

Association of University Technology Managers®

# The BetterWorld Report

Respond, Recover, Restructure:  
Technologies Helping the World  
in the Face of Adversity



2011 Edition  
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Association of University Technology Managers®

## **The Better World Project**

The Association of University Technology Managers launched the Better World Project in 2005 to promote public understanding of how academic research and technology transfer have changed people's way of life and made the world a better place. The project draws from more than a decade's worth of case studies and news from AUTM members — the professionals who make academic technology transfer happen.

The 2011 edition of the project focuses on innovations that help the world respond, recover and restructure in the face of adversity.

## **Materials and Support**

The Better World Project materials are available in print and electronic formats.

Visit the Better World Project website or contact AUTM headquarters for details.


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## **The Association of University Technology Managers**

AUTM is a nonprofit professional association with a mission to advance the field of technology transfer and enhance the ability to bring academic and nonprofit research to people around the world. AUTM's 3,000 members represent intellectual property managers from more than 350 universities, research institutions, teaching hospitals and government agencies as well as hundreds of companies involved with managing and licensing innovations derived from academic and nonprofit research.

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The *Better World Report* is a testament to the efforts of institutions' technology transfer offices, their directors and staffs, who gathered and submitted these stories and more. These contributions illustrate that institutions are doing their part to improve the world we live in not only through education but through innovation. It is the return on investment that AUTM brings to light in this report.

## Editors and Staff

The stories in the *2011 Better World Report* were researched and written by Ellen Blum Barish, Jock Elliott, Ralph N. Fuller, Mary Roberts Henderson, Kirsten Lambert, Dave Perilstein, Emily Stone, Sandra Swanson, Susan Zelvin Weiss and Deborah Leigh Wood. (For more information on the writers, see the Writer Biographies section.) Lisa Richter served as managing editor.

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# Preface



As AUTM president, I am privileged to be a part of the annual compilation of the human stories behind technologies being developed and transferred into the marketplace to meet a specific challenge — this year focused on mediation of human and natural disasters.

The 2011 report represents the sixth edition of this much-anticipated book — a book that has evolved in just a few short years into one of AUTM's signature publications.

And with good reason. No other publication illustrates so clearly the most basic premise of what AUTM members do as professionals: advance academic innovation and discoveries for a better world.

This year, taking into consideration recent prominent disasters — both natural (hurricanes, flooding, droughts and famines) and human-made (oil spills, sludge dam bursts and forest destruction) — and the recognition that humans can be more respectful in working with the environment to provide a sustainable, good life for all humankind — the *2011 Better World Report* focuses on stories of technologies that meet these challenges.

The *2011 Better World Report* presents more than 20 technology development success stories of inventions that are making their way through the often-arduous journey from a scientist's lab all the way into the marketplace. From the Corn Belt of the Midwest to a Canadian metropolis to the heart of South Africa, these stories represent the amazing range of needs that these innovations address. From the food we eat, to the resources we use, to the water we drink, to the land we live on, and to the state of our health.

I invite you to take a minute to read these fascinating stories.

- Find out how a chance meeting over a neighbor's fence led to a skateboard made from leftover corn stalks.
- Wonder at the ingenuity of a group of people using a tea-bag, activated carbon and a hair straightener to make the prototype of an inexpensive water filter that could mean the difference between life and death.
- Discover how years of anonymous, often-repetitive lab work built the foundation for a DNA microarray to monitor microbial populations — a scientific breakthrough that could help detect a number of threats, from bioweapons to pathogens in the food supply.
- Marvel at the creativity and cooperation of a group of students and their teachers as they use their architectural skills and sweat equity to build affordable, green modular homes and donate them to the community.

These are but just a few of the intriguing examples of ingenuity featured in this book. There are so many more, and I urge you to explore every one. You will not be disappointed and, in fact, I hope you will find them uplifting. These are stories of hope in the face of adversity. They are stories of success. They are stories about what we as technology transfer professionals *do*.

Finally, I invite my colleagues to join me in one last request: to feel so very privileged to be among these ranks.

— Robin Rasor, M.S., CLP, RTPP  
AUTM 2011 President

## Foreword

# Developing Technology to Help People in Need

By Gail J. McGovern



Public attention too often is focused on the most recent natural disaster — whether it is the latest hurricane to strike the United States or an earthquake striking Indonesia — and we fail to see the bigger picture of trends in natural disasters.

This year, nearly 250 million people around the world are predicted to be affected by climate-related disasters, more than triple the 80 million of just 20 years ago.

