemporary feminist philosophies.



BIOMECHANICS AND ROBOTICS

Marko B. Popovic
Pan Stanford Publishing, 2013

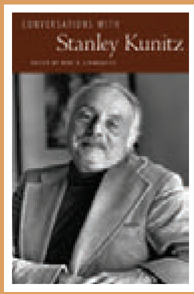
The science and technology of biomechanics and robotics promises to be among the most influential research directions of the 21st century. In this, the first unified textbook on the subject, **Popovic**, assistant research professor of physics, goes beyond the individual areas of biomechanics, robotics, biomedical engineering, biomechatronics, and biologically inspired robotics to present a big-picture look at the field.



COMMERCIALIZING INNOVATION: TURNING TECHNOLOGY BREAKTHROUGHS INTO PRODUCTS

Jerome Schaufeld
Apress, 2015

Commercializing technology is not easy. In this book, **Schaufeld**, professor of practice in the Robert A. Foisie School of Business and successful technology entrepreneur, offers a step-by-step commercialization process that begins with assessing technology from a variety of sources and ends with taking viable products into the market. The book draws on case studies and models, as well as Schaufeld's own experience.



CONVERSATIONS WITH STANLEY KUNITZ

Kent P. Ljungquist, Editor
University Press of Mississippi, 2013

Born in Worcester, poet Stanley Kunitz was an eloquent spokesman for poetry and the power of the human imagination. The interviews and conversations in this volume, edited by **Ljungquist**, professor of literature, derive from four decades of Kunitz's distinguished career and touch on aesthetic motifs in his poetry, the roots of his work, and his comments on a host of other poets.

highlights

FACULTY ACHIEVEMENTS

HOY EARNS LIFETIME ACHIEVEMENT AWARD

Frank Hoy, PhD, Paul R. Beswick Professor of Innovation and Entrepreneurship in the Robert A. Foisie School of Business and director of WPI's Collaborative for Entrepreneurship and Innovation, received the 2014 Max S. Wortman Jr. Award for Lifetime Achievement in Entrepreneurship from the United States Association for Small Business and Entrepreneurship (USASBE), the world's largest independent, professional, academic organization dedicated to advancing the discipline of entrepreneurship. The award is presented in recognition of a lifetime in entrepreneurial achievement that encompasses the ideals of entrepreneurial activity through new venturing, corporate venturing, or social venturing. An internationally known authority on entrepreneurship and family businesses, Hoy has been an active member of USASBE for many years and served as its president in 2003. He has published more than 50 academic articles on small business and entrepreneurship and coauthored nine books and textbooks.

DOMINKO HONORED AS SLOVINIA AMBASSADOR OF SCIENCE

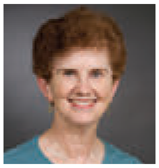
Tanja Dominko, DVM, PhD, associate professor of biology and biotechnology, was named the Slovenian Ambassador of Science in late 2013. The national award is given to one Slovenian native each year in recognition of outstanding achievements and global scientific impact. The award also honors Dominko's international engagement in developing programs that bring together WPI students and faculty members with Slovenian colleagues to address important biomedical challenges. Slovenia's president, Borut Pahor, hosted the awards ceremony, where Dominko joined nine other scientists and engineers who received national awards for a range of accomplishments. Pahor (above, with Dominko) spoke of the vital need to support scientific research and education on a global basis to help improve the human condition—a message that Dominko says resonates deeply with her personal and professional goals to discover and translate new knowledge of human physiology to help cure disease. Dominko is globally recognized for her research in stem cell biology and regenerative medicine.

MALLICK NAMED FULBRIGHT FELLOW

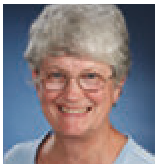
Rajib Mallick, PhD, Ralph White Family Distinguished Professor and associate head of Department of Civil and Environmental Engineering, has been awarded a Fulbright Scholar grant to lecture and conduct research at the University of Peradeniya in Sri Lanka. Mallick (shown here at a faculty recognition event with WPI Board Chairman Phil Ryan, far right, and WPI President Laurie Leshin) will teach and conduct research on sustainable road construction through pavement recycling. His work will reinforce existing research on recycling in Sri Lanka, build interest in adopting sustainable technology, and help American and Sri Lankan engineers work collaboratively on sustainable road construction. Mallick has ongoing research collaborations with faculty members at the University of Peradeniya, the largest government university in Sri Lanka.

