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SMALL CURES

THAYER RESEARCHERS HELP TURN NANOPARTICLES AND HEAT INTO A TREATMENT FOR CANCER.

DARTMOUTH ENGINEER
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EDUCATING INNOVATORS

BY DEAN JOSEPH J. HELBLE

UNTIL RECENTLY MOST DISCUSSIONS OF INNOVATION and entrepreneurship on university campuses were largely confined to schools of business. Although engineers have always contributed to making the discoveries and inventing the core technologies that led to the establishment of commercial enterprises, the process of building a team and converting these ideas into business opportunities was not something engineering students were generally taught.

Things have certainly changed.

Innovation and entrepreneurship, concepts that have long been part of Dartmouth's undergraduate program in ENGS 21: "Introduction to Engineering," and other courses, are now embraced as core elements of an engineering education at most leading universities. Students are taught to work in teams, identify a need, brainstorm possible solutions, evaluate and rank all possible approaches, design, prototype, build, test, evaluate, assess societal benefit, and assess potential commercial value. I am convinced that embracing the creative process of discovery, invention, and commercialization as a natural part of an engineering education is helping to transform student perceptions of what an engineering education is all about. I am also convinced that it is a major reason for the nationwide surge in interest in engineering.

Early data from the American Society for Engineering Education (ASEE) tell us that B.S. degree totals increased by nearly 10,000 in 2012 to their highest total in three decades. Growth was certainly evident at Dartmouth, where we graduated the largest A.B. and B.E. engineering classes in our nearly 150-year history this past June. Engineering, in fact, was the largest science major at Dartmouth in the class of 2013, and the third largest major overall. Looking at the number of declared engineering majors in the sophomore and junior classes, I see continued growth, a story repeated by many engineering deans across the country.

While the Thayer community has long understood the connection between engineering and technology entrepreneurship, for years we mainly provided this education for our undergraduate students. Recognizing that a comparable need existed at the doctoral level—where engineering students are helping develop advanced solutions to challenges in medicine, energy, the environment, and communications—Thayer School undertook an experiment in 2008: We founded the nation's first doctoral-level program in engineering innovation and entrepreneurship. Our Ph.D. Innovation Program students receive advanced academic training in engineering and business, undertake an internship to develop their own technology or gain experience working in a startup, and receive funding independent of faculty research grants to help them pursue the development of their own ideas. Admission to this selective program is capped at five students per year.

During the first five years of the Ph.D. Innovation Program, two successful startups have already emerged, an entrepreneur who is a member of the National Academy of Engineering has assumed leadership of the program, and a growing number of students have learned to ask a different set of questions, build a team, assess risk, and develop a different set of solutions. Several students have noted how participation in this program has given them the knowledge and confidence to transform research discoveries into viable enterprises. All signs indicate that this experiment has been a success, and that this program is here to stay.

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Photograph by John Sherman

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ALL CHARGED UP
Chris Bilger '11 Th'13 drives Dartmouth Formula Racing's first all-electric car. The DFR team raced its way to three awards in this year's Formula Hybrid competition.

COMPETITION

Going Electric at Formula Hybrid

DARTMOUTH FORMULA RACING (DFR) took a new approach for the seventh annual Thayer-hosted Formula Hybrid Competition: building an all-electric racecar.

"We completely rebuilt last year's car so that it could hold the battery and house all of the necessary electric components. This involved re-welding the frame, building an electric motor, and optimizing all of the car's systems for electric operation," says DFR captain Darren Reis Th'13. "Going all-electric was quite the engineering challenge."

But challenge is what Formula Hybrid is all about. "It's the most difficult and most challenging of all the SAE Collegiate Design Series competitions," says organizer Douglas Fraser.

Since Formula Hybrid, held at the New Hampshire Motor Speedway in Loudon, N.H., in early May, requires students to collaborate across mechanical and electrical engineering disciplines, corporate sponsors Chrysler, Ford, and General Motors view the competition as a unique recruitment opportunity. "I was on Drexel University's team last year," says GM's Nathalie Capati. "From it, I got recruited into the field of hybrid-electric vehicles." Serving as a technical inspector at this year's competition, Capati looked for the latest talents. "Seeing the teams working together is enough for me to recruit them. At Formula Hybrid I can see them in their real form," she says.

This year's 11 teams experienced a new competitive twist: The 22-km endurance event took place on the speedway's sports car road course instead of its oval track. With two climbs per lap, the course favored cars with effective regenerative braking.

DFR's all-electric vehicle scored well. The team took first place in the all-electric category, won the IEEE Excellence in Engineering Award, and earned a Ford Efficiency Award.

For videos, photos, and more, visit formula-hybrid.org and dartmouth.edu/~dfr/.

—Wesley Whitaker

"The metric to measure success is the number of lives impacted by what we do."

INNOVATION

Gerngross Boosts Entrepreneurship

IT TAKES SUCCESSFUL ENTREPRENEURS to know what entrepreneurs need to succeed.

That's the principle behind Dartmouth's appointment of Thayer Professor Tillman Gerngross and Trip Davis '90 to lead the College's new Office of Entrepreneurship & Technology Transfer. Gerngross will serve as associate provost of entrepreneurship and technology transfer while Davis serves as the office's executive director.

Both Gerngross and Davis are experienced entrepreneurs. Gerngross has cofounded four biotech companies, GlycoFi—which was acquired by pharmaceutical giant Merck for $400 million in 2006—Adimab, Arsanis, and Avitide. Davis, most recently technology entrepreneur and administrator at the University of Virginia, cofounded Green Room, a travel technology company, and TRX Inc., a global leader in travel technology and data services.

Gerngross wants to smooth the way at Dartmouth for innovators to have an impact on the real world. "We should be in the business of catalyzing spin-off innovations and technologies, not taxing them," he says. "To be successful, innovators have to be empowered. It is not about getting in the middle of negotiations, it is about being an enabler and supporter of the process."

Overseeing the Dartmouth Entrepreneurial Network, Dartmouth Regional Technology Center, and Technology Transfer Office, Gerngross and Davis will link experts throughout Dartmouth, Thayer, Tuck School of Business, Geisel School of Medicine, and Dartmouth-Hitchcock Medical Center. They'll also tap Dartmouth alumni in business to help faculty and students bring their innovations to market. "I want this to be the place where they say 'No one is better than Dartmouth in helping me translate my discoveries into something that has an impact,'" says Gerngross. "The metric to measure success is the number of lives impacted by what we do."

Gerngross brings a sense of personal mission to his new responsibilities. "I feel Dartmouth has allowed me to do things that would have been very hard to do at any other place. This environment has provided me with the freedom to fully explore translational research all the way to having real commercial impact," he says. "I feel there is an opportunity to give something back that allows us to carve out a space that is different from other universities or colleges."

—Kirsten Mabry

LEADING BY EXAMPLE
Professor Tillman Gerngross brings personal expertise to Dartmouth's new Office of Entrepreneurship & Technology Transfer.

OPPOSITE PAGE: HARVEST MOON DESIGN. THIS PAGE: JOHN SHERMAN

kudos

>> Professor Lee Lynd Th'84 delivered the 2013 address, "Bioenergy, Food, and the Sustainable Resource Transition", in the Winthrop Rockefeller Distinguished Lecture Series at the University of Arkansas. Lynd is founder of the Global Sustainable Bioenergy Project, which seeks to develop large-scale bioenergy production while addressing the need to feed humanity.

>> Professor Mark Borsuk earned the Integrated Environmental Assessment and Management Best Paper Award from the Society of Environmental Toxicology and Chemistry Europe. His paper, "A Bayesian Network Model for Integrative River Rehabilitation Planning and Management," integrates mathematical analysis into decision-making critical to solving river ecosystem impairments.

>> Professor Erland Schulson, named the Fulbright Arctic Chair for 2013–2014, will spend seven months as a Fulbright Scholar in Norway.

>> Construction of a 12,000-square-foot Center for Surgical Innovation (CSI) is nearing completion at Dartmouth-Hitchcock Medical Center. Dedicated to translational research, the center will have its own operating rooms, angio X-ray, MRI, CT, and other med-tech equipment, enabling innovation, commercialization, and out-of-the-box thinking, according to CSI director Professor Keith Paulsen, the Robert A. Pritzker Professor of Biomedical Engineering. The center will become a testing ground for faculty and student research and will provide opportunities for Thayer School to partner with companies needing to do preclinical work for FDA clearance.

STUDENT PROJECTS

I Want One of Those!

All Wired Up

IF YOU WERE TO SUFFER a bone fracture after a hip replacement, here's something you'd want your orthopedic surgeon to use: a combined clamp and wire-passing device that makes it easier for a surgeon to encircle fractured bones with wire and cables without damaging surrounding soft tissues, blood vessels, and nerves. When designing and prototyping the device, Amy Couture '14, Bianca Jackson '15, Bridget Shaia '15, and Freddy Yang '14 consulted with Dr. Robert Cantu, an orthopedic surgeon at Dartmouth-Hitchcock Medical Center, and Dr. Michael Mayor, a Geisel School of Medicine professor and Thayer adjunct professor. The students won the Phillip R. Jackson Prize for outstanding performance in ENGS 21: "Introduction to Engineering." Their teaching assistant was Ariana Sopher '14.

lab report

LEADERSHIP

New Overseer, Reappointed Dean

Christine Burnley Bucklin '84, a Dartmouth Trustee from 2001 to 2010, has been elected to Thayer School's Board of Overseers. An independent consultant, Bucklin has served as Senior Vice President of Corporate Strategic Planning for Sun Microsystems, Chief Operating Officer at Internet Brands Inc., and as a consultant and partner with McKinsey & Company. She earned her A.B. in mathematics summa cum laude and her M.B.A. from Stanford Graduate School of Business.

Joseph J. Helble has been reappointed to a third four-year term as Dean of Thayer School. During the first eight years of his leadership, Thayer established research focuses in Engineering in Medicine, Energy Technologies, and Complex Systems, initiated the nation's first Ph.D. Innovation Program [see page 16], launched three international engineering exchange programs for students, increased the faculty from 34 to 55, taught record numbers of undergraduate and graduate students, and doubled the number of patent applications among faculty and students.

Medical Imaging with the Čerenkov Effect

DARTMOUTH'S OPTICS IN MEDICINE laboratory released an optical imaging plug-in that interfaces with the GEANT4/GAMOS Monte Carlo architecture and enables the software package to simulate radiation-induced light transport in biological media. The plug-in allows researchers to model biomedical applications of the Čerenkov effect, the emission of light by a charged particle passing through a medium at a speed greater than the speed of light in that medium.

"The plug-in developed by our lab allows scientists to simulate and study new radiation-induced optical measurements of cancerous tumors. We hope that these results will help in the development of novel cancer detection and treatment methods," says Thayer Ph.D. student Adam Glaser, who worked on the plug-in with physics Ph.D. student Rongxiao Zhang, Thayer research scientist Chad Kanick, and Thayer Professor Brian Pogue, director of the lab.

The plug-in and user's guide are available for free download on the Optics in Medicine Laboratory's website (dartmouth.edu/optmed/research-projects/monte-carlo-software/). The site also links to the lab group's article, "A GAMOS plug-in for GEANT4 based Monte Carlo simulation of radiation-induced light transport in biological media," published in Vol. 4, Issue 5 of *Biomedical Optics Express*.

—Wesley Whitaker

LIGHT SHOW
Ph.D. student Adam Glaser experiments with the Čerenkov effect in biological media.

investiture

FORWARD THINKING
Investiture speaker Subra Suresh wants engineers to better anticipate future consequences of technologies.

THAYER'S GRADUATING class was honored at Investiture, held June 8 at the Hopkins Center. Dean Joseph J. Helble presided over the presentation of hoods, caps, and awards to a record 178 recipients of B.E. and graduate degrees.

The annual Robert Fletcher Award, named for Thayer's first dean and recognizing distinguished achievement and service in the highest tradition of the School, was presented to Subra Suresh, president-elect of Carnegie Mellon University and former director of the National Science Foundation.

"A great many of the challenges of the 21st century are issues that arise out of the engineering achievements of the 20th century," Suresh told the graduates. "The success of the petroleum-based economy we built over the last century has given us the problem of how to control carbon emissions and slow climate change; the invention of nuclear technologies now leads to the challenge of preventing nuclear terrorism; the spread of instant global connectivity made possible by the internet now presents the challenge of securing cyberspace, preserving citizens' privacy and protecting confidentiality of personal information; and the aeronautical engineering that transformed the global transportation system also means that infectious diseases can travel fast from anywhere on the planet to anywhere else, almost at the speed of sound, and threaten the planet with a deadly pandemic."

Suresh asked graduates, "What do we engineers need to do differently in the 21st century in order to respond to the challenges of our time while also doing a much better job at anticipating future consequences?"

And he gave his insights on addressing these challenges. "First, by creatively engaging engineering with the social, behavioral and economic sciences, we can better understand human interaction with technologies. Second, our new era of engineering and science is offering new tools and big data for observation and interpretation about our world, and these tools need to be carefully employed and managed. And third, our most difficult problems, and their solutions, are global ones, and working within that global context is essential."

In his farewell to graduates, Dean Helble recounted some of the many accomplishments of the Class of 2013, including creating businesses, mentoring local youth, and showcasing inventions at the Dell Social Innovation Challenge, Unite for Sight's Global Health and Innovation Conference, and the National Sustainable Design Expo. "You took to heart the words inscribed on the side of our building," he said. "You are without a doubt ready to take on the most responsible positions and the most challenging service."

For videos, photos, and more, visit engineering.dartmouth.edu/events/investiture/2013.

CLASS OF 2013
Engineering Graduates

21	Doctor of Philosophy
6	Master of Science
51	Master of Engineering Management
100	Bachelor of Engineering
96	Bachelor of Arts, Engineering Sciences

OPPOSITE PAGE: CLOCKWISE FROM LEFT, COURTESY OF ALL WIRED UP TEAM, COURTESY OF CHRISTINE BUCKLIN, LIZA FRIEDMAN, JOHN SHERMAN
THIS PAGE: MARK WASHBURN

kudos

>> In an article published in *Breast Cancer Research*, Professor Paul Meaney Th'95 reports that microwave tomography can be used to monitor if treatment for breast cancer is working. The imaging technique can distinguish between cancer, benign growths, and normal tissue.

>> Ph.D. candidate Kelly Michaelson '06 was named a Schweitzer Fellow for 2013–14. She plans to dedicate 200 hours to intergenerational programming between Dartmouth students and the Bugbee Senior Center in White River Junction, Vt.

>> M.E.M. candidate Matthew Rice was on the winning team of the inaugural online business simulation challenge presented by the Master of Engineering Management Programs Consortium. Five teams—each with one student from Dartmouth, Stanford, Cornell, Northwestern, Duke, and MIT—collaborated online to present a business plan for a hypothetical car company.