As the humanitarian sector faces increased need for new and improved ways to deliver disaster preparedness and disaster response assistance, we are compelled to adapt technology to the diverse environments in which we operate around the world.

Technology is saving thousands of lives, but the key is to match the right technology in the right environment. A technology that works in a first-world country with a robust infrastructure may be irrelevant in a developing country or a country where the power or telecommunications infrastructure is not robust or the “back office” is not established.

Fortunately, we are seeing creative uses of technology that are saving lives in both the developed and the developing world. In 2010 and 2011, numerous uses of technology have saved lives or otherwise helped deliver assistance to survivors of disasters. Here are some examples:

- In Haiti, text messages deliver warnings about oncoming hurricanes, lifesaving messages about cholera prevention

and even alert search and rescue teams where victims were trapped following the January 2010 earthquake.

- In Japan, tsunami warnings sounded over loudspeakers and television, coupled with clearly marked evacuation routes, warned residents in March 2011 that a dangerous tsunami was approaching. These investments in disaster preparedness saved hundreds of thousands of lives. Technology is being utilized to quickly construct temporary housing for hundreds of thousands of survivors of the 2011 Japan disasters.
- Following the earthquake and tsunami in Japan, people searching for missing loved ones were able to quickly post their searches on numerous websites designed to facilitate the restoration of family links. Many survivors saw these posts and responded that they were alive.

These are just a few examples of how technology is helping save tens of thousands of lives or otherwise helping alleviate suffering for hundreds of thousands of survivors of disasters.

Within the pages of this book are even more examples of how technologies born from academic research is helping the world respond to the challenges that natural disasters bring. They include antenna-aiming technology that could revolutionize broadband usage in situations where communications links are hard to establish and difficult to maintain; new topical applications that relieve pain and stop infections; and a simple, tiny teabag filter for water bottles that will help address one of the greatest challenges to the health and well-being of disaster survivors: access to clean drinking water.

Let's be clear: Technology is not a panacea. Many in the first world often fail to see the irrelevancy of technology when they

# Foreword

are working in the developing world. Cultural, legal or political barriers may prevent the full utilization of technology. For example, a government that limits the availability of the Internet to its citizens will find itself at a disadvantage when responding to a disaster.

However, when adapted to the particular needs of the people we are trying to help, technology has and will continue to save lives and improve living conditions for people around the world.

---

**Gail J. McGovern** — who was recognized by *Fortune* magazine twice as one of the top 50 most powerful women in corporate America — joined the American Red Cross as president and CEO in 2008. Since then, she has taken a strong leadership role at the nation's leading emergency response and blood services organization.

Along with overseeing responses to several high-profile disasters, McGovern has initiated steps to invigorate the \$3.3 billion organization, including dramatically reducing its deficit and streamlining its operations.

Prior to joining the Red Cross, McGovern was a faculty member at the Harvard Business School and served as president of Fidelity Personal Investments, a unit of Fidelity Investments. She was also executive vice president for the Consumer Markets Division at AT&T.

McGovern is currently a member of the board of trustees of Johns Hopkins University and the board of directors of DTE Energy.

## About the American Red Cross

The American Red Cross shelters, feeds and provides emotional support to victims of disasters; supplies nearly half of the nation's blood; teaches lifesaving skills; provides international humanitarian aid; and supports military members and their families. The Red Cross is a charitable organization — not a government agency — and depends on volunteers and the generosity of the American public to perform its mission.

# Introduction

## Respond, Recover, Restructure: Technologies Helping the World in the Face of Adversity

“Those who tell the stories rule the world.” — Plato

Nowhere else is that more evident than among the pages of the *2011 Better World Report*.

As you will see from reading these stories, for each new idea conceived by a scientist, there is a whole network of people, institutions, funders and, in more than a few instances, Lady Luck, who help nurture the nascent technology from a budding idea into an achievement that has the potential to change the world.

But as fascinating as the growth process is, the stories within this book reveal an even more intriguing look into just how varied and vast these baby inventions are that grow up and give back to the global village.

In particular, in keeping with the 2011 theme, the more than 20 stories in this year's report showcase how technologies are helping the world respond, recover and restructure in the face of human-made and natural disasters. And how humans can be more respectful in working with the environment to provide a sustainable, good life for all.