PROFESSORS NAMED FELLOWS

Ramdas Ram-Mohan, PhD, professor of physics, has been elected a fellow of the *American Vacuum Society* (AVS). He was recognized for his work on the development of advanced algorithms to optimize design methods for mid-IR quantum well lasers, for advancing the paradigm of wave-function engineering, and for mentoring students in optoelectronics and quantum mechanics simulations.

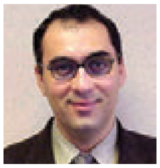


Candace Sidner, PhD, research professor of computer science, has been elected a fellow of the *Association for Computational Linguistics* (ACL), a scientific society started in 1962 to serve the community of scientists who study language from a computational perspective. Sidner was honored for her seminal contributions to discourse focus and collaborative dialog.



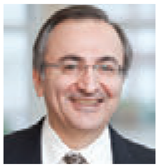
Pamela Weathers, PhD, professor of biology and biotechnology, has been named a fellow of the *American Association for the Advancement of Science* (AAAS), the world's largest general scientific society. She is being honored for distinguished contributions to the field of plant biology, particularly for her research on the plant *Artemisia annua*, which produces an anti-malarial agent known as artemisinin.

Three WPI professors have recently been elected fellows of the *Institute of Electrical and Electronics Engineers* (IEEE). Fewer than one tenth of one percent of voting IEEE members are named fellows in any given year.



Michael Demetriou, PhD, professor of mechanical engineering and aerospace engineering, was recognized for contributions to estimation and optimization of distributed parameter systems.

Yehia Massoud, PhD, professor and head of the Department of Electrical and Computer Engineering, was recognized for his contributions to the modeling and design of nanoscale interconnects.



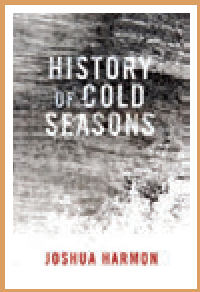
Jamal Yagoobi, PhD, George I. Alden Professor and head of the Department of Mechanical Engineering, was honored for his contributions to the field of electrohydrodynamics (the study of the dynamics of electrically charged fluids).

NEW BOOKS BY WPI FACULTY

DeWITT CLINTON AND AMOS EATON: GEOLOGY AND POWER IN EARLY NEW YORK

David L. Spanagel
Johns Hopkins University Press, 2014

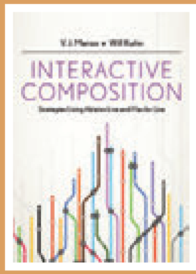
Spanagel, assistant professor of history, explores the origins of American geology and the culture that helped give it rise. By focusing on Eaton, the educator and amateur scientist, and Clinton, the masterful politician who led the movement for the Erie Canal, Spanagel sheds light on a particularly innovative and fruitful period of interplay among science, politics, art, and literature in American history.



HISTORY OF COLD SEASONS

Joshua Harmon
Dzanc Books, 2014

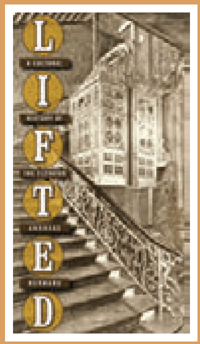
This short fiction collection by **Harmon**, assistant teaching professor of writing in the Department of Humanities and Arts, tells the stories of families broken apart and stitched back together over the course of harsh New England seasons. BBC Culture included the book on its list of "Ten Books to Read in December." BBC book critic Jane Ciabattari called it "a remarkably assured and poetic first collection."



INTERACTIVE COMPOSITION: STRATEGIES USING ABLETON LIVE AND MAX FOR LIVE

V. J. Manzo and Will Kuhn
Oxford University Press, 2015

Co-authored by **Manzo**, assistant professor of music, the book provides readers with the practical skills and insights they need to compose and perform electronic music in a variety of popular styles. Readers, whether beginners or advanced musicians, will be led through the process of creating original compositions and will then learn techniques for performing them in idiomatic fashion.