>> An ENGS 89/90 capstone B.E. project, Microflora Isolation for Fecal Microbiota Transplantation, has won first place in two national competitions: the National Collegiate Inventors and Innovators Alliances' 2013 BMEStart biomedical design competition for undergraduates and the Institute of Biomedical Imaging and Bioengineering's 2013 Design by Biomedical Undergraduate Teams (DEBUT) Challenge. Team members Jennifer Freise '12 Th'13, Taylor Gray '13 Th'13, Pauline Schmit '13 Th'13, and Alison Stace-Naughton '11 Th'13, won $10,000 from the DEBUT competition, and, with Sharang Biswas '12 Th'13, another $10,000 from the BMEStart competition. The project, carried out for sponsor Pureflora, aids treatment of the intestinal pathogen *Clostridium difficile* by creating a closed system for handling donor stool samples for intestinal transplantation. The team built on prior ENGS 89/90 work by Peter Ankeny '12 Th'12, Alex Engler '12 Th'13, and Will Hart '12 Th'12. The prize money may go toward commercializing the device.

the POWE

THAYER RESEARCHERS

R of small cures

BY ANNA FIORENTINO

HELP TURN NANOPARTICLES AND HEAT INTO A TREATMENT FOR CANCER.

When a dog named Carmen was diagnosed with an oral melanoma, there was both bad news and good news. The bad news was that the aggressive tumor could kill her within a few months. The good news was that the black Lab could join a clinical trial of magnetic hyperthermia, a new treatment being developed by the Dartmouth Center of Cancer Nanotechnology Excellence (DCCNE), a collaborative research initiative involving engineers from Thayer School and clinicians from Geisel School of Medicine and Norris Cotton Cancer Center at Dartmouth.

<< TRIAL PHASE
Professor Jack Hoopes uses magnetic hyperthermia to treat cancer in animals.

DETECTION >>
Professor John Weaver develops sensing tools to track locations and concentrations of nanoparticles.

PHOTOGRAPHS BY JOHN SHERMAN

Wedged between her gumline and lip, Carmen's grape-sized malignancy was the largest that DCCNE researcher Jack Hoopes, a Geisel School of Medicine professor and Thayer adjunct professor, had seen since embarking on trials in thousands of mice and three other dogs. Standing above an anesthetized Carmen in an operating room at Dartmouth-Hitchcock Medical Center (DHMC), Hoopes says, "We're seeing if magnetic hyperthermia treatment can be adapted to these kinds of larger lesions."

The first step for Carmen will be surgery to excise as much of the tumor as possible. Then magnetic iron-oxide nanoparticles will be injected into the tumor site to penetrate any remaining cancer cells. The dog will be placed under an alternating magnetic field that will cause the nanoparticles to heat up. The heat will kill the cells that come into contact with the nanoparticles.

"You can allow for a more precise delivery of toxins from the heat to one specific area instead of giving a limited dose of chemotherapy or radiation to a large area of the whole body," Hoopes says. And unlike chemo, which can stop working or be too toxic to tolerate, magnetic hyperthermia can be repeated as often as needed.

Ideally, magnetic hyperthermia would be a stand-alone therapy, but for now DCCNE researchers are combining it effectively with standard cancer treatments. "We've had good success pairing magnetic hyperthermia with chemotherapy, radiation, surgery, or a combination," Hoopes says, adding that all three dogs treated before Carmen are now cancer-free.

Getting magnetic hyperthermia to work in animals is a step toward the DCCNE's ultimate goal: using magnetic hyperthermia to treat ovarian and breast cancers—including metastases—in humans. Now in the third year of a five-year, $12.8 million grant from the National Cancer Institute, the DCCNE brings together multiple areas of scientific, engineering, and clinical expertise to make that happen.

Materials scientist Ian Baker, who is both director of the DCCNE and Thayer School's Sherman Fairchild Professor of Engineering, heads up efforts to create new biocompatible iron-oxide nanoparticles that work better than commercially available nanoparticles. His group's newest nanoparticles are coated with dextran, a kind of glucose. "They heat better than those sold commercially," says Baker. Producing particles that range in size from 8 to 100 nanometers, his group is characterizing the properties of the particles, including measuring how well they absorb electromagnetic power.

Protein engineers, led by Thayer professors Karl Griswold and Tillman Gerngross, are creating antibodies that couple with the iron-oxide nanoparticles and carry them to cancer cells. The group's in-vitro studies have shown promise. "Depending on the types of nanoparticles and cancer cells we are examining, we can get, in some cases, two orders of magnitude better targeting having an antibody on the nanoparticle versus not having an antibody on it," says Griswold. In the group's early studies of ovarian cancers in mice, the antibodies are able to deliver nanoparticles to some but not all tumors. In studies of breast cancers in mice, only small nanoparticles arrive at the tumor. The group will continue to tailor the coupling of antibodies and nanoparticles until they can target cancers from different patient populations and better understand the biological complexities of tumor targeting. "Our current results highlight the need to carefully match particle design with the intended clinical application," says Griswold.

Another team of researchers, led by Geisel radiology professor and Thayer adjunct professor John Weaver, is developing sensing methods to provide the hyperthermia systems the information they need to be effective. "The first piece of information required is where the nanoparticles are within the tissue. We have developed methods of measuring the nanoparticles' relaxation time, which characterizes their ability to rotate freely. It provides information about which microscopic compartment the nanoparticles are in—vascular, extracellular, intracellular—and how tightly the nanoparticles are bound to the surrounding structures," says Weaver. "The second piece of information required is how many nanoparticles are present. We have tools that correct for relaxation effects so the number of nanoparticles in a given volume can be measured.

NEW MATERIALS >> Professor Ian Baker, director of the DCCNE, creates biocompatible iron-oxide nanoparticles.

DARTMOUTH IS ONE OF NINE NATIONAL CANCER INSTITUTE-FUNDED CENTERS OF CANCER NANOTECHNOLOGY EXCELLENCE. "OTHER CENTERS ARE RESEARCHING NANOTECHNOLOGY, AND TWO OR THREE ARE WORKING TOGETHER, BUT WE'RE THE ONLY CENTER WITH MULTIPLE PROJECTS FOCUSED ON A SINGLE TOPIC: MAGNETIC HYPERTHERMIA," SAYS PROFESSOR IAN BAKER.

The third, and possibly most important, piece of information is how hot the tissue is during the treatment. Blood flow is very efficient at pumping heat out of tissue, so it is very difficult to predict what temperature is being achieved with a given power. We have tools that are able to measure the temperature during the hyperthermia application so you know exactly how hot the tissue is and can adjust the treatment to achieve therapeutic temperatures."

One of the DCCNE's several Geisel colleagues, Steven Fiering, a professor of microbiology, immunology, and genetics, has demonstrated that nanoparticles carry the body's own pathogen-fighting phagocytic cells into tumors with them. Fiering's group has also shown that when mice with melanomas are treated with magnetic hyperthermia, their immune systems are able to slow or block recurring tumors.

Dartmouth isn't the only National Cancer Institute-funded Center of Cancer Nanotechnology Excellence. There are eight others, including Stanford, Johns Hopkins, and MIT. "Other centers are researching nanotechnology, and two or three are working together," says Baker, "but we're the only center with multiple projects focused on a single topic: magnetic hyperthermia."

In the operating room, Hoopes watches as Dr. Eunice Chen, a DHMC surgeon, excises as much of Carmen's tumor as she can with a cauterizing scalpel. Hoopes hands Chen a syringe filled with a black fluid containing about 80 milligrams of nanoparticles. "Inject the nanoparticles into the tumor bed. Get as many as you can in," he says.

Chen rotates Carmen's head so the nanoparticle-laced fluid won't trickle out of her mouth. In the future, the team will likely use a new slow-release gel that will prevent leakage. Ben Cunkleman Th'13 '14 and Robert Collier '13 Th'13 invented the gel, made of a starch polymer, in a course Hoopes teaches at Thayer, ENGS 56: "Introduction to Biomedical Engineering." The students applied for a patent for the gel in February—one of nine patents associated with the DCCNE so far. "The idea is to apply the gel onto a tumor margin after surgery and after a certain amount of time the gel will degrade, leaving the nanoparticles on the margin," Cunkelman explains.

But for now, Chen injects the nanoparticles into the tumor site and lets them settle for a half hour or so. Then Carmen's bed is rolled across the hall into Hoopes' laboratory. Hoopes positions Carmen's head over a grid of red dots that looks more like a child's game than an alternating magnetic field. He and Thayer Ph.D. Innovation Program student Alicia Petryk '06 Th'07 '08 '13 attach four probes to Carmen's smooth, black coat and inside her mouth, connecting her to a thermal camera that will monitor her temperature. The magnetic field is applied to the nanoparticles, raising their temperature a tenth of a degree every 10 seconds. "Inappropriate use of the magnetic field could result in dangerous toxicity from overheating of the patient's outer-circumferential body tissues if the electromagnetic frequency and field strength is too high or incorrectly matched, so we're being conservative," says Hoopes.

Demonstrating that magnetic hyperthermia can be done safely and effectively will be one of the many hurdles involved in securing FDA approval to treat humans. "We think the magnetic iron-oxide nanoparticles will be very safe at the doses we are using," says Hoopes. "Similar nanoparticles have been used to treat anemia and as an MRI contrast agent in the past, and neither have shown any toxicities."

Hoopes keeps monitoring the probes and adjusting Carmen's head to regulate the direct heat she receives. After 45 minutes, Hoopes powers down and Petryk disconnects the probes. Carmen begins to wake from the anesthesia.

At last Carmen is released to her owner, who tells Hoopes, "It's been a real honor to be part of this." Hoopes reassures him that the dog should have a new lease on life.

"But if we have to," Hoopes adds, "we can always treat her again."

Anna Fiorentino is senior writer at *Dartmouth Engineer*.

"IDEALLY, WE'LL INJECT PARTICLES SYSTEMICALLY AND HAVE THEM CIRCULATE AND ACCUMULATE AT SITES OF MALIGNANCY TO TARGET METASTASES," SAYS PROFESSOR KARL GRISWOLD.

ON TARGET >> Professor Karl Griswold, left, and research associate Christian Ndong, right, engineer antibodies to carry nanoparticles to cancer cells.

ECONOMIC CLIMATE
Chris Davis urges executives to see the long-term connections between prosperity and sustainability.

PHOTOGRAPHS BY WEBB CHAPPELL

THE BUSINESS CASE FOR SUSTAINABILITY

ENGINEER, LAWYER, AND ACTIVIST CHRIS DAVIS '76 EXPLAINS WHY IT PAYS TO GO GREEN.

BY LEE MICHAELIDES

CHRIS DAVIS '76 GAVE UP A HIGH-POWERED LEGAL CAREER TO SPREAD A MESSAGE THE WORLD cannot afford to ignore: "Climate change is a risk to the entire global economy."

Davis argues that businesses must become sustainable, "generating long-term shareholder value by embracing opportunities and managing risks from economic, environmental, and social issues." As director of the investor relations program at Ceres, a nonprofit that advises corporations and institutions on sustainable business practices, he puts his argument into action.

Davis and his colleagues at Boston-based Ceres are proponents of paying attention to the Triple Bottom Line (TBL) as a way of evaluating if a business is sustainable. TBL is an idea hatched in England almost 20 years ago. The United Nations and community governance groups embraced it as an accounting standard about six years ago, and the idea is gaining credibility in the private sector, too. TBL calls for businesses to track and report environmental, social, and governance—a.k.a. E, S, and G—metrics as well as conventional profits and losses.

> BIG COMPANIES ARE STARTING TO GET THAT SUSTAINABILITY ISSUES SHOULD BE INTEGRATED INTO CORPORATE STRATEGY AND MANAGEMENT.

OPPORTUNITIES IN SUSTAINABILITY
Which business sectors will grow as the global economy embraces sustainability? Here's Chris Davis' list:

> Health care ("A sustainable business has happy, healthy employees.")
> Energy efficiency
> Renewable energy
> Distributed generation ("The future is not giant power plants.")
> Green buildings
> Improved operational efficiency
> Life cycle analysis of products
> Sustainable agriculture
> Transportation efficiency
> Waste reduction and recycling
> Water-efficient technologies

According to Davis, the sustainability concept is helping companies widen their thinking. "Some of the most successful businesses, like IBM and 3M, are good at not only the financial part, but the E, S, and G parts," he says. And he's working to show other corporations the value of environmental, social, and governance factors.

DAVIS WORKS AT THE INTERSECTION of big money and environmentalism. He rubs elbows with Fortune 500 executives, money managers who control billions of dollars, and eco-celebrities such as Bill McKibben, who founded 350.org to help solve the climate crisis.

Davis himself has been interested in environmental issues since high school, when the first Earth Day grabbed his attention. At Dartmouth, Professor Hans Grethlein, who courses on systems and environmental engineering, and Gordon McDonald from the College's fledgling Environmental Studies Program, influenced him as well. Having come of age when fire on Ohio's Cuyahoga River was symbolic of the country's pollution problems, Davis started his career in wastewater treatment. He worked in that field for two years and was on the verge of returning to Thayer for an advanced degree when he realized, as he puts it, that "my verbal skills were better than my quantitative abilities." He left his engineering job and enrolled at Harvard Law School, where he later became a member of the Harvard Law Review.

After practicing environmental law for almost 30 years, Davis joined Ceres in 2010, taking an 80 percent pay cut to gain a new career direction. "I quit as a partner at a big law firm because I was convinced I wasn't working on things that made a difference," he says. "I wanted to spend the rest of my working life trying to solve problems like climate change."

His personal pay cut aside, the economic case Davis makes for sustainable business and investment strategies is straight and to the point: socially conscious investing isn't code for poor monetary returns.

"Big companies are starting to get that sustainability issues should be integrated into corporate strategy and management. These things are important and impact the bottom line. There is an increasing amount of data that suggests that this isn't just feel-good stuff. Sustainable business practices really matter. Deutsche Bank did a meta-analysis that came out last year of more than 100 academic studies that showed in virtually all cases, companies that had a high rating for sustainability had superior financial performance and had a lower cost of capital in terms of raising debt and equity," says Davis. Other studies, he notes, report that companies with high sustainability ratings outperform market averages in the long term.

Like many in the environmental community, and even some in the business community, Davis is a critic of quarterly capitalism. "It's bad for everybody except the traders and speculators and hedge funds. If you are managing a perpetual endowment or pension fund, you need to take a longer view, which is not necessarily beating your benchmark every quarter," he says. Davis is aware that making the case against quarterly capitalism can be tough because the compensation packages of many money managers, his target audience, are based on annual results. Even so, he says, "We argue for long-term capital investment strategies."

Thinking long-term makes it hard to ignore climate change. Indeed, corporations and investors are paying more attention to scientists and environmentalists on the realities and consequences of climate change. Accordingly, Ceres has been advising its partners, including heavyweights such as the California Public Employees' Retirement System

(CalPERS) and BlackRock, to ask more questions about sustainability and risk. For example, if a pension firm owns stock in an oil company that has extensive coastal refineries, what long-term risks does the firm face from rising sea levels and stronger hurricanes? Large institutional investors need that kind information to make smart choices for their portfolios, Davis insists.

Increasingly money managers are feeling pressure from their stakeholders to do something about climate change. Dartmouth is a case in point. When environmentalist Bill McKibben and writer and activist Terry Tempest Williams came to campus this past May to advance their campaign for colleges to divest from fossil-fuel stocks, a standing-room-only crowd filled 105 Dartmouth Hall, and 400 people signed a divestment petition addressed to the Dartmouth trustees.