To that end, you will notice that the *2011 Better World Report* deviates from previous editions by grouping the stories into sections that tie into the overall theme, “Respond, Recover, Restructure: Technologies Helping the World in the Face of Adversity.” The sections are:

- Technologies to Restore the Earth
- Technologies to Enhance Food Sources
- Technologies to Further the Green Movement
- Technologies to Improve Health
- Technologies to Replenish Water Supplies

Within these five sections you will find stories that tell of technologies as tiny as a microchip to as big as a communications tower. You will read tales of innovations as simple as a wooden tool to crack open nuts to as complex as mapping the DNA sequences of bacteria.

These stories are as diverse as they are far-ranging. But they all have one thing in common: They are a testament to the very real way innovations and technology transfer collaborate to ensure that people around the world can respond, recover and restructure.

To paraphrase Plato again, “Come then, and let us pass a leisure hour in story-telling, and our story shall be an education about our heroes.”

— Nikki Borman and Marc Malandro, Co-Editors

# Technologies to Restore the Earth





## Cornell University, Ithaca, N.Y.

# Green Technology Cleans up with Waste

Cornell University opened its Technology Farm in Geneva, N.Y., in 2005 to foster new, innovative technologies and the startup companies that develop them. Since its builders had asked plant biologist Gary Harman, Ph.D., to solve the facility's soil-contamination problems, there was a karma-like symmetry to his founding a company for new water-remediation techniques — and basing it there.

"We didn't solve the Technology Farm's soil problem," notes Harman, a professor in Cornell's Department of Horticultural Sciences, "but the experience started a thought-process that led to ways to clean up pollutants in water — oils, heavy metals and hydrogen sulfide. It was a direct link."

He adds: "These are ecologically friendly techniques that are less expensive and more easily handled than traditional approaches."

Like a lot of old farmland in upstate New York, the campus at the Technology Farm — officially Cornell's Agriculture and Food Technology Park — was laced with lead arsenic, a consequence of heavy pesticide use over the years.

Harman and his Cornell colleagues, chemist Terry Spittler, Ph.D., and technician Robert Patrick, began with the idea of planting ferns to take up the substance. The reality, they concluded, was that while ferns would do this, they couldn't accumulate enough to be effective, since much of the soil-based contaminate isn't soluble. At present, the only solution in such a case is to scrape up the polluted soil and haul it to a hazardous waste site.

## The Lignin Solution

"The episode started us thinking about the general problem of heavy metal contamination," Harman says. "Then, we were at a conference where we heard a discussion about bioproducts' capacity for removing heavy metals from watery materials like sewage sludge. We wondered, 'If so, how?' That led us to think about lignin, a complex compound that binds cellulose and strengthens the cell wall of plants, and its potential for binding with contaminants."

Lignin fills the spaces between cellulose and other components in trees and plants and helps strengthen cell walls. The Cornell



Thomas Bourne

The containment vessels used for MetalMaster and SulfaMaster filtering are specially made for each project to ensure even, consistent flow of the liquid or gas through the filtering medium. This SulfaMaster vessel is used to remove hydrogen sulfide from biogases.





team knew that its complex structure gives it strong negative binding capabilities.

“It binds heavy metals very tightly, in a way that the accumulated pollutants won’t leach out,” Harman notes. “Then, it usually can be placed in a regular landfill without having to be taken to a hazardous waste site. The remediated water can then be dealt with according to local regulations — for instance, returned to the groundwater or disposed into a waste stream.”

The question was where large quantities of inexpensive lignin could be obtained. In fact, they found a number of sources, testing 30 to 40 materials that might be feasible, such as ground-up cornstalks. One good source was the plant fiber in cow manure, as the ruminants’ digestive process strips away the cellulose, leaving a high-quality lignin. Manure fiber proved to be a highly effective absorbent for oil and other contaminants.

Tree bark, the material accumulated in massive amounts by landscapers and used as mulch around shrubs and flowers, also proved to be an excellent binding substance for heavy metals like nickel, copper and iron. Among the varieties tested, hardwood barks proved to be the best. The team published its results in the Winter 2007 issue of the journal *Industrial Biotechnology*.

### Enter Terrenew

“Once Gary and his associates had promising results, they did two things,” notes Jeff Fearn, senior technology commercialization and liaison officer in Cornell’s Center for Technology Enterprise & Commercialization. “They brought their results to our office, and they established a company, Terrenew.

“Gary felt that starting a company was essential,” Fearn says. “He felt that even though he had a patentable result, there are wide gaps between patents and viable products. Larger companies tend to be reluctant to take on new, unproven technologies that need extensive work to become commercially feasible. Smaller companies and startups tend to be more innovative in that way.”