LIFTED: A CULTURAL HISTORY OF THE ELEVATOR

Andreas Bernard, translated by David Dollenmayer
New York University Press, 2014

This fascinating look at how the elevator changed our notions of verticality and urban space was translated by **Dollenmayer**, professor emeritus of German (the *Economist* noted that Dollenmayer "has valiantly tried to render Mr. Bernard's solemn prose into readable English"). The elevator's wide-ranging effects included fundamentally restructuring building design to reinforcing social class hierarchies by moving luxury apartments to upper levels, previously the domain of the lower classes.

highlights

CAMESANO CO-CHAIRS NATO NANOTECHNOLOGY WORKSHOP

Terri Camesano, PhD, professor of chemical engineering and dean of graduate studies, was the lead organizer and co-chair of "Nanotechnology to Aid Chemical and Biological Defense," an international scientific workshop organized by WPI and the Georgian National Academy of Sciences and sponsored by the Science for Peace and Security Programme of the North Atlantic Treaty Organization (NATO). Part of NATO's Advanced Research Workshop series, the event was held in Antalya, Turkey, in September 2014.

The workshop explored nanoscale science and technology as applied to pathogens like Methicillin-resistant *Staphylococcus aureus* (MRSA), *Francisella tularensis* (tularemia), and *Bacillus anthracis*, the bacterium that causes anthrax. The goal was to eventually engineer new materials that can detect and defend against many biological and chemical agents at the atomic and molecular levels. "Our hope is that by sharing the latest science and discussing the key challenges in the field, we can accelerate technology development to help protect people around the world from these terrible threats," Camesano said.

More than 20 leading researchers from Europe and the United States participated in four days of presentations and rigorous discussions, along with graduate students from their labs and collaborating institutions. In addition to co-chairing the event, Camesano presented a talk on the potential to use naturally occurring antimicrobial peptides to detect biological threats.

LADOS HONORED BY SAE INTERNATIONAL AND TMS

Diana Lados, PhD, associate professor of mechanical engineering and founding director of the university's Integrative Materials Design Center (iMdc), recently received two major career achievement awards. SAE International, a global association of engineers and related technical experts in the automotive, aerospace, and commercial vehicle industries, presented Lados with the 2014 Ralph R. Teetor Educational Award "in recognition of significant contributions to teaching, research, and student development."

Earlier, the Minerals, Metals and Materials Society (TMS) awarded Lados (pictured with TMS president Elizabeth Holm, right) the Brimacombe Medalist Award at its 2014 annual meeting and exhibition in San Diego, Calif. The award recognizes sustained excellence and achievement in materials science and engineering.

WORK BY BRITT SNYDER INCLUDED IN FANTASY ART ANNUAL

Box, a painting by **Britt Snyder**, professor of practice in the Interactive Media and Game Development Program, is featured in the new book *Spectrum 21: the Best in Contemporary Fantastic Art* (Flesk Publications, 2014). *Spectrum* is the premier annual for fantasy-themed illustration. The 2014 edition includes works by 300 artists, selected from among more than 5,000 applicants by a panel of judges that included Greg Ruth, author of the *New York Times* best-selling graphic novel *The Lost Boy*, and Dice Tsutsumi, an illustrator and painter who has worked on such animated films as *Ice Age* and *Toy Story 3*. Snyder is among a small number of artists making their debut in this 2014 *Spectrum*.

In another significant career milestone, Snyder was one of four artists selected (from among more than 200 entries) as Rising Stars for 2014 by *Muddy Colors*, a widely recognized art blog covering the fantasy illustration and the video game art community. The winners, the blog noted, "have demonstrated outstanding and/or innovative techniques, as well as a persevering passion that has resulted in their sustained growth over the years. We have no doubt that they will play a key role in the future of our industry."

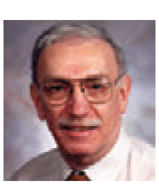
JOE ZHU HONORED BY CHINA'S MINISTRY OF EDUCATION

Joe Zhu, PhD, professor in WPI's Robert A. Foisie School of Business, was awarded a Chang Jiang Scholar Chair Professorship by the Ministry of Education in China. The prestigious award is part of a program started by the Chinese government in 1998 that aims to improve the quality of research conducted at major research universities in China by making it possible for eminent scholars from China and other countries to work in China. It recognizes special contributions made by scholars around the world in particular research fields; Zhu was honored for his outstanding achievements in operations management. About 50 such professorships are awarded each year, mostly in the areas of science and technology. Only a select group of recipients have expertise in the social sciences and management.