Davis, who answered questions about divestment when he delivered a Jones Seminar on Science, Technology and Society at Thayer School last January, advises students to take a more nuanced approach to the issue. Students need to "understand a little about fiduciary duty," he says. "It would be irresponsible and illegal for trustees to make a political statement in how they invest the endowment." Instead, Davis says, students should ask for a climate and carbon risk assessment of the portfolio. They should also ask tough questions, such as: How big is the carbon footprint of the portfolio? How dependent is it on investments in so-called dirty energy? "Students need to figure out how the endowment can be part of the solution while still earning strong returns," he says.

Davis is not defending the status quo for investors or big oil. "Oil companies have reasonably good short-term returns, but the transition to a low-carbon economy is essential or we're going to cook the world," he says.

"There are real risks in investing as usual," he points out, "and money managers need to take a serious look at a portfolio from a fiduciary duty standpoint. Ignoring environmental factors and ignoring sustainability or not seriously integrating them into an investment strategy is not consistent with fiduciary duty."

Pension funds and endowments won't sell their investments in fossil-fuel companies instantly for a two reasons. "Immediate divestment of fossil-fuel companies may not be a legal option trustees could exercise," says Davis, speaking as a former lawyer. A second reason is the amount of money involved. The energy sector is worth some $6 trillion, and there are not enough sustainable businesses or new technologies to absorb all that money right now. Instead Davis argues that a five-year window for divestment and reinvestment is more realistic.

As Davis convinces money managers about the benefits of the sustainable investing, the capital they invest will fund a host of new opportunities [see sidebars].

Davis urges engineers who will help create those opportunities to think broadly. "All engineering and business problems have technical, operational, environmental, social, political, and financial dimensions, all of which need to be addressed for a successful solution," he says. "Getting it right technically might get you halfway there."

And in today's climate—both business and environmental—halfway is not a viable option.

Lee Michaelides is a contributing editor at *Dartmouth Engineer.*

BUILDING A BETTER FUTURE

Thayer faculty recommendations of technologies that show promise for sustainability

Cross-laminated timber systems. More widely used in Europe than in the U.S., these are being used for larger-scale structures (buildings 20 stories tall or more). Using timber rather than steel and concrete is more sustainable, as the wood is renewable, recyclable, recoverable, and stores carbon.

—Professor Vicki May

Fusion energy. It will require massive social commitment to make a scaled-up system of supply and distribution, but it is capable of removing energy as a constraint on development and the accompanying distortions.

—Professor Daniel Lynch

Hybrid-electric and high mpg vehicles; solar hot water heating. These open up the possibility to dramatically reduce energy use and carbon production without a significant paradigm shift or painful modification of behavior/habits of the general public. Rethinking building management and intelligently designing heating and cooling processes—for example, solar hot water heating—could have a tremendous impact.

—Professor Jason Stauth

Hydraulics. Using pumps and high-pressure fluid to transfer power from offshore wind turbines or hydrokinetic tidal turbines to on-shore electric power-generating stations may prove to be a more economical way to harness wind and tidal energy.

—Professor Brenden Epps

Integrated food production systems. Beef production accounts for more than half of all land devoted to agriculture in the United States and yet delivers a much smaller fraction of both calories and protein. The land devoted to beef production could be devoted to producing food in a more land-efficient way, thus lessening pressure to clear land, which is a major source of habitat loss and greenhouse gas emissions. Producing and consuming food in a more land-efficient way could also make room for biofuels, which likely have to be substituted for fossil fuels in a carbon-constrained world for a significant—about half—of mobility requirements.

—Professor Lee Lynd

Net zero homes. They're available now and will become more affordable with faster paybacks every year.

—Professor Solomon Diamond

Photovoltaic solar energy; smart buildings and cities. Photovoltaic solar technology has made significant progress, and prices are coming down. Smart buildings and cities, which use censors and remote control to balance energy loads, decongest traffic, and the like, are reducing energy consumption and emissions.

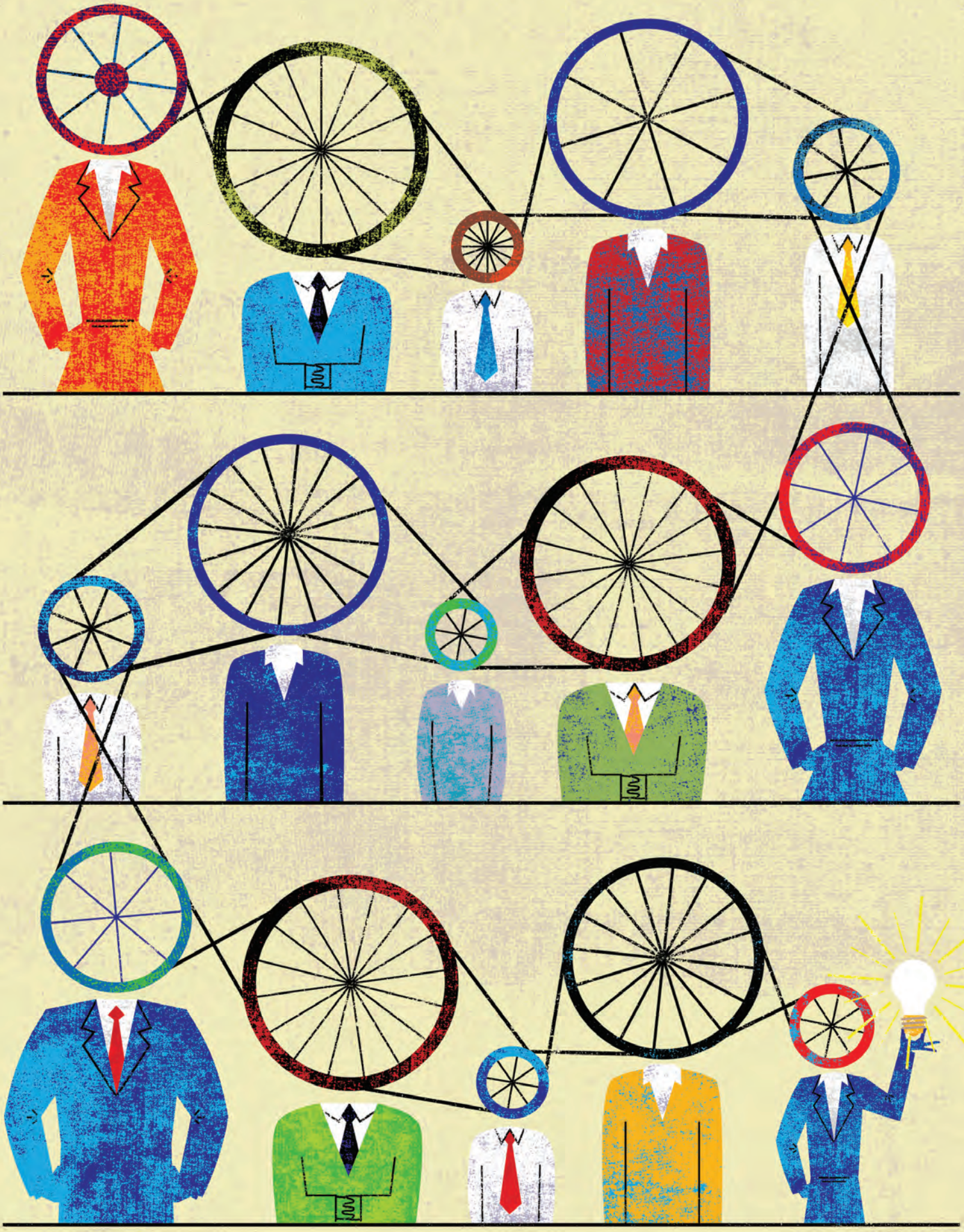
—Professor Benoit Cushman-Roisin

A smart grid. It enhances the integration of renewables into our energy mix.

—Professor Mark Borsuk

Pulse-Electro-Thermal Deicing. PETD technology uses quick pulses of electricity to instantly loosen ice from surfaces such as solar panels and wind turbine rotors. (In the United States and Canada about 17 percent of power generated by windmills is lost due to rotor icing.) The technology can remove ice from windshields in two seconds using very low energy from a car battery. If used to loosen ice in commercial, industrial, and residential ice-makers, PETD would save up to 40 percent of electric energy used by those devices. If used in no-frost refrigeration and AC-evaporators, PETD could save from 15 to 40 percent of electric energy.

—Professor Victor Petrenko



ENGINEERING ENTREPRENEURS

WHEN THAYER SCHOOL DEBUTED THE PH.D. INNOVATION PROGRAM five years ago in 2008, it created a novel solution to a national challenge: how to develop leaders with both technical and entrepreneurial expertise.

In the program, launched by Dean Joseph Helble, students complete all the requirements of a traditional Ph.D., plus specialized studies that prepare them to build an enterprise based on technical innovation.

"Students learn about intellectual property, funding, capitalization, cash-flow issues, how to operate a business, management practices, ethics, how to hire a good team, how to balance an organization, and how to be a leader," says the program's faculty coordinator, Professor Eric Fossum, an inventor, entrepreneur, and CEO with decades of experience commercializing technologies.

In courses such as ENGM 180: "Corporate Finance" and ENGM 188: "Law, Technology, and Entrepreneurship," Innovation Program students learn about patents, intellectual property, contracts, copyright, and trademarks. They learn the language of business.

In the capstone course ENGG 321: "Introduction to Innovation," Innovation Program students go through the steps of creating their own startup. "If a student has the opportunity to do something entrepreneurial, understanding how business works—how technology and innovation really go from an idea to a product—is important. It's critical that they have the knowledge of how the whole process comes together," says Fossum.

The opportunities—and demands—of ENGG 321 are widespread. The course requires students to serve on review panels for the undergraduate course ENGS 21: "Introduction to Engineering." It involves a heavy reading load and numerous one-on-one conversations with Fossum, a National Inventor's Hall of Fame inductee whose CMOS imaging system made digital cameras ubiquitous. Students also meet other successful entrepreneurs .

And in ENGS 321 students identify a particular technology and go through what it would take to create an enterprise that is based on that innovation, from start to finish. "They identify strengths and weaknesses. They build a market forecast and a real strategy for getting the technology to market," says Fossum. "They have to show what the whole product really is, which means more than just the widget but also how to use it and the know-how that has to be sold along with it. They develop a five-year financial plan, which includes not only manufacturing costs, but also the infrastructure—everything from salaries and HR managers down to desks and chairs."

For some students ENGG 321 is an opportunity to work on real startups. For others it's a preparatory exercise for the future. For all it's a step in developing a succinct pitch for selling their technology.

An internship, in which students work in a startup company—possibly their own—or in an R&D department in their field of interest for up to six months, is also part of the program. "It's very good for them to get experience in an existing company, to learn how things are done and how people think. It exposes them to new ideas and sharpens their vision of what they want to do, what kind of enterprise they want to create," says Fossum.

The Innovation Program takes an enterprising approach to funding as well as studies. Students receive five years of support, spending their first two years working in their advisor's lab and the next three years exploring their own ideas.

So far, 13 students have participated in the program. Two of the earliest have already established successful companies: Ashifi Gogo Th'09 '10, founder of the counterfeit-drug-detecting company Sproxil, and Dax Kepshire Th'07 '09, cofounder of the isothermal compressed-air energy-storage company SustainX.

"While the students here are all on different trajectories, they all catch the entrepreneurial bug," says Fossum. "We're small and flexible enough to tailor the program to each individual student's needs and backgrounds. It's a really fantastic opportunity."

In the following pages, eight Ph.D. Innovation Program students tell us how the program has changed them and prepared them for an inventive future.

BY KATHRYN LOCONTE LAPIERRE

MICHAEL AUSTIN

ALICIA PETRYK '06 TH'07 '08 '13

RESEARCH ADVISOR:
Professor Jack Hoopes

RESEARCH: We are working on developing iron-oxide nanoparticles—very small crystals of iron oxide in a biocompatible coding—as a cancer therapy. When iron-oxide nanoparticles are exposed to an alternating magnetic field, they produce very localized heat. Because they are so small and can be internalized by tumor cells, we can deliver a focused and controlled thermal dose. I've been combining this treatment with chemotherapy.

STARTUP IDEA: For my ENGG 321 project I looked at using iron oxide nanoparticles for female sterilization. I already knew a lot of the science, but the project made me think about it as a small business, exploring what resources I had and what would be necessary before I could make it a reality.

WHY THE INNOVATION PROGRAM: I wanted to build upon what I had learned in the Master of Engineering Management (M.E.M.) program. Engineers should understand patent law and intellectual property. If you want your great idea to actually help people, then you're going to have to figure out how to make it into a viable business.

INTERNSHIP: For my internship, I wrote a grant with a small business that our lab was collaborating with. The company was applying for a Small Business Innovation Research (SBIR) grant for imaging nanoparticles for cancer treatment on large animals. In Hanover I'm actually doing the research and treating oral tumors in dogs [see page 6]. My biggest takeaway was seeing how the company makes big decisions. They spent a lot of time gathering data, looking at market reports, and talking to people. Figuring out the correct move for the business is a long and drawn-out process. It's both exciting and scary.

TAKE-AWAYS: What I've learned has already started to help me. Our lab has applied for a provisional patent. Having the Innovation Program experience made me much more prepared and confident in my understanding of how patent law works—or how one might write about or present such a technology in a medical setting. If I had to do that for real now, I would be prepared.

STEVEN REINITZ '09 TH'09

RESEARCH ADVISOR:
Professor Douglas Van Citters

RESEARCH: I'm looking at improving ultra-high-molecular-weight polyethylene, the material used as a bearing surface in artificial knee and hip implants. Ideally you want material that won't change, crack, or wear through over time in the body. We're using a new polymer-processing technique developed here at Thayer called equal channel angular extrusion (ECAE). We tangle the polyethylene in knots to improve its wear resistance without sacrificing its mechanical properties and biocompatibility. My thesis work is optimizing and validating the technique to make sure that it's scalable for industry.

STARTUP IDEA: My Innovation Program work stemmed from my Bachelor of Engineering project, in which my team worked with Dr. Corey Burchman at Dartmouth-Hitchcock Medical Center on preventing hospital-acquired infections and IV-line contamination. We developed a medical device that uses IV in an optimized flow pattern to sterilize the fluid before it reaches the patient. That project led us to start B.B.R. Medical Innovations Inc. to produce the device [see page 22].

I LEARNED VERY QUICKLY THAT THERE IS AN ART TO KNOWING WHAT NEEDS TO GO INTO A GOOD PITCH.

—STEVEN REINITZ '09 TH'09

WHY THE INNOVATION PROGRAM: When we decided to form the company, we had no idea what to do next. We had the engineering and the medical background but no business or legal background. I wanted to get exposure to the business side of things. I talk about the Innovation Program in my business pitch to show why we make sense as a team: our team has the medical, biotech, and law background, and I'm honing the engineering and business skills. Through the program I also have access to everyone at Thayer, Tuck, and the Dartmouth Entrepreneurial Network. All of those resources give a new startup a lot better chance of succeeding. As engineers we get good at the technology, but in the business world the most important skill to succeed is the ability to network and talk with people. And as an engineer whose comfort zone is in the lab, that is a really hard thing to do. The Innovation Program has given me those skills.

TAKE-AWAYS: I learned very quickly that there is an art to knowing what needs to go into a good pitch. The single most useful thing that I've gotten out of the Innovation Program was the enterprise plan-writing portion of ENGG 321 and the slide deck that I finished. It's ready to go. I can take it anywhere and have my pitch to try to sell my idea.

AUSTIN BOESCH

RESEARCH ADVISOR:
Professor Margie Ackerman

RESEARCH: Our lab focuses on understanding how antibody variants interact with the immune system with the aim of developing more potent vaccine immunogens and antibody therapies. Antibodies bind antigens on pathogens, such as viruses or diseased cells, and act as molecular beacons for the immune system to bring in effector cells that can kill diseased cells. Antibodies also bind receptors on effector cells, creating bridges between the two cell types. When enough bridges form, the effector cell releases toxins that lead to the death of the diseased cell. This process is called antibody-dependent cellular cytotoxicity. I am developing a mathematical model to describe this and other cellular processes. With a mathematical framework for these processes we can optimize therapeutic strategies for cancer or even gain better insight into the types of antibodies most effective at preventing or eliminating HIV infection.

STARTUP IDEA: Before I entered the Innovation Program, my former boss and I invented a new technology for selectively separating antibodies that are 10–100x more effective at killing cancer cells. The company I worked for was not interested in pursuing the technology, as developing purification products was not a part of their core business. Therefore, we worked with the company to get the patent rights assigned to my startup, Zepteon Inc. As part of the Innovation Program I hope to work in a similar space developing a panel of purification technologies that could provide immediately value to pharmaceutical companies.

WHY THE INNOVATION PROGRAM: This is a great opportunity to learn the language of business and get the toolkit necessary to function in industry as an entrepreneur. Businesses want engineers who can immediately translate their research from academia into the industrial realm, and the Innovation Program puts an emphasis on this skill. We are the flagship school for it, and I think that more schools are going to follow our lead.

INTERNSHIP: I have applied for Small Business Innovation Research (SBIR) grants from the federal government, and if approved, those could fund me so that I can work at my own startup company.

TAKE-AWAYS: I'm already applying some of what I've learned. Before I came here, I didn't know where to start when it came to forming a business. Learning about where to incorporate, how to protect intellectual property, how to make the right decisions when choosing an attorney, and how to come up with a strategy is so valuable. The Innovation Program's fundamentals give engineers a leg up for the future.

DANIEL HARBURG
DUAL DEGREE '06 TH'09

RESEARCH ADVISOR:
Professor Charles Sullivan

RESEARCH: My research focuses on designing and building micro-scale magnetic components for electrical power conversion systems. We're collaborating with three other universities to build smaller, more efficient, and lower cost power converters for applications in solid-state lighting and handheld electronics.

ONE OF THE BIGGEST THINGS THAT SURPRISED ME IS HOW LITTLE COMMUNICATION THERE IS BETWEEN ENGINEERS AND BUSINESS FOLKS, AND GENERALLY HOW POORLY THOSE COMMUNITIES VIEW EACH OTHER.

—DANIEL HARBURG DUAL DEGREE '06 TH'09

STARTUP IDEA: I've been investigating the smart phone market to learn how our power conversion research would be best integrated into the existing supply chain. Today almost 30 percent of a smart phone's circuit board is taken up by power conversion components. Our miniaturized converters could free up space within the phone for a larger battery to improve run time or for advanced features.

WHY THE INNOVATION PROGRAM: I'm interested in the application of interdisciplinary academic research to solve big problems. In order to collaborate in a meaningful way, innovators have to speak the languages of business, law, and technology, among others. The Innovation Program has allowed me to begin learning these critical languages.

INTERNSHIP: I'll be working with a startup that is developing electronic systems that can biodegrade after a specific amount of time. These systems could be embedded within the body to perform important tasks before dissolving harmlessly into the body. Silicon-based electronics have traditionally been built to last as long as possible; we're turning that thinking upside down to consider situations in which it may be useful to have electronics that disappear.

TAKE-AWAYS: One of the things I've found most surprising is how little communication there is between engineering and business people, and how poorly these communities often view one another. We need innovators who can think from multiple perspectives and bridge the divide between the academic and corporate communities that are so often segregated. Breakthrough innovation happens at the intersection of disciplines; the Innovation Program is well-poised to equip students with the skills they need to create disruptive teams.

PHOTOGRAPHS BY DOUGLAS FRASER

GENEVA TROTTER

RESEARCH ADVISOR:
Professor Ian Baker

RESEARCH: I'm working on novel high-temperature austenitic alloys for energy conversion applications. The right alloys would allow the construction of power plants that operate at higher temperature, are more efficient, and are more environmentally friendly due to decreased CO2 emission.

WHY THE INNOVATION PROGRAM: I wanted to gain the knowledge base necessary to take ownership of any technological innovations I work on in the future. Professor Fossum and other entrepreneurs provide us with encouragement and the necessary straight talk we need to hear so we're better equipped to take on future challenges.

STARTUP IDEA: For ENGS 321 I proposed a company that would provide coal-fired power plants with enhanced and low-cost tubing based on a novel Laves-phase-strengthened steel. The goal was to help meet energy industry needs nationally, with an outlook to expanding abroad. I analyzed market demands, gained insight into the current energy landscape, and was able to talk with key individuals who contribute to and impact the coal-fired power-plant industry.

TAKE-AWAYS: I'm learning things that will help me for whatever business I might decide to work in. Sitting with people who have actually brought something to fruition, I've learned about the sacrifices and judgments they've made along the way. When you hear the stories, it's always just, "Oh, and they invented this." But it's not that simple. There are a lot of steps involved. There are people who contribute to your success. The program is helping me decide where I want to go with my research and how to plan my future projects.

HARRISON HALL

RESEARCH ADVISOR:
Professor Laura Ray

RESEARCH: We are trying to enable real-time visualization of joint positioning in the in-situ environment using sensors, cell phones, and artificial learning techniques.

There is a big divide in both physical therapy rehab and sports training in terms of what your body appears to be doing and what it is actually doing. I'm looking at wearable sensors that detect movement—specifically joint activation—to reconstruct kinematic 3D body position in real time and transmit it to a cell phone or store it in the cloud, in order to give helpful feedback to rehab patients and athletes. I've also been researching ADHD diagnosis. Boys aged 8–13 who have been diagnosed with ADHD have 2.3 times the head motion of boys who do not have ADHD. Motion sensors that measure how much their heads move relative to their classmates could be used as a diagnostic tool.

STARTUP IDEA: I've been focusing on trying to get 3D kinematics in real-time from wearable sensors. I see two end-game strategies. One is to partner with a company that has been outfitting shirts to NFL athletes that measure heart rate, respiration, and gross acceleration of the body; I am trying to do more specific body 3D kinematics repositioning. The second is to go to the medical side and develop either a garment or discreet sensors that patients can wear on the wrist, elbow, or knee so physical therapists can see what the patient is actually doing and respond appropriately if the patient is in distress.

WHY THE INNOVATION PROGRAM: A lot of schools were hesitant to take on a pure computer scientist for an engineering role. Dartmouth let me design my own program and do the research I want, overseen by my professor but without more direction than I wanted. I would like to start a company at some point and want to develop some business acumen here.

TAKE-AWAYS: A lot of the great companies that have come out in the last decade or so were started by engineers who hired someone to do their finances. If I do start a company, I want to maintain a leadership role.

MATT PALLONE '07 TH'13

RESEARCH ADVISOR:
Professor Keith Paulsen

RESEARCH: I was an undergrad here at Dartmouth and then transitioned into the master's program. At that time, Professors Keith Paulsen and Paul Meaney had developed a clinical microwave imaging system for breast cancer. They worked on increasing the resolution of the images by integrating an optical scanner into the microwave system, so that they could position the patient correctly and know exactly where the patient was relative to the microwave antenna array that they used to image. I was brought on to develop that optical scanner, which I integrated into the existing system. When I transitioned into the Ph.D. program, I started looking at real-

EARLY ON IN THE PROGRAM WE TALK ABOUT WHAT INNOVATION IS. IT'S NOT JUST GETTING AN IDEA FOR AN INVENTION AND SAYING, "I'M THE CEO," AND GOING AND DEVELOPING THE COMPANY. IT'S SITTING DOWN AND HASHING OUT WHAT IT TAKES ON THE RESEARCH SIDE OF THINGS TO DEVELOP THIS IDEA. ON THE BUSINESS SIDE, IT'S TAKING SOMETHING FROM EARLY-STAGE FUNDING TO A MARKETABLE DEVICE IN THE END.

—MATT PALLONE '07 TH'13

time image registration with preoperative MRIs and intraoperative optical scanning of the patient. Surgeons look at mammograms or MRI images before surgery, but patients are usually in a completely different position in the operating room than they were for the imaging. So what the surgeon sees in the operating room is different in shape and size from what they see in the pre-op images. We're trying to provide real-time image registration so surgeons can have accurate 3D images during surgery.

STARTUP IDEA: I looked at the potential market value for integrating optical scanners into surgical planning. One focus was reducing the number of times a patient has to go in for a second or third surgery because part of the tumor was missed. We compared how many surgeries were done per year and looked at the equivalent market share based on that. It was a good exercise in terms of learning what it takes to start a company, get funding, or even think about startup costs and salaries. The research was at too early a stage to progress it into a startup company. However, we have a few patents for the technology, and ultimately it could go in that direction.

WHY THE INNOVATION PROGRAM: I like the idea of not just staying on the research and development side of devices, but actually seeing the whole process from start to finish. Early on in the program we talk about what innovation is. It's not just getting an idea for an invention and saying, "I'm the CEO," and going and developing the company. It's sitting down and hashing out what it takes on the research side of things to develop this idea. On the business side, it's taking something from early-stage funding to a marketable device. I knew that this program would be a great opportunity to get exposure to the business side of things and that's what drew me to it.

INTERNSHIP: I worked with a company, Mobile Medical International Corp., in St. Johnsbury, Vt., that makes mobile operating suites. I was brought in to look at opportunities in the United Kingdom, focusing on the different regulations and updating the existing systems so that they would be functional there.

TAKE-AWAYS: Learning to see things from a business side early on and in an academic setting is really advantageous for those of us who want to learn to communicate between the head of business and the head of research to bridge that gap.

PHOTOGRAPHS BY DOUGLAS FRASER

REGINA SALVAT

RESEARCH ADVISOR:
Professor Karl Griswold

I try to make therapeutic proteins that can evade the immune system. Many proteins now used in protein therapies trigger an immune response that quickly clears them from the body, making the treatment less effective—and sometimes even dangerous. Our goal is to give these therapies a longer time in the body by removing the things that trigger the immune response. I look at a protein, Beta-lactamase, that is used in a cancer therapy called Antibody Directed Enzyme Prodrug Therapy (ADEPT). In ADEPT, an antibody that is attached to an enzyme specifically targets tumor cells. The chemotherapy happens only at the site of the tumor cell, so you have a lot fewer bad side effects.

STARTUP IDEA: For my ENGG 321 class, I developed a biotech company that would de-immunize therapeutic proteins for large pharmaceutical companies. I went through the process of determining our costs and how much we could sell the service for, and I thought through the entire business plan. It is something I originally did for class, but I am interested in biotech startups, and the class helped me think about them in ways that I never thought of before.

WHY THE INNOVATION PROGRAM: Before Dartmouth I worked in a pharmaceutical company and was really interested in how the business decisions were made. When I heard about this program, which incorporates business classes with the engineering Ph.D., I thought this would be the perfect place for me. In biotech engineering you're really close to the engineering problems that you are trying to solve. Now, having been in this program, when I think about these questions and problems, I think about them from a completely different approach than I would have when I first joined the program.

TAKE-AWAYS: From my coursework, I have learned a lot about the business world. Professor Fossum and Professor Tillman Gerngross, a biotech innovator, have pushed me to understand the biotech industry from the business perspective rather than just the engineering perspective. Once I leave this program, I'll have a much better understanding of how the biotech world fits into the business world and why certain decisions are being made about mergers, acquisitions, and startups, and how companies get funded through venture capitalists and other sources. Those are all tools that I didn't have when I first came to the program.

—Kathryn LoConte Lapierre is senior editor at Dartmouth Engineer.

Alumni News

HEIGHT OF INTEREST
James Kirchner '80 Th'83 goes to great lengths to study how interacting forces shape the earth's surface.

spotlights

"If it happens within 10 meters below the surface *and* 10 meters above the surface, I'm probably interested in it," says **James Kirchner '80 Th'83**. "I work on a wide range of topics, basically concerned with how physics, chemistry, and biology interact to shape the surface of the earth." A researcher at the Swiss Federal Institute for Forest, Snow, and Landscape Research just outside of Zurich, Kirchner says, "Our institute has lead responsibility in Switzerland for such issues as response of forests to climate change, protection of biodiversity, impact of regional development patterns on natural habitats and human quality of life, and management of natural hazards—a particularly interesting issue in the Swiss Alps, of course!" After heading the institute for five years, he is now a senior scientist there and a professor of the physics of environmental systems at the Swiss Federal Institute of Technology, Zurich. "I'm very interested in problems like how does the earth's surface fall apart, what controls the strength and resistance to erosion of, say, a plot of land on a hillside or an entire mountainside, how do landslides happen, how do rock falls happen?" he told the European Association of Geochemistry (youtube.com/watch?v=oBqLrmngEFQ). He also considers questions such as: Where does rainwater go? How long do landscapes store water underground, and what regulates how quickly they release water to make streamflow? What regulates the chemistry of the water we drink? "We need practical answers so that people can decide how to handle these issues," he says. "I work in Switzerland, and half the country would be uninhabitable if we could not successfully manage the risks of living in steep mountainous regions." After majoring in physics and philosophy at Dartmouth, Kirchner earned an M.S. in systems analysis at Thayer and a Ph.D. in 1990 from the Energy and Resources Group at the University of California, Berkeley. He serves as director of Berkeley's Central Sierra Field Research Stations—usually from nine time zones away. Kirchner was awarded the 2013 Ralph Alger Bagnold Medal from the European Geosciences Union, which cited his outstanding contributions to "slicing through the complexity of earth's surface systems to uncover the underlying physics."

FAST TRIKE
Bob Mighell '85 Th'86 broke the land-speed record for three-wheeled motorcycles at Bonneville Salt Flats.

Jian Lu Th'93 is the new chief technology officer at Beijing-based Ku6 Media, one of China's top Internet video companies focused on user-generated content. Lu previously served as VP of multimedia technology at tech incubator Shanda Innovations, cofounded content identification provider Vobile, and led technical development of QuickTime compression and streaming at Apple Inc. Through its website, ku6.com, Ku6 Media provides online video upload and sharing services, video reports, information, and entertainment in China.