SARKIS TOP-RANKED AMONG SUPPLY CHAIN SCHOLARS

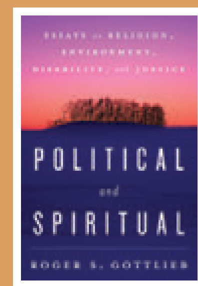
A study of scholarship in the field of sustainable supply chain management published in 2014 in the *International Journal of Production Research* ranked scholars based on a review of the articles they'd published in the most prestigious journals included in the Web of Science database. **Joseph Sarkis**, PhD, professor and dean ad interim of WPI's Robert A. Foisie School of Business, was ranked No. 1 in the area of performance measurement for sustainable supply chain management and second in decision support technology for supply chain management.

WEININGER HONORED FOR WRITING ABOUT CHEMISTRY HISTORY



Stephen Weininger, PhD, emeritus professor of chemistry and biochemistry, received the 2013 Outstanding Paper Award from the American Chemical Society's History of Chemistry Division for "Chemistry for the 'Industrial Classes': Laboratory Instruction, Mass Education, and Women's Experiences in Mid-Western Land-Grant Colleges, 1870–1914," published in the *Bulletin of the History of Chemistry*. The award recognizes the best paper published over a three-year span. Weininger, former chair of the History of Chemistry Division, has published extensively on the history of physical organic chemistry, thermodynamics, and chemical representation.

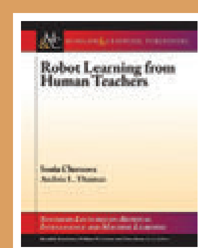
NEW BOOKS BY WPI FACULTY



POLITICAL AND SPIRITUAL: ESSAYS ON RELIGION, ENVIRONMENT, DISABILITY, AND JUSTICE

By Roger S. Gottlieb
Rowman & Littlefield, 2014

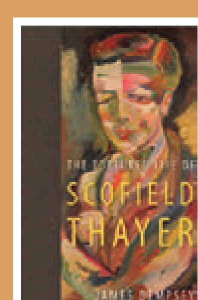
Gottlieb, professor of philosophy, is internationally known for his groundbreaking studies of religious environmentalism, spirituality in an age of environmental crisis, and the role of religion in a democratic society. His latest book brings together for the first time his most powerful essays on these and related themes.



ROBOT LEARNING FROM HUMAN TEACHERS

By Sonia Chernova and Andrea L. Thomaz
Morgan & Claypool Publishers, 2014

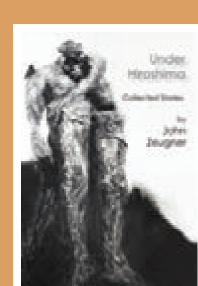
This book, co-authored by **Chernova**, assistant professor of computer science and robotics engineering, introduces the field of learning from demonstration, which explores how robots can learn tasks by observing the examples of a human teacher. The authors focus on the unique technical challenges associated with designing robots that learn from naive human teachers.



THE TORTURED LIFE OF SCOFIELD THAYER

James Dempsey
University Press of Florida, 2014

In this biography of the editor of the influential literary magazine *The Dial*, **Dempsey**, instructor in humanities and arts and administrator of literary studies, looks beyond the public figure to reveal a paradoxical man fraught with indecisions and insatiable appetites, and deeply conflicted about the artistic movement to which he was benefactor and patron. Dempsey's "central claim—that Scofield Thayer was a man divided—is both enthralling and convincing," the *Wall Street Journal* noted in its review.



UNDER HIROSHIMA

By John Zeugner
Snake Nation Press, 2014

Winner of the Serena McDonald Kennedy Prize for Fiction, this collection of short stories by **Zeugner**, professor emeritus of history, includes new and previously published works that are linked by their Japanese settings and recurring characters, and by "their guarded assessment of Japanese and American values, especially as those values play out in a marriage," Zeugner notes.

SERVING A GROWING INDUSTRY

BY ERIC BUTTERMAN

Since the 1980s, when the first recombinant therapeutic agents — medications produced by living cells, rather than chemical synthesis — were approved for sale, the market for so-called biologics has grown substantially. Today, recombinant drugs, vaccines, and antibodies are the fastest-growing segment of the biopharmaceutical industry. That growth has been accompanied by a strong demand for a workforce with the specialized training needed to work in the biomanufacturing facilities where these biologics are produced.

"These places are highly regulated by the FDA and must follow standard operating procedures," says Kamal Rashid, PhD, director of WPI's Biomanufacturing Education and Training Center (BETC), which opened its doors in 2013 with the mission of helping meet that demand. "Most college graduates don't have the skill sets needed to work in a biomanufacturing facility. But we can take undergraduates and graduate students and provide them the kind of experience that will give them a leg up on almost everyone else in the country."

Funded, in part, by a grant from the Massachusetts Life Sciences Center, the BETC is located in the second building to rise at Gateway Park, the mixed-use, life sciences–based campus WPI is developing a third of a mile from its main campus. The center offers open-enrollment, nonproprietary programs for people already in the biomanufacturing business who are looking to advance, along with fundamental training programs for people looking to get into the field.

Zbigniew Kacprzyk, who was laid off from his job as a photoengraver for the *Worcester Telegram & Gazette*, used his severance pay to sign up for the BETC's Fundamentals of Biomanufacturing program. As the newspaper reported in 2014, the training enabled him to earn positions at Lonza Biologics and Bristol-Myers Squibb. Rashid, who has trained thousands of biopharmaceutical industry employees in his career, says Kacprzyk's story is an excellent example of the BETC's potential to bolster the community.

The BETC also provides training for its corporate partners, which include AbbeVie, Biogen Idec, Bristol-Myers Squibb, Eppendorf, Pfizer, and Shire Human Genetic Therapies (a number of which have provided equipment and other types of support for the center). These firms often find it more practical to send their employees to WPI rather than do training in-house, Rashid says. Much of that training is customized to meet each company's needs.

"The FDA requires these companies to assure that their employees keep their knowledge up to date," he notes. "But as the industry grows each year, and as companies devote more and more of their resources to research and development, they are looking to academic institutions to do what they do best and provide this required training."

The center's courses, which are taught by a roster of more than 20 instructors, all of whom have extensive industry experience, cover everything from upstream processing of mammalian and microbial cells to downstream principles and techniques, with training focusing on such industry-standard process areas as equipment preparation and sterilization, buffer and media preparation, fermentation and cell culture, protein capture, and purification.

While the BETC's primary mission is to provide a unique and valuable educational opportunity to its students, Rashid, an internationally recognized leader in biotechnology education, research, and workforce development programs, says the center's state-of-the-art facilities, ranging from laboratories with equipment for seed culture preparation, inoculation, fermentation, and analysis, to a 200-liter pilot-scale bioreactor, have the potential to serve other interests.