B.B.R. Medical Innovations Inc.—a startup that grew out of an ENGS 190/290 (now 89/90) capstone project by **Kathryn Boucher Bi '09 Th'09**, **Steve Reinitz '09 Th'09**, and **Renée Cottle '08 Th'09**—has been chosen for the 2013 MassChallenge Startup Accelerator. The company will receive mentorship and space at the MassChallenge office in Boston for four months and will compete with other teams for $1 million in funding. Bi, Reinitz, and Dartmouth-Hitchcock Medical Center anesthesiologist Dr. Corey Burchman founded B.B.R. in 2011 to develop Sanit-IV, an in-line intravenous fluid sterilizer that works in less than six seconds. "My goal is to one day see one of our devices on every IV pole, since I truly believe that our technology has the

potential to save thousands of lives per year while also preventing unnecessary healthcare expenses," says Reinitz, who is now in Thayer's Ph.D. Innovation Program [see page 16].

After earning degrees in engineering and economics, **Fernando Orta '08** returned to his hometown of Mexico City and in 2010 founded a financial services company called Podemos Progresar ("We can move forward"). "In an effort to solve the multi-dimensional problem of poverty in Mexico, Podemos has a mission to create products and services that change people's lives," **Maura Pennington '08** reported in *Forbes* in March. Podemos offers services such as help with navigating Mexico's healthcare system, and has set up a microfranchise program that allows members to buy wholesale products to distribute to their communities. "Microcredit is not just about giving people money," says Orta. "It's about giving people a chance to pursue opportunities. We want to become the platform that provides the products and services that allow people to make rewarding transactions."

Science has again answered one of society's most pressing questions: Could the Ice Wall in HBO's *Game of Thrones* survive? While the 700-foot-tall ice structure could hold its own against medieval weaponry in the TV show, gravity would eventually bring it down. "Even at very cold temperatures, large ice masses deform under their own weight," Thayer Professor **Mary Albert Th'84,** a polar regions snow and ice expert, told *Wired* magazine in March. "And over long timescales, ice flows, so it would not hold its original shape for thousands of years." The full story is at wired.com/wiredscience/2013/03/game-of-thrones-ice-wall-science.


Fernando Orta '08

The drug-authentication service Sproxil, founded by **Ashifi Gogo Th'10**, the first graduate of Thayer's Ph.D. Innovation Program, ranked No. 7 on *Fast Company*'s list of "Most Innovative Companies 2013." Sproxil is lauded "For sticking it to anyone selling fraudulent goods."

Tilting Motor Works founder and CEO **Bob Mighell '85 Th'86** put his motorcycle conversion package—which replaces a motorcycle's front wheel with two wheels—to the ultimate test: the annual motorcycle speed trials at the Bonneville Salt Flats. Despite 100-degree temps and variable crosswinds, Mighell broke the land-speed record for three-wheeled motorcycles by more than 10 mph last year, hitting 132.342 mph over one mile. "Anything can happen at those speeds," he says, "and every motorcyclist knows how dangerous crosswinds and rough surfaces can be. The salt was all damp and loose and pitted, so it was ideal for putting our trike solution to the test." The lifelong powersports enthusiast has been developing the conversion for almost nine years. With the help of a Thayer student engineering team a few years ago, he patented a front-end linkage that lets him lean into corners. Tilting Motor Works (tiltingmotorworks.com) is now selling the conversion package, starting at $10,000.

The Dartmouth Alumni Council recently honored **Ken Johansen '60 Th'62** with an Alumni Award for "long-standing and meritorious service to the College, career achievement, and other community service." Johansen, who retired from International Paper Company after a 40-year career in paper manufacturing, served 18 years on the Montvale (N. J.) School Board, and since 1990 has served almost continually in a Dartmouth class leadership position.

OPPOSITE PAGE: LEFT, COURTESY OF JAMES KIRCHNER; RIGHT, COURTESY OF BOB MIGHELL. THIS PAGE: LEFT, COURTESY OF FERNANDO ORTA; RIGHT, JOHN SOARES


BEYOND SILICON
Drew Endy Th'98, pictured when he was a professor at MIT, mixes cells and computers.

BREAKTHROUGH

Biological Computers

Drew Endy Th'98 builds a computer inside a living cell

A team of Stanford University engineers led by Drew Endy Th'98, a professor at Stanford's School of Engineering and a pioneer in the field of synthetic biology, has succeeded in making a simple computer inside a living cell.

"We're going to be able to put computers inside any living cell you want," said Endy, who earned his doctorate at Thayer School in 1998. "Any place you want a little bit of logic, a little bit of computation, a little bit of memory—we're going to be able to do that."

The creation completes 10 years of work and represents the final chapter of Stanford researchers' quest to build the biological computer. It is the latest step in the new field of synthetic biology where—one gene at a time—engineers strive to design organisms unlike anything made by Mother Nature.

These tiny computers could deliver true-false answers to virtually any biological question that might be posed within a cell. For instance: Is toxic mercury present in plants or animals used for food? Scientists could introduce a detective "sentinel" organism to find out.

The internal computers could communicate by engineering cells to change. The "simplest way is to have the cells change their smell or color," Endy said.

These cellular computers also can count, providing a useful tool when treating diseases like cancer, where cells divide uncontrollably. Suppose a liver cell carries a computer that records how many times it divides. Once the counter hits 500, for instance, the cell could be programmed to die.

Conceptually, it's like electronics, where a transistor controls the flow of electrons along a circuit. But biology is the basis for what the team calls a "transcriptor," which controls the flow of an important protein as it travels along a strand of DNA like an electron on a copper wire. Transcriptors are a biological version of electrical engineers' logic gates—the building blocks of digital circuits that send and receive signals.

"Biology is not just a science of discovery, but also a technology for making things," Endy said. "We're not going to replace the silicon computers. We're not going to replace your phone or your laptop. But we're going to get computing working in places where silicon would never work."

Last year, the team delivered two other core components of their computer. The first was a type of rewritable digital data storage within DNA. Information can be stored inside cells by flipping DNA sequences back and forth between two possible orientations to represent and store the 0 and 1 that represent one bit of computer data. The other was a mechanism for transmitting genetic data from cell to cell, a biological Internet.

These new biological computers will be slow, working on a millihertz frequency, Endy cautioned. "But they'll work in places where we don't have computing now," he said.

—Lisa M. Krieger

Originally published in the San Jose Mercury News, *this article is adapted and reprinted with permission.*

ALL TASTE, NO WASTE
John Lamppa Th'11 leads R&D at WikiCell Designs, a startup that makes packaging for ice cream and other foods completely edible.

just one question

Q. Are you involved in any efforts related to sustainability?

At age 91, my main effort related to sustainability is to sustain myself.

—Tom Streeter '44 Tu'48 Th'48

I am involved in sustainability efforts only peripherally through organizations I contribute to, such as Negative Population Growth, Carrying Capacity Network, and several environmental organizations. I also write a column for the local newspaper, the Glenwood Springs, Colo., *Post Independent*, that I occasionally devote to sustainability issues.

—Hjalmar Sundin '47 Th'47

My work since 1972 has been in renewable energy. I was on the General Electric team that wrote the solid waste management and resources recovery plan for the State of Connecticut, which included a series of waste-to-energy plants (waste-fired power plants using the steam cycle). Next, I worked as a consultant to develop waste-to-energy plants in a number of cities (e.g., Brooklyn, St. Louis, San Francisco). I developed a 3-megawatt plant using landfill gas and spark-fired diesel engines. Then I consulted with EPA's methane mitigation programs, Landfill Methane Outreach Program, and Coalbed Methane Outreach Program. I created cash-flow models to assess the feasibility of methane capture-and-use projects, especially using ventilation air methane, which is more than 99-percent air. (The EPA considers methane to be between 21 and 23 times as powerful as carbon dioxide in causing climate change.) I consulted with the EPA from 1996 to 2007. I wrote manuals and articles, gave technical presentations in Thailand, Russia, Poland, China, and the U.S., and prepared feasibility studies for generic and site-specific proposed projects. I feel we were effective in promoting change. The largest challenge was to convince coal-mining corporations that it is in their best interests to gather coal-mine methane and ventilation-air methane and convert it to usable energy.

Now I am president of Acorn Energy Co-op. Our projects range from wood pellets, small district heating (planning), and solar hot water to solar photovoltaics—both rooftop and large ground-mounted projects. With respect to wood pellets, we are trying to make our delivery systems smooth and simple. We can now install a range of storage bag or bins and fill them pneumatically. We advertise that this system is just about as smooth as receiving a fuel oil delivery. We want to grow our membership to more than 300 people and offer them discounted renewable energy installations on a competitive basis. There is a rising awareness that turning away from oil and fossil-fueled power is very important, primarily to combat climate change. The Vermont legislature has been a leader in creating incentives for community projects (e.g., large PV arrays) as well as home-based projects.

Since moving to our farm in Vermont I have stayed with trying to develop renewable energy. We have three renewable energy systems on the farm: heating a 4,600-square-foot house with wood, a 5.28-kilowatt PV system on the barn roof, and a solar hot water system.

—F. Peter Carothers '57 Tu'60 Th'60

As a member of our community board (and ex-president) I have been responsible for the management of our well-based water system for the last seven years. Recently we agreed with the Connecticut Department of Public Health (DPH) to upgrade our water treatment by adding filtration. As a part of this we considered selling our water system to a public water system. Our community recently voted to finance the building of the new treatment facility, and I formed a committee of board members and outside experts (engineers, suppliers, etc.) to manage this process. We are in the middle of that implementation now, having just received the final DPH approval of our technical plan. I am reorganizing the committee so that members' duties will prepare them to sustain the board's capability to manage the new system. Knowing that management is at least as important as technology in such projects, my major concern is management sustainability. No one else on the board has engineering training or got an "A" in Thayer's fluid dynamics course.

—Bruce Clark '60 Tu'61 Th'61

We compost all of our garbage and recycle cans, plastics, newspapers, and office waste paper. As a result, we send less material to the landfill than anyone else on our street. We use our compost in our flowerbeds. Recycling in our town of Bella Vista, Ark., is an AARP project. The AARP returns the profits to nonprofit organizations in our town—particularly those whose members volunteer at the recycle center—and provides one-half of all office paper profits to our Bella Vista Library. We believe that our recycling operation is one of the finest in our state.

—Harris McKee '61 Th'63

I've transformed my career from sustainability and environmental consulting to academia. This was motivated by my observation that my clients' issues often stemmed from unwise business decisions regarding the use of resources and that significant opportunity for moving sustainability forward rested with educating future business leaders. I offered a course on sustainable business practices to M.B.A.s in the Fisher College of Business at Ohio State University and then developed a yearlong undergraduate course on sustainability in business. Related to this work, I received the 2013 Undergraduate Service Award from the Fisher College of Business. I also helped develop a new undergraduate sustainability major at Ohio State. That led to the incorporation of my undergraduate courses at Fisher into the core curriculum of the major, and my selection as the program director for the new major, which led to my becoming full-time at Ohio State in 2012. The new major, Environment, Economy, Development, and Sustainability (E.E.D.S.), bundles together about 150 existing courses from across the Ohio State campus and offers students the opportunity

SURF AND TURF
As president of the La Jolla Beach & Tennis Club, Bill Kellogg '73 ensures that its three restaurants serve locally and sustainably sourced foods.

to specialize in one of four aspects of sustainability. It is the fastest-growing major on campus, and a minor will be offered beginning this fall. Recently the E.E.D.S. major was a key factor in the selection of Ohio State as the 2013 winner of the Enviance Environmental March Madness Tournament.

—Neil Drobny '62 Th'64

I bought my first house around the time of the first Earth Day and built my first compost bin that fall for practical reasons: fewer trips to the landfill and less mulch to be purchased. My next residence was a small farm. Small farmers are the ultimate sustainability freaks due to their relative isolation. The nearest real hardware store could be 25 miles. As a result, baling wire and string become the repair materials of choice—and it's amazing how much you can accomplish with scraps and ingenuity.

My contention is that recycling an old house is superior to new construction, particularly in terms of carbon footprints. A 2012 study by the National Trust for Historic Preservation states that in my West Coast climate, a new energy-efficient house will take 50 years to pay back the negative carbon balance compared to an existing home. I believe the intensive improvements that I have made in my home would stretch the payback another 30 to 50 years. In 1977, I purchased a six-unit apartment building in San Francisco. The first environmental impact was that this urban location allowed me to walk to work in about 15 minutes. The first phase of the renovation required curing the life-threatening aspects of the condemnation order and winding through the planning and approval process to secure the necessary building permits. We then engaged in major structural work, which included hand digging a four-car garage below the house, pouring new foundations, tying the building together with a number of massive steel beams and metal clips (earthquake safety), and rebuilding the roof with a two-room penthouse. All of these activities resulted in a significant low-cost project focus for the next five years while I regained some semblance of financial heath. We renovated the three apartments on the first floor, updating the floor plans to a more modern layout, upgrading the water systems to copper, and providing 100-amp circuit breaker panels to each apartment. We installed a rooftop solar hot water system that produces about two-thirds of our hot water for free. The final phase was to scrape and sand all the old lead-based paint and begin a program of regular painting with acrylics.

When I retired in 2000, I finally got to begin the true heart of the project: my dream home. I started by rebuilding all of the second-floor, double-hung windows with much improved insulated glass. We have a high-tech, 92-percent efficient wood-burning system that will supposedly heat the entire space by itself. All built-in lighting is 24-volt LED, which is driven by a bank of power supplies to convert from AC to low DC. The wiring for this has been extremely challenging, but the payoff in kilowatts is simply amazing. Eventually, this will tie to a battery bank and PV system on the roof.

—Bill Reilly '67

My current research program concerns reducing the carbon dioxide emissions from concrete production. Portland cement plants emit significant amounts of carbon dioxide from both fuel combustion and the calcining of limestone. "Green" concrete reduces these emissions by replacing some of the cement content with pozzolanic materials, such as fly ash, a waste product of coal combustion. Widespread use of fly ash in concrete is hampered by a lack of knowledge of its chemical reactivity in the concrete mix. Under a National Science Foundation grant, I am working with Catholic University of America to develop a better fundamental understanding of how the properties of the fly ash—chemical composition, particle size distribution, and inert fraction—influence its reactivity. This research will result in more reliable predictive models of fly ash reactivity, which will enable more effective replacement of Portland cement in concrete. It will also reduce the requirements for landfills to dispose of fly ash as a waste product.

—Richard Livingston '68 Th'69

My firm is a major investor in the venture capital industry, investing in the funds managed by venture capital firms, both new and well-established teams. A number of these firms are active investors in "clean tech," which includes alternative energy, environmental, and advanced materials. We are not investing our clients' capital with these funds because of the "good" they are trying to do, but because we (and they) think it is financially in our clients' interest to be invested in these sectors. Every investment has to be justified based upon an expected attractive (risk-adjusted) financial rate of return. I think that this is by far the best way to approach the sector. Companies that are not financially successful will ultimately fail no matter how good their intentions—and will also fail to meet their non-financial objectives.