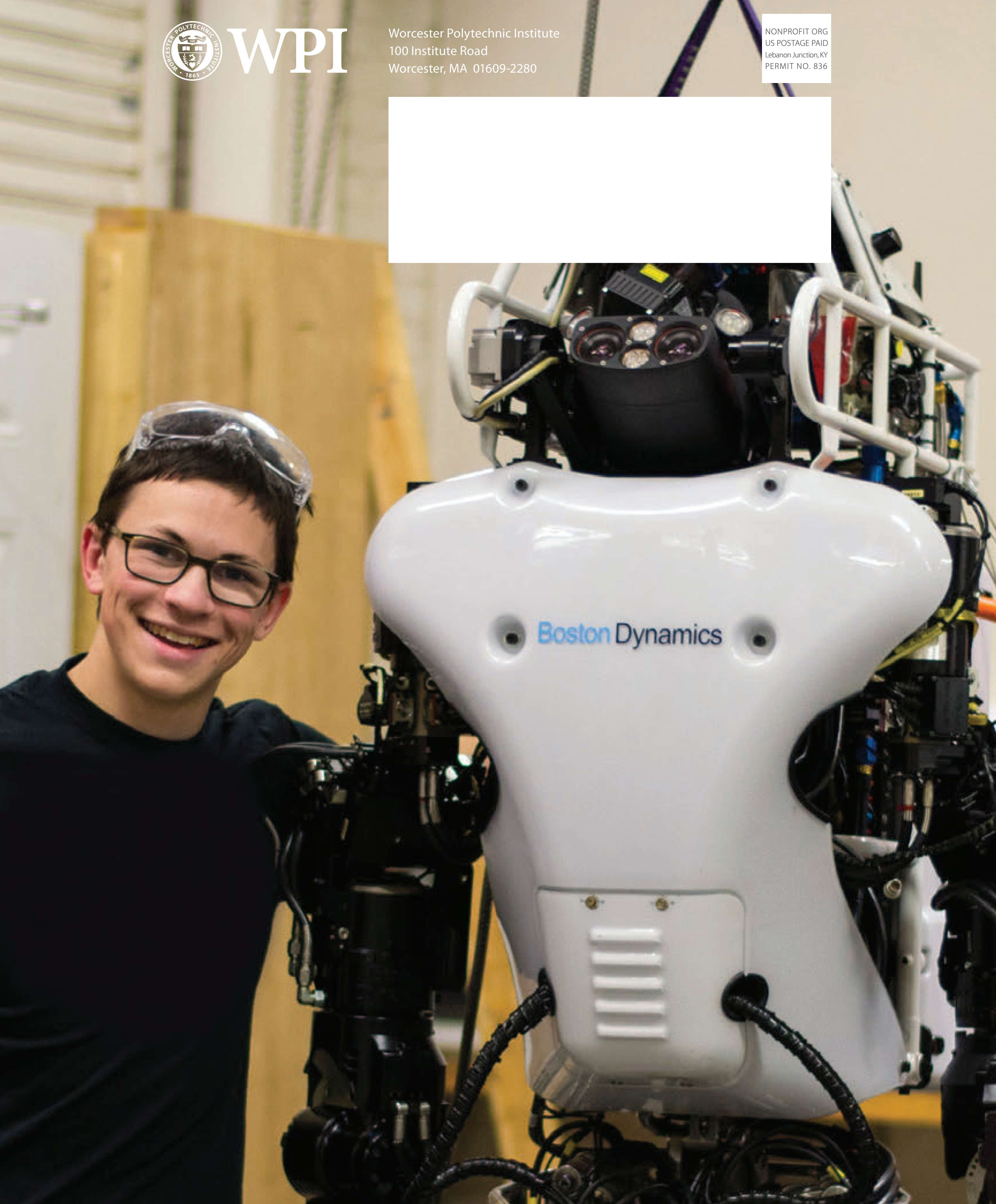
Kamal Rashid directs the Biomanufacturing Engineering and Training Center (BETC), which offers fundamental and advanced educational programs on the manufacture of recombinant therapeutic agents, or biologics. The center is also exploring contract work and research using its advanced equipment. In the background, from left, are BETC and Continuing and Professional Education staff members Jodi Reis, Peter Huie, Susan Fischer, and Dan Mardirosian.

For example, Rashid, who has more than 30 years of experience in academia and industry, most recently as a research professor and associate director of the Center for Integrated BioSystems at Utah State University, is exploring opportunities to engage the center in consulting and contract services for industry. "We can help companies solve production problems, optimize existing processes, or design new ones," he says. "We can utilize the experience of our own faculty and center staff, who can help lead these projects."

A research professor in WPI's Department of Biology and Biotechnology, Rashid is also having conversations with members of the WPI faculty whose research may benefit from having ready access to bioprocessing facilities. "There are faculty members working in WPI's Life Sciences and Bioengineering Center who are developing new approaches to making therapeutic compounds using living cells," he says. "They may need to test out processes or experiment with scaling up production. We have the equipment and the expertise right here at WPI; it would be wonderful to have them see the BETC as a valuable partner."

Rashid is also anxious to share his experience with grantsmanship. "I've been fortunate to have helped secure several millions of dollars in sponsored awards over the years and I've helped others be successful in that area," he says. Among the major awards he oversaw was a five-year, $2.6 million grant from the Department of Health and Human Services and the Biomedical Advanced Research and Development Authority to train or retrain scientists from 13 developing countries in vaccine biomanufacturing, with an emphasis on influenza vaccines.

That award is just one example of the extraordinary potential of biomanufacturing to create new medications and other therapeutic compounds to improve healthcare on a global scale, Rashid says. And, he notes, the impact of the BETC, whether through education, consulting, or research, is just beginning to be felt. "We can help to truly change things." Re



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