—Clint Harris '69 Th'70

I am president of a fourth-generation family business, La Jolla Beach & Tennis Club, in San Diego, Calif. For our three restaurants we purchase in-season, locally grown fruits and vegetables from neighboring farms to reduce our carbon footprint, keep costs under control, and ensure we are purchasing top-quality food. A commitment to excellence is the reason we began focusing on sustainability. Knowing the source of your ingredients, the procedures used to produce the crops, catch fish, or harvest meat products is essential to controlling food quality. If basic supplies are wiped out by over-fishing and over-harvesting, the restaurant continually needs to adapt. If you select suppliers who employ responsible procurement approaches, both the farmer/fishermen and the restaurants can develop a great long-term relationship.

Over time, our customers have become more sophisticated and much more aware of environmental and sustainability issues. Our restaurants' focus on this aspect of developing menus has been well received by our customers and the media, resulting in many awards and very loyal customers.

The philosophy of our executive chef, Bernard Guillas, is that sustainability is the key to future growth and development of our oceans and land. Understanding the origin of our ingredients helps to guarantee the well-being of our planet. Searching and sharing information will bring strength and knowledge for generations to come. As chefs and restaurateurs, our duty is to be caretakers of our resources and educators to our customers.

—Bill Kellogg '73

My wife and I are amateur beekeepers with beehives at our house and at the farm next door. The gardens have never been better! We give the honey away to family and friends when they stop by. Last fall, we hosted the local high school "green scholars" to introduce them to bees and beekeeping. I'm also the chairman of a committee that manages a 15-acre hayfield that was donated to the town. Winthrop Field is kept as an open recreation space. We contract out the mowing and hay baling. We're working on wetlands restoration in one corner of the field.

While renovating our house, we worked with a local contractor to devise a rain-collection system for the roof and back deck. We store up to 200 gallons of rainwater and use it to irrigate the gardens. Also, a couple of

OPPOSITE PAGE: COURTESY OF JOHN LAMPPA. THIS PAGE: COURTESY OF BILL KELLOGG

HOME ENVIRONMENT
Margaret Fanning Th'79 lives at Cobb Hill Cohousing, a sustainable agricultural and residential community in Hartland, Vt.

friends and I have sponsored Thayer B.E. projects on the Walvisstaart System, a marine propulsion system that should result in a 30-percent reduction in fuel usage. And I've been a presentation judge at Thayer's Formula Hybrid event since it started.

—Mike Chapman '76 Th'77

My current work focuses on developing large natural gas reserves off the coast of northwestern Australia to support residential, commercial, and industrial demand for energy in Western Australia and in countries in the western Pacific Rim. I am a member of a large international team developing the Wheatstone Project, which will deliver liquefied natural gas (LNG), primarily to Japan, and pipeline-quality natural gas (referred to as "domestic gas") to customers in Western Australia. During 2009–12, I had a senior project engineering role with the design team as we completed the front-end engineering and carried out the detailed engineering and procurement for the LNG and domestic gas production plant. In 2013 I moved to a team leader role in the project execution team, overseeing the actual plant construction near the town of Onslow. Our goal is to keep the lights on in Perth and Tokyo. With the shutdown of the damaged Fukushima Daiichi Nuclear Power Plant and other nuclear generating stations in Japan, there is increased need for supplies of natural gas to sustain that country's economy. The Wheatstone Project will help meet that need.

A major development project such as Wheatstone always considers environmental and social impacts in the project planning, design, and execution. That includes completion of an environmental impact statement (EIS) and specific environmental management plans. In my project engineering role, I was responsible for reviewing portions of the EIS, providing information on the plant design to support environmental modeling studies, and considering environmental impacts, such as relative levels of greenhouse gas emissions, when making design decisions that affected the plant configuration. During the front-end engineering, we compared different technologies and configurations for the refrigeration compressor systems that are the heart of any LNG production plant. For these massive compressors we selected an aero-derivative gas turbine driver system, which has lower emissions of nitrogen oxide and greenhouse gas than the alternatives. The gas turbines will be fitted with waste-heat recovery units, which will capture heat from the hot exhaust gases in a circulating heat medium system. This cogeneration system will supply essentially all process heat requirements for both the LNG and domestic gas production facilities. Our project team is involved in social infrastructure projects that will benefit the community of Onslow, including new power and water supply systems, improved educational and recreational facilities, and supporting construction of a new runway at the airport.

—Will Fraizer '78

My wife, **Nellie Pennington '83**, and I have been off the grid in Strafford, Vt., since 1989 and raised two sons who were in no way computer-deprived and who both have grown into pretty decent engineers themselves. I am director of engineering at Solaflect Energy, in charge of the research and development work we are doing on heliostats and overseeing a staff of three full-time and three part-time engineers as well as getting our manufacturing operations up and running. We did our first customer installations in May. We are also working on a design for a solar hot-water application, in which a small field of our heliostats will provide concentrated heat for businesses or institutions that use a lot of hot water, such as breweries, paper mills, swimming pools, and hospitals.

Like everyone in this industry, we hear a lot of confusion regarding the relative merits and financial viability of various energy options. Unfortunately, a good deal of this is plainly attributable to decades of disinformation on the part of the traditional energy sector. However, I think we are turning the corner. The wind and PV industries have considerable momentum now and will begin to accrue political capital and lobbying strength. Likewise, Hurricane Sandy, droughts, heat, and tornadoes may yet prove to be another turning point for public perceptions of the real and imminent costs of climate change. The financial benefits of solar energy are starting to be visible to people, alongside the environmental ones.

We have 1.2 kilowatts of solar panels on our roof and a 1.5-kilowatt (10-foot diameter blades) wind turbine on the ridge behind us. Our house batteries are a bank of lead-acid 6-volt solar batteries, similar to golf cart batteries. All of this is tied together with an inverter, charge controller, and various other pieces, and backed up by a propane generator. When we started in 1989, we used 12-volt lights and a square-wave inverter. We needed a big capacitor to run our washing machine. The lights were slow to start and quick to burn out. Later we got a sine-wave inverter and converted everything to AC, and life is much more "normal." The systems we are selling, as with most domestic PV these days, are grid-tie systems, with no batteries or generator. When the sun shines, you sell electricity to the grid, and when it doesn't, you buy the electricity back.

Renewable energy is fun. It's clear that the endpoint will be ubiquitous deployment of a variety of technologies at a variety of scales—but we don't know which technologies. And we know that as good as current products are, a lot of great things are yet to be invented.

—Nate Hine '78 Th'80

As a college student in the 1970s I took to heart the idea, "If you're not part of the solution, you're part of the problem." Through the years this notion guided the choices I made about the work I did. When my husband and I moved to Cobb Hill Cohousing (cobbhill.org) in Hartland, Vt., seven years ago, I felt as if I'd finally aligned the non-work part of my life with my beliefs. Cobb Hill was founded in 2000 to integrate sustainable agriculture, community, and environmental responsibility. We have 23 households, with about 40 adults and 20 children, living in a mix of single-family houses, duplexes, and apartments. Our Energy Star-certified buildings are served by a district wood-fired heating system, and we all take turns moving wood and stoking the boiler. With 10 active agricultural enterprises, there's always something interesting to do. Our most well-known product, Cobb Hill Cheese, is made from milk from our Jersey cows and has won a number of national awards. I'm involved in the forestry and shiitake mushroom enterprises and have also done a lot of work to maintain, repair, and upgrade our infrastructure. An example week for me might include inoculating logs with mushroom spawn, cooking a community dinner for 30, diagnosing a gray-water system problem, attending a meeting to consider whether the cheese cave can be expanded into the community root cellar, and marking the public access trail. In 2010–2011 I sponsored a Thayer ENGS 89/90 project to determine the best way for us to eliminate the 15 percent of our energy use that was derived from propane. In 2012 we implemented the students' recommendation, and last winter we used no propane. Success!

There is no one vision of Cobb Hill's purpose. For some residents, this place is a launching pad for their internationally known environmental work. For others, Cobb Hill is a model or prototype of what is possible, and we share what we have learned through education and outreach. Some of us think of Cobb Hill as an experiment in social, agricultural, and environmental sustain-

MORE SUN, LESS STEEL
As director of engineering at Solaflect Energy, Nate Hine '78 Th'80 is reducing the amount of materials needed for heliostats.

ability, and we are always pushing to learn more and find the edges. For all of us, it is home.

—Margaret Fanning Th'79

Much of my career has focused on energy conservation and solar PV. My first job after I graduated from Dartmouth in 1979 was to serve as a Peace Corps volunteer in Gambia, West Africa, where I was an "appropriate technology advisor." Most of my time was spent promoting a low-cost cooking stove technology that greatly reduced the amount of wood cooking fuel required for meal preparation. After leaving the Peace Corps, I traveled home the long way and then returned to Thayer to get my B.E. I later received an M.B.A. from Stanford and afterward moved to Washington, D.C., to work for AES Corp. developing large-scale cogeneration plants.

In 1992 I was hired by the EPA to be the first program manager for the Energy Star buildings program, which uses an innovative non-regulatory partnership model to educate building owners about the potential positive returns resulting from investing in energy-saving technologies, which can reduce a building's energy usage by 25 percent or more.

Since 1995 I've held senior management positions in the solar PV industry with Solarex (later BP Solar), Sharp Solar, and TEL Solar (formerly Oerlikon Solar). I'm currently head of market development for TEL Solar, a subsidiary of Tokyo Electron Corp. The company is a leading supplier of thin-film silicon PV technology and turnkey manufacturing lines. From 2003 to 2008 I was chairman of the largest U.S. solar trade association, Solar Energy Industries Association, and I am active in several industry trade associations. I'm also a solar consumer, having recently installed a rooftop PV system on my home in D.C.

—Christopher O'Brien '79 Th'84

I am almost continuously involved in projects dealing with sustainability. My business partner and I have owned a building automation systems contracting company, Mid-Atlantic Controls Corp., since 1989. We are heavily involved in the planning and implementation of energy management for commercial and industrial facilities.

—Mike Startt '79

I am developing utility-scale solar projects in Massachusetts with Mercury Solar Systems. One project is a 2.5-megawatt project, with approximately 8,000 solar panels on a 12-acre plot of land. The process is complex and lengthy, starting with the idea, securing access to the land, obtaining land-use and building permits, working with the utility company to secure access to the grid, securing rights to the environmental attributes (which utility companies purchase over time), and structuring debt and equity financing. This is followed by the engineering, procurement, and construction implementation, covering engineering and design, materials and equipment procurement, surface preparation, and installation.

Before this I was the CEO for four years of Hy9 Corp., a development-stage company focusing on a very small niche for hydrogen purification systems. The company was based on technology developed by a serial entrepreneur who had left Germany for the United States just before the war. The company's future was in doubt when I arrived. I redefined the company's strategy to focus on the $3 billion market for backup power systems for cellular telecommunications. I led a fast-cycle development of a new product that converts methanol (a liquid hydrocarbon) into pure hydrogen, which is then fed into a fuel cell to produce electricity for the cell tower. This results in a high-efficiency, very-low-emission, and reliable backup power solution. Before Hy9 I had my own company, Velerity Management Consulting, providing strategy and market consulting services to a range of companies in hydrogen, energy storage, emissions reduction, utility company services, and waste to energy.

During this time, I cofounded the New England Clean Energy Council, which has codified and integrated clean energy industry interests into Massachusetts' Green Communities Act, which became law in 2008. This legislation has resulted in Massachusetts being the No. 1 state in the country for efficiency last year and achieving 250 megawatts of solar power four years ahead of plan. I helped designed the solar portion of the legislation that resulted in $1 billion of solar being implemented in the past three years. I also founded the Massachusetts Hydrogen Coalition and helped lead the annual Conference on Clean Energy for four years and the Eco-Film Festival.

I am also writing a book on sustainable economics. The book is focused on understanding how value is created in an economy, why economies grow and contract, why societies fail, and how to create policies and initiatives that create long-term well-being that lasts. There are four principles underlying sustainable economics: sustainable vs. unsustainable value creation; drawing upon stores of value vs. drawing upon flows of value; temporary impacts of fiscal and monetary policy vs. true value creation; and false value created by market forces vs. true value created by economic activity.

—Donald "Brad" Bradshaw '82

My sustainability work is mostly related to research, disseminating information, and finding ways to incorporate it into my company's work. I'm a designer at Degenkolb Engineers, where we specialize in seismic structural engineering. I recently wrote an internal paper about different life-cycle analysis processes and programs and how we can use them as structural engineers. I'm working on another paper comparing sustainable building rating systems, and I'm updating all of our typical details to limit the effects of thermal bridging.

Through my business, the Energy Emporium (energyemp.com) in Enfield, N.H., I design, install, and maintain renewable and sustainable energy systems for homes and small businesses. This includes solar electric and hot water, wood/solar combination systems, wind and water turbines, and (soon) geothermal systems. I renovated my home and business from an 1858 shell to a zero-net-energy building. All of the heating, hot water, and electricity come from the sun. The first floor houses the Energy Emporium, a resource center and showroom of renewable energy technologies. I live above it. I chair the Enfield energy committee and am a member of Vital Communities/Local First (promoting sustainable businesses and communities), Sustainable Energy Resources Group, and the New Hampshire Sustainable Energy Association.

—Kimberley Smith Quirk '82 Th'83

As a consulting engineer with RSG (rsginc.com) I am working with the Federal Highway Administration to implement an energy and emissions reduction policy analysis tool (EERPAT). A growing number of states have set ambitious goals for increasing the use of renewable fuels and reducing the production of greenhouse gases in the transportation sector. EERPAT is designed to provide policy guidance on the best set of policies for achieving those goals. EERPAT encompasses transportation fuels, engine technology, pricing (fuel taxes, vehicle miles traveled taxes, carbon taxes), transportation supply and management, and land use. The tool provides rapid analysis of many scenarios that combine effects of various policy and transportation system changes. EERPAT compares, contrasts, and analyzes the effects of various greenhouse gas reduction policy scenarios on greenhouse gas emissions from the surface transportation sector at a statewide level.

OPPOSITE PAGE: EUNICE CHANG. THIS PAGE: COURTESY OF NATE HINE

Implemented in the R data analysis language, all code and data used in EERPAT are freely available and can be reconfigured by technically adept users, should that be necessary to support a specific analysis. EERPAT was initially developed for Oregon and has since been tested in Florida with success. RSG is currently conducting pilots in Washington and Colorado.

—Robert Chamberlin Th'84

I have been involved in pollution prevention for more than 20 years in Rhode Island and New York. I am the assistant director of technical programs with the N.Y. State Pollution Prevention Institute at the Rochester Institute of Technology. These programs, mostly government-funded, are designed to help companies reduce waste/pollution and become more profitable. The main focus is modifying processes so that fewer toxic chemicals and less water are used. The end result is that less waste is created and more money saved. Not all manufacturing processes can be readily changed to reduce or eliminate waste. Reasons include costs (heavy investment may be needed and would have to be recovered through anticipated cost savings), reluctance to change a process that has produced acceptable quality, and no viable technical solutions that can be applied. Sometimes we get involved with engineering-based research to find solutions. We work with many different N.Y. companies. Long-term goals include expanding our program and embarking on more pollution-prevention research projects to find innovative solutions.

It is important to realize that both the environment and the economy can be supported by pollution prevention. We can be both pro-environment and pro-economy at the same time!

—Eugene Park '84 Th'85

In 2008, 15 years after my Thayer M.S. in materials science, I completed a master of architecture degree at the Boston Architectural College. In the past five years I've added the titles registered architect and certified "passive house" consultant. The passive house standard, now gaining traction in the United States after more than 20 years and 40,000 buildings in Europe, requires exceptional airtightness and dramatically reduced heating, cooling, and primary energy demand. Meeting the standard in New England is a challenge due to the cold climate. I've designed several passive houses and the first is starting construction.

I recently joined a Brooklyn, N.Y.-based startup founded by passive house consultants, 475 High Performance Building Supply, which refers to the passive house annual heat demand requirement of 4.75 kBtu/square foot/year). With this venture, my backgrounds in architecture, materials science, and building science have coalesced. Our company is dedicated to transforming American construction to high-comfort and low-energy building. We believe that all building projects, no matter how modest their goals, can be helped toward higher performance. We import state-of-the-art air sealing and vapor control components and high-efficiency ventilation units. We also provide the building science and architectural expertise to help clients optimize wall and roof assemblies to achieve the highest performance. For the most sustainable solutions, we show how this can be achieved resiliently and robustly without petroleum-based foam insulation products. As the building industry adapts (albeit slowly) to the realities of climate change, building energy specialists like us are positioned to smooth the transition to a low-energy future.

—Oliver Klein '88 Th'91

I work for a dedicated environment-sector investment fund, Asia Environmental Partners, investing in private businesses in India and China. Our focus is on renewable energy, water and water treatment, waste management, and energy efficiency. In India, we have invested in a renewable energy business, generating power from biomass and wind, and in a water and wastewater treatment engineering, procurement, and construction business. We provide growth capital to medium-sized businesses working on proven technologies, helping them with management inputs on key strategic areas as they scale up.

Ever since graduating from Dartmouth with additional degrees from Thayer, I searched for such interdisciplinary, environment-related work. To get the full flavor of interdisciplinary work cutting across engineering-economics-finance-environmental issues, I had to take a turn toward business in the early 1990s and have been working in business since. Yes, I did the then-obligatory M.B.A.! Through the years, I have become a huge fan of liberal education for permitting me so many windows to complex daily realities.

The success of a single business may be purely financial. However, each successful business is attracting so many others in its wake that, collectively, they should lead to sectoral transformations and, operating at a larger scale, environmental benefits.

—Himraj Dang '89 Th'90

I was the founding chair of the Concord, Mass., Comprehensive Sustainable Energy Committee, which allocated funds toward energy efficiency and renewables projects in town buildings, raised visibility around energy issues in town, and is currently organizing the Concord Solar Challenge to promote residential solar installations (go.astrumsolar.com/concord). I was not directly involved with this program, but consider myself a grandfather of the effort. I was also on the board for our municipal electrical utility, Concord Municipal Light Plant. We (mostly) fixed the solar net metering rate policy, formulated a long-term renewables strategy, and pursued utility-scale solar installations. I was the "green guy" on the committee designing our town's new high school. I handed that off after a year to a green architect with more relevant expertise. For my day job, I've done a carbon footprint project for a heavy truck manufacturer and have benchmarked carbon outputs for warehouse operations and various transport modes.

—Brian Crounse '94 Th'95

In 2007, I founded a consulting and development company, Aquinergy (aquinergy.com), which deploys renewable energy assets and advises clients on energy strategies. My firm has developed two large-scale (2-megawatt) wind-energy facilities in Massachusetts in the past year, and we have been recognized as a leader in the Boston and Rhode Island region for renewable energy development. In 2012 I was selected as a "Top 40 Under 40" business leader in Rhode Island and selected by the Boston Asian American Civic Association as one of the leading immigrants who have achieved success in the Boston area while developing a strong business relationship with the Asian-American community in Boston. I am a proud cofounder of the Rhode Island Green Building Council and the Massachusetts Citizens Advocating Renewable Energy Solutions.

My company is now advising the State of Rhode Island on the development of its state energy plan, a visionary strategy for the state to grow its economy in a sustainable manner. We have consulted for global leaders, such as Hyundai Corp., along with local and state governments and universities. We are developing a large-scale solar and wind energy power plant in the Dominican Republic, my country of origin.

Nearly all of our facilities have been developed at challenging locations (brownfield sites that were previously landfills or contaminated) utilizing the most advanced

AERODYNAMIC IMPACT
Jeff Grossman '06 helped design ATDynamics' TrailerTail, which has saved truckers some 4 million gallons of diesel fuel.

COURTESY OF ATDYNAMICS

engineering technology. We developed the largest wind turbine in Massachusetts on a capped landfill in Kingston that is expected to generate more than 4 million kilowatt-hours per year in clean energy, enough to offset the energy use of 100,000 light bulbs per year. Our engineering consultant had to design a special foundation that would completely anchor the wind turbine while minimizing disturbance of the landfill soils. The design proposed by our engineering consultant involved dozens of steel rods driven up to 120 feet into the soil to create a rock anchor foundation, a design they have patented. The design has been recognized by the National Renewable Energy Laboratory as a breakthrough design. Later in 2012, we developed a second facility in Ipswich, Mass., with the support of Mass Energy Consumers Alliance, that is expected to generate an equal amount of clean energy. The combined output of these facilities is enough to power 2,000 typical American homes.

Rhode Island has a very nice feed-in tariff program that streamlines the process for renewable energy distributed generation. Of all the incentives that have been dreamed up for renewable energy, I think the feed-in tariff (as originally developed in Germany) is still the most direct market-based mechanism for incentivizing renewables. For energy efficiency, the best programs are those that enable financing of retrofits, such as improved high-efficiency heating equipment, and insulation. If the utility provides financing directly to consumers, we see a significant increase in energy efficiency.

At the end of the day, ensuring the availability of energy supplies along with reasonable costs is essential to development, whether in an industrial economy such as Massachusetts or a developing economy like the Dominican. When it comes to energy, a dollar invested today results inevitably in many dollars saved some 10 or 20 years down the road. I realize it is hard to think that far in advance these days, but ultimately the way we generate growth is by putting in the resources today for a better future.

—Kially Ruiz '98

I'm the director of engineering at Boston-Power Inc. (BPI), a small private company that designs and manufactures lithium ion batteries. When I joined five years ago, we mostly focused on notebook computers and other consumer devices, but now focus on developing battery packs for electric vehicles, primarily in mainland China, although we have customers in other areas as well. My group is designing the battery management system that monitors the state of the battery (voltage, current, and temperature), looks for any unsafe operating conditions, communicates those conditions to the vehicle, and performs some higher-order battery management algorithms (calculating state of charge, available power, etc.).

—Scott Milne '99 Th'01

I'm the director of corporate development and project finance at Standard Solar Inc. (standardsolar.com). It's a company based in Rockville, Md., that develops, engineers, and builds solar PV systems for residential, commercial, and small utility customers up to 10 megawatts. We also have an energy efficiency, LED, smart home, and generator division. We look to create sustainable solutions and save money for our customers.

—Kush Patel '01 Th'02

I'm VP of engineering at ATDynamics (atdynamics.com), which designed and manufactures the TrailerTail, an origami-folding rear aerodynamic device for the long-haul trucking industry. Our company was started in 2006 by **Andrew Smith Tu'07** while he was enrolled at Tuck. I joined the company as the first hire after working for Andrew with two other Thayer students for ENGS 190/290 in 2006–07. **Chuck Horrell '00 Th'01** and I were the two engineers who designed the TrailerTail for production (Chuck left ATDynamics in 2010 to pursue other ventures). Our company has grown to 50 people and has had four Thayer interns along the way. We are still the only supplier in this field, and have 10,000 units traveling North American highways. TrailerTails have saved an estimated 4 million gallons of diesel fuel so far. This experience has left a mark on me. While renewable energy sources such as solar and wind get most of the media attention, there is a large opportunity for individuals and small groups to carve out innovative niches in the energy-efficiency space that can make an immediate and powerful impact on sustainability.

—Jeff Grossmann '06

I have been involved with a sustainability initiative at Mission Motor Co. in San Francisco. A colleague and I were involved in transforming our operations and facility to meet the requirements of the San Francisco Green Business Program. In reward for our effort, the company is exempt from payroll tax.

Oftentimes one of the hardest things to justify in a sustainability program is cost. You know what feels right, but it doesn't always seem quite as palatable for those in charge of the balance sheet. Luckily for Mission Motor Co., a startup company designing drivetrain components for electric and hybrid vehicles, San Francisco takes some of this burden upon itself. In order to stimulate the environmental consciousness of businesses operating within the city, the San Francisco Green Business Program was formed to register businesses and require them to uphold standards for resource usage; the program rewards companies with an exclusion from payroll tax. For startup companies working on a limited budget, this can make all of the difference. At Mission our two-person green team, known as "Sustainable Mission," was able to address issues of water and energy use as well as waste prevention. Being engineers, we were happy to add quantified metrics to track our progress in all of these areas. A simple spreadsheet that tracked our water bills over time (normalized with headcount) let us see that our waterless urinals and faucet aerators were indeed making a difference, with a savings of nearly 40 percent. A similar form for electricity allowed us to see our usage spike during times of extensive motor and battery lab testing and motivated us to optimize our test facilities. Monitoring other activities, such as recycling, composting, printing, heating/cooling, and lighting, allowed us to get a grasp on where we could make a difference. Once these differences were captured in a quantified manner, we were able to put a number on the savings that we were experiencing with our "feel good" practices. In the end, sustainability is largely about efficiency, and once it is quantified, it can prove to be a cost-effective way to run a business.

Thanks for the jump-start, San Francisco!

—Karl Johnson '06

I work for Solaflect Energy in Norwich, Vt., with an all-Thayer contingent. We make tracking machines for solar applications. We design heliostats, tracking mirror dishes that reflect the sun onto a central target. This is primarily a commercial-to-industrial-scale application. We also use the same structure to support PV modules to make a PV tracker that has residential applications. We've sponsored four ENGS 89/90 projects during the past several years. My coworkers are **Bill Bender '78, Nate Hine '78 Th'80, Mike Wood '10 Th'11**, and **Kelly Mallery '11 Th'12**.

—Dan Schneider '07 Th'08

I recently returned to London after demonstrating our new biotech software product at the Dartmouth Ventures entrepreneurship conference. Our service, AutoClone, dramatically reduces the need to build synthetic DNA from hazardous, flammable chemicals. Instead, it automatically figures out how a given DNA molecule can be recycled from those a scientist already has in his or her laboratory. Basically, it maximizes the recycling of this important part of the laboratory.

I founded the company last year along with two of my classmates from grad school at the University of Cambridge after we won the university business plan competition that June. Our short-term goal is the successful launch of our public beta by the end of summer, followed by our first paying customers by the end of the year. In five years, my hope is that AutoClone will have helped save our customers millions of hours that are currently wasted on the mundane process of building DNA molecules and substantially reduce the need for expensive chemical DNA synthesis.

Learning to program in Professor Shepherd's ENGS 20 class made this all possible. Even though my focus at Thayer was working with Dr. Berngross in biochemical engineering, the breadth of Thayer's curriculum has proven to be tremendously helpful.

—Riley Doyle Th'08

I work as the senior director of research and development at Mascoma Corp. (mascoma.com) in Lebanon, N.H., where I lead the team developing our technology for converting lignocellulose into low-carbon fuels and chemicals. The company was founded by Professors **Lee Lynd Th'84** and Charlie Wyman and continues to have a strong connection to the Thayer School. We have developed technology, including genetically modified strains of yeast, to allow low-cost production of ethanol from hardwoods. These organisms produce enzymes and ferment a variety of sugars at high yield. Mascoma has also applied its technology to the first-generation corn-ethanol market, and has commercialized a product called Transferm in conjunction with Lallemand Inc. This product reduces inputs needed for corn-ethanol production and has been used in the commercial production of hundreds of millions of gallons of ethanol to date. The challenges facing Mascoma are similar to the development of any new technology attempting to break into an established market and similar to those any new company faces. We must overcome the risk associated with scaling up new processes and biotechnology and find a way to deploy our technology into the market rapidly. In addition, we face the unique challenge of an ever-changing policy and regulatory framework for ethanol and advanced biofuels.

—John McBride Th'08

I am a project engineer at Environmental Resources Management (ERM), where I develop, implement, and report on global sustainability and carbon-reduction programs for clients in the manufacturing and retail sector. At Dartmouth I did my thesis with Professor Mark Borsuk on quantifying the human health and societal benefits of mercury reductions from coal-fired power plants. After graduating, I was a member of the Big Green Bus 2010 tour. In my job I apply my background in quantifying and monetizing environmental risk in various projects, from a portfolio-level assessment of environmental and social risks for an oil and gas client to financial reserve estimation for asset retirement obligations for a global manufacturing client.

I also work closely with the ERM Foundation's Low Carbon Enterprise Fund, which provides debt and equity finance and technical and management support for small, low-carbon social enterprises in the developing world. I've assisted with business plan review and due diligence of low-carbon ventures in Thailand and Belize, and recently spoke on a career development impacts investing panel at Columbia's School of International and Public Affairs.

The greatest challenge I see from a business point of view is determining what is most material to your organization and where you can have the biggest impact. There are a variety of sustainability metrics to manage energy, water, and various waste streams, not just in your direct footprint but across the entire value chain. From a risk-management perspective, a lot of our work starts with regulatory and climate risk-mapping. We first help our clients understand and comply with existing environmental regulations, and then start down the initial path of resource efficiency and carbon-reduction goals. More and more companies are asked to respond to public ranking platforms, such as Carbon Disclosure Project, Newsweek Green Rankings, or the Dow Jones Sustainability Index, and, in turn, are thinking about how they present their sustainability strategy to shareholders and other stakeholders. From a personal development perspective, it's exciting to be able to get into the data and help my clients track progress against their defined energy and carbon goals, and then take a step back and see where the bar is going for the next year.

Coming down the pipeline, we see a lot more emphasis on supply chain and looking beyond traditional operational footprints. There are numerous case studies proving that sustainability can go beyond just resource efficiency and cost-cutting—which is just good business sense—to how you can grow sales through more efficient or sustainable products or services. It goes back to the initial materiality question and where businesses can make a real impact.

Whenever a company can identify the real business advantage of its sustainability program, things accelerate. Many companies recognize that sustainability should not be a separate group, but rather part of every function and measured with the same rigor as financial metrics and operational key performance indicators. As an engineer, you have the advantage of thinking from a systems point of view, and so you intuitively understand that inputs, outputs, and costs are all related. At the end of the day, when you clearly link your sustainability efforts to the balance sheet, you have the greatest chance of success.

Drawing on both my client experiences and my work with the ERM fund, I serve on the board of directors for the Young Professionals in Energy N.Y.C. chapter (along with Thayer M.E.M. alum **Arjun Thampan Th'11**), where I coordinate networking and thought leadership events for a network of nearly 3,000 professionals. We represent all sectors of the energy industry, from renewables to oil and gas to transmission and energy efficiency. We host networking events once a month, and it's a great way to have interesting conversations and learn something new. ERM works with many oil and gas clients in the Northeast. I've been involved in some risk-assessment work around shale gas, so I am bringing in an ERM expert to present a Marcellus Shale 101 talk this summer, with a focus on managing the environmental impacts of shale gas development.

—Ann Elise DeBelina '10

I work as a process engineer for Primus Green Energy, an alternative fuel company based in Hillsborough, N.J. Primus has developed a thermochemical process that converts various feedstocks—including biomass, municipal solid waste, and natural gas—into "drop-in" gasoline, diesel, or jet fuel that can be readily distributed throughout the existing fuel delivery infrastructure. The highly integrated nature of the process makes it cost competitive even at smaller scales.

COOL COMPANY EFFICIENCY
Karl Johnson '06 helped electric vehicle components maker Mission Motor Co. lower its water and energy use—and win a tax exemption from the San Francisco Green Business Program.

COURTESY OF MISSION MOTOR CO.

Most of my efforts have supported the construction of our demonstration plant, which is expected to come online in the fall of 2013. I am involved in developing the demonstration plant designs, working with the engineering team to fine-tune the process and optimize it for production of high-quality fuels. I have also had the opportunity to work on the business side of the company, which I've enjoyed very much.

A major challenge for alternative fuels is managing both the technology risk as well as the feedstock risk. The combination of these risks makes project financing and development more difficult, and many companies have been unable to overcome these challenges in their efforts to commercialize. Primus is mitigating these risks by initially pursuing natural gas as a feedstock, which has very attractive pricing economics and which relies on Primus' liquid fuel synthesis technology that is market-ready today.

In the short term, our demonstration plant will provide the performance data necessary to break ground on our first commercial plant, which is expected to take place next year. In the longer term, Primus will expand its production line at the demo plant to include jet fuel, diesel, and specialty chemicals, such as xylene and toluene. We will also look to further develop the use of biomass as a feedstock and roll out additional commercial plants.

—Ben Moskowitz '10

I work on the smart grid, energy-water nexus and gas industry-related sustainability investments.

—Sid Nagendraprasad Th'10

I am working for Navigant Consulting in its energy efficiency policy analysis group. Our major client is the U.S. Department of Energy, for whom we do the engineering analysis that helps it select efficiency levels for appliances. Basically, we try to figure out the most cost-effective way to make everyday appliances (e.g., microwaves, refrigerators, and air conditioners) reduce their energy use. Our efforts help Americans save billions of kilowatt-hours of electricity every year.

—Caitlin Johnson '10

I'm leading the research and development efforts at WikiCell Designs (wiki cells.com), a small startup focused on replacing plastic food packaging with edible packaging. We are working on developing all-natural edible skins that can be wrapped around ice cream, yogurt, juice etc., much like fruit skins protect their inner content. (See bloomberg.com/video/eat-ice-cream-like-an-apple-2hKL_O99R6CbFXYHTYCa2g.html.)

The concept of WikiCell was invented by David Edwards and Francois Azambourg, and much of the initial work leading up to the full launch of the company in 2012 was supported by ArtScience labs (art sciencelabs.org). WikiCell still has lab space at ArtScience in Paris, and this is where many of the recipe formulations are still being conducted. The product can be any food or beverage wrapped in an edible or biodegradable skin. You can think of an apple, where you wash the skin and then eat everything, or like a coconut, where you crack the shell and eat the inside, but the entire item is biodegradable.

My role within the company is to manage and lead the research and development efforts for the Cambridge, Mass., side of the company as the senior scientist of the team. A typical work week for me is to take David's ideas and formulations from Paris and basically figure how we're going to make them work. I have a team of four scientists, and much of our work focuses on skin development, both from a stability point of view (how shelf stable will the product be) and from the flavor/taste end of things. We will develop various prototypes throughout the week and test electrostatic interactions, diffusional properties, tensile strength, scalability, and, of course taste, to name a few considerations. Much of my work is focused on joining biotechnology, chemistry, and food science. It's really interesting when you start looking at food with a scientific eye and realize that many of the concepts you know to be true in the biotech field can also be applied to food. We do a lot of work around food particle electrostatic interactions and polymer chemistry. Nature has given us the blueprints, and now we're just trying to apply them.

Part of our goal is to not only eliminate plastic, but to create a skin that provides additional nutrition to the consumer and also creates a food item that brings together new flavors and textures not seen with conventional food items. An example of this is our coconut-mango sorbet (a favorite of mine). As you bite into the skin, which consists of mostly coconut flakes and tastes and feels like the meat of a coconut, you reach the food item inside, which in this case is a delicious mango sorbet. The interplay between the flavors and textures creates an amazing product that not only tastes good, but is good for you and good for environment. We believe that people want to reduce waste, reduce plastic, but to really get them on board with these ideas you need to make something that they want more than the traditional plastic-wrapped food item.

Our greatest challenges are both scientific- and consumer-based. Can consumers make the jump from buying yogurt in a plastic container to buying a product that looks like a grape, can be washed like a grape, but contains yogurt inside? We believe that if we can produce a product that provides a new and unique eating experience, is all-natural and healthy, tastes as good or better than conventional food items, and can be delivered at a similar price point, consumers can and will make that jump.

We launched WikiCell ice creams and sorbets in Paris this summer. Most likely you will see WikiCell popping up in the United States in 2014. Longer-term goals include developing yogurt, juice, and even cocktails as well as expanding the availability of WikiCell products.

—John Lamppa Th'11

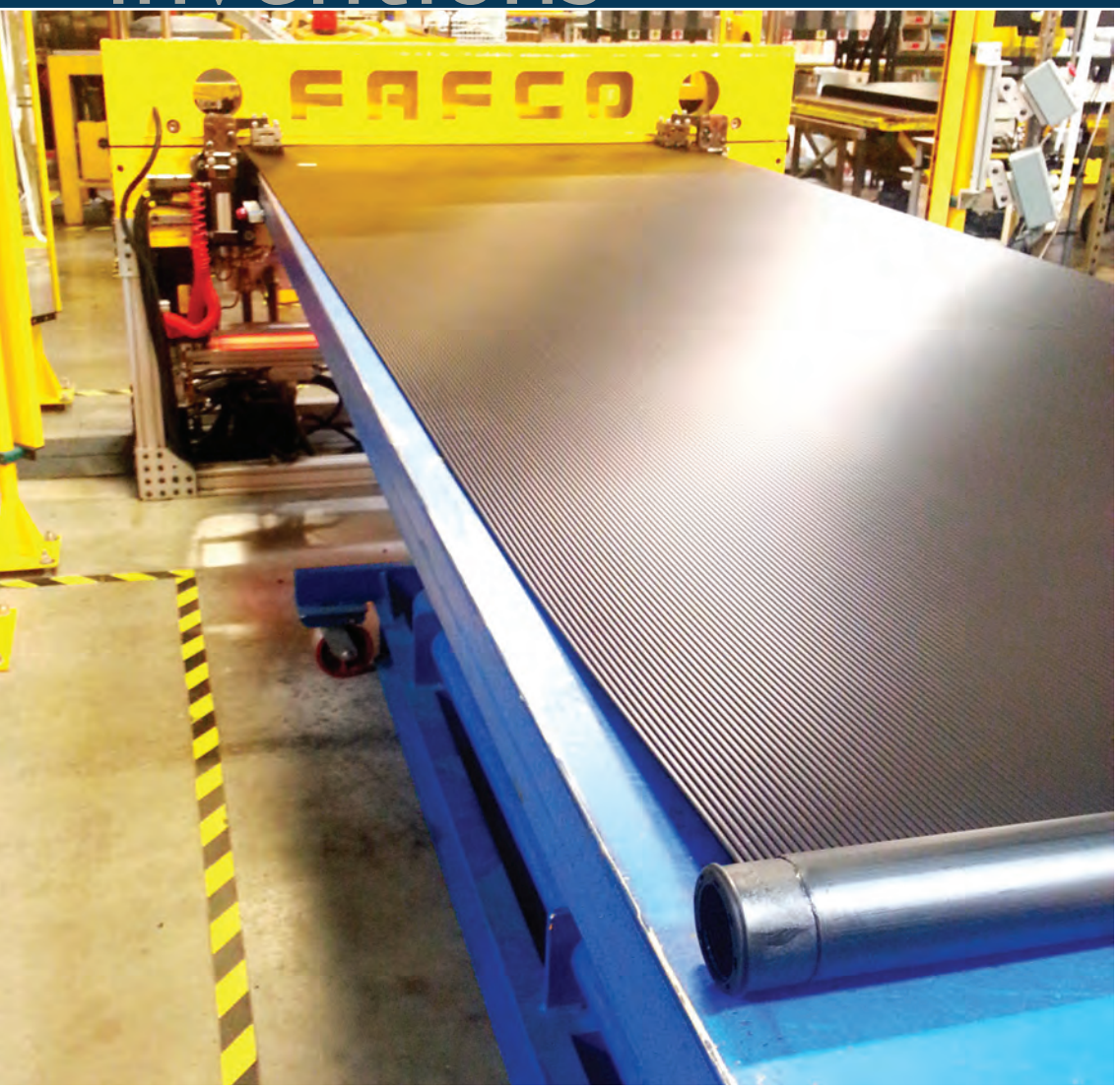
I work at General Compression, a Boston-area company that is developing technology for large-scale grid storage. The technology will be coupled with a renewable generator, such as wind, to provide clean energy on demand. The storage technology can also be coupled with nuclear plants to make their power output more responsive or installed directly on the grid to provide storage and load-shifting services. The storage mechanism is compressed air, meaning that the technology is fuel and carbon emission-free.

—Lakshmi Srinivasan '11

OBITUARY

Former Thayer School registrar **Marion C. Morhouse**, 98, died March 18 in Shelburne, Vt., where she had lived since 1996. In recognition of her 22 years of service to Thayer, she was inducted into the Dartmouth Society of Engineers as an honorary member. Born in 1914, she graduated from Bradford Academy and attended Middlebury College. She lived in Woodstock, Vt., for 22 years and Enfield, N.H., for 27 years. She was involved with the Girl Scouts, local garden clubs, school groups, the Congregational Church, historical society, and Shaker Museum. In her 80s she delivered Meals on Wheels, hiked the Milford Track in New Zealand, and parasailed at age 86. Morhouse is survived by two of her four children, 10 grandchildren, and seven great-grandchildren.

inventions



SOLAR FLAIR
Freeman Ford turned a bright idea into a company.

LIGHTWEIGHT SOLAR THERMAL PANELS

>> INVENTOR:
FREEMAN A. FORD '63

"Plastics. There's a great future in plastics. Think about it."

When Freeman A. Ford '63 recounts the founding of his solar energy company FAFCO (the name is a play on his initials), he jokes, "maybe we watched 'The Graduate' one too many times." Back in 1969 Ford and his business partner, Richard Rhodes, did think about plastics—and now FAFCO is the oldest and largest solar thermal panel-making company in the country.

"The key to any entrepreneurial endeavor is finding a need and filling it," says Ford. He found his opportunity at home—his backyard swimming pool was too cold. At the time pool heaters were expensive to install and operate, and they added a rust color to the water. So Ford thought like an engineer. "Swimming pools use a huge amount of energy, they are a big storage tank, and they have a circulation pump, so they have the three things necessary for a solar thermal system," he says. "The only thing they don't have is a collector."

Ford decided to build solar collectors—out of plastics. "Polymers are easily processed, and the manufacturing of large surface areas using extrusion can be easily automated," he says. But polymers also have a downside. "It is extremely difficult to get plastics to last for 20 years sitting out in the sun with chlorinated water running through them," says Ford

"Getting it right was not easy," he recalls. In 1976 FAFCO had 60,000 collectors fail. "The key was the chemistry and the mechanical structure which would allow the polymers to perform an unnatural act—which is to last indefinitely in the sun," says Ford. More than 25 patents related to the chemistry and fabrication of solar thermal panels document FAFCO's success.

Ironically, Ford doesn't have Thayer class numerals after his name. "I didn't graduate from Thayer as an engineer," says Ford, who was an economics major with a passion for engineering and physics. He took Thayer courses and was mentored by Blanchard "Bunny" Pratt '47 Th'51, a researcher in radio physics at Thayer, and by Fred Schleipman, an equipment-maker in Dartmouth's physics lab who later became director of Thayer's machine shop. "I was forever building electronics at Thayer," says Ford.

Today the company he built on plastics and electronics has sold more than 1.75 million solar heating systems, and its product line now includes pool and domestic hot water systems. In 2006 Ford was inducted into a cool international honor society created by Congress: the Solar Hall of Fame.

—Lee Michaelides

COURTESY OF FREEMAN FORD

RANDOM WALK

The lawn behind Thayer became a racecourse at the end of spring term when students tested diwheel cars—vehicles with two wheels side-by-side—that they made in ENGS 146: "Computer-Aided Mechanical Engineering Design."

"Diwheels contain all of the design elements that I want to teach: computer-aided design, statics and dynamics simulations, mechanism design, computer-aided manufacturing, advanced prototyping with computer-numerically controlled machining, welding, and rapid prototyping," says Professor Solomon Diamond '97 Th'98. "But making the diwheels in three-and-a-half weeks is incredibly challenging. All the diwheels were operational on the smooth and level floor of the GlycoFi Atrium, but taking the race outside introduced difficulties due to the roughness of the terrain, slipperiness from grass getting into the mechanisms, and the slope of the lawn." Indeed, most of the students had trouble getting their cars around the track. But even failure can be useful. "My plan is to share the lessons learned with next year's class so that we can make improvements collectively," says Diamond. "Having students learn from their predecessors helps to create a sense of intellectual continuity and shared purpose."

Photograph by Kathryn LoConte Lapierre

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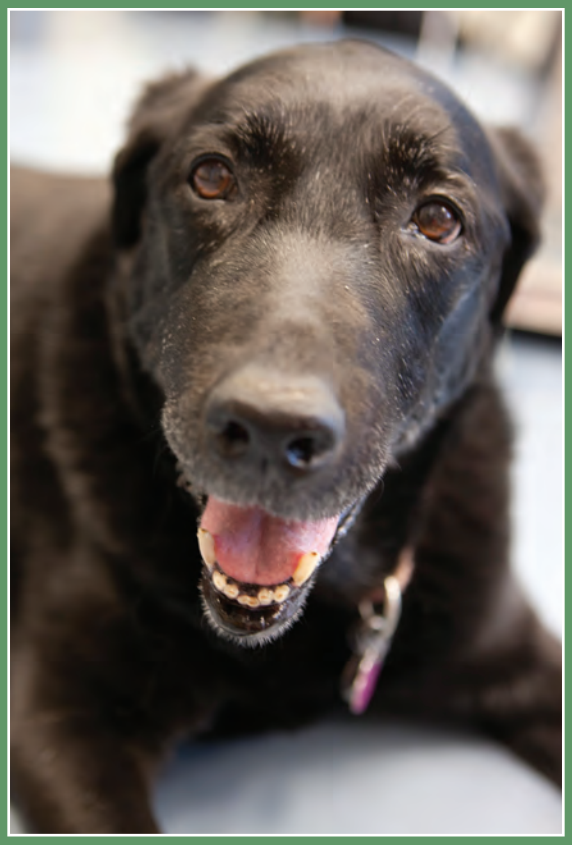

See Carmen's story, page 6