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The question was where large quantities of inexpensive lignin could be obtained. In fact, they found a number of sources, testing 30 to 40 materials that might be feasible, such as ground-up cornstalks. One good source was the plant fiber in cow manure, as the ruminants’ digestive process strips away the cellulose, leaving a high-quality lignin. Manure fiber proved to be a highly effective absorbent for oil and other contaminants.

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While the university filed a patent on the technology in early 2005, Harman and four colleagues established Terrenew LLC, and the university subsequently licensed it back to the new organization, which moved quickly to pursue a range of products based on the work.

“Soon, all our products will have been commercialized, and we’ll be at a point of needing additional investors to move to the next level,” notes Terrenew CEO Thomas Bourne.

He adds: “There’s no shortage in the world of polluted water supplies that we can serve — contaminated groundwater, industrial process water and mining waste-water sites.”

Bourne is an environmental engineer whose background involves extensive consulting on economic development for environmental companies. He and Harman met at a scientific meeting, heard each other speak, liked what each said and began talking about the intellectual properties related to Harman’s work.



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While the university filed a patent on the technology in early 2005, Harman and four colleagues established Terrenew LLC, and the university subsequently licensed it back to the new organization, which moved quickly to pursue a range of products based on the work.

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“Gary asked me to help start the company and help find a CEO once it was formed,” Bourne says. “After a while, I was intrigued by the company and what it could accomplish, so I dropped the ‘interim’ label.” Harman serves as the company’s chief scientific officer, Spittler as its director of research and development.

Harman’s early research was supported with funding from the Cornell Center for Advanced Technology and the United States-Israel Binational Agriculture Research and Development Fund. Since its establishment, Terrenew has received support in the form of small business innovation research grants through the National Science Foundation and the U.S. Department of Agriculture.

### The Process and the Products

Terrenew’s offices are based at the Cornell Technology Farm in Geneva, but its operations are located in 18,000 square feet of leased space about four miles away. There, agriculture wastes are collected and processed — manure is dried in a mechanical dryer, tree bark is collected in 10-to 15-foot-high piles for sorting and shipment.

Terrenew placed its first remediation product, OilMaster, on the market in 2008, producing it in granular forms for dry-surface

oil spills and in a pad form for oil spills in water. As with all their products, they stress its qualities as lighter-weight, less-expensive, easier to handle and more effective than traditional agents — and far safer ecologically.

SulfaMaster uses lignin fiber from manure to remove hydrogen sulfide from biogases, as might be produced and recovered in waste-water treatment plants. Since hydrogen sulfide causes acid rain, corrodes machinery and can be toxic to humans and animals, the ability to strip it out enhances the prospect of biogases as alternative fuels.

As a separate line, the company also produces an AgriMaster category of growing products, including organic potting soil, dry cow manure soil conditioner and mushroom compost concentrate.

### MetalMaster

The newest product to approach commercialization is MetalMaster, which uses tree bark to take up heavy metals in water. As a waste product from logging operations, the bark is purchased from landscapers who otherwise collect it for use as mulch.

While it’s important that manure fiber be thoroughly decomposed for oil treatment, the tree bark for heavy metal work doesn’t require extensive decomposition. Preparation is primarily a matter of sifting through to remove twigs and other inappropriate matter and to produce a medium that is properly sized for the vessel and use anticipated. The ability to achieve an even flow of water through the tree bark mass is essential.

And whereas treatment of oil contaminants tends to be fairly straightforward, each MetalMaster treatment needs to be individualized for the site, depending on the target metal, the quantity of water to be remediated, the concentration of the contaminant and the pH of the tree bark (which affects its ionic binding capability).





“MetalMaster works well on three situations,” Harman notes, “including large bodies of polluted water, metal processing operations that produce contaminated water as a byproduct and contaminated drinking water. It binds up a range of contaminants, including magnesium, potassium, nickel, copper, iron and lead. A project to treat water used in a jewelry manufacturing operation removed some 90 percent of the silver, zinc and copper present.”

Essentially, the remediation of contaminated water involves a process of filtering it through a mass of MetalMaster tree bark placed within a containment vessel, making sure the water moves at a consistent rate.

The desired flow dynamics determine how big the vessel needs to be. For an early project to clean up chromium from a groundwater spill in upstate New York, the vessels consisted of a series of 55-gallon steel drums. More often the vessels are specially designed and constructed by affiliate companies. The size depends on how long the water needs to be in contact with the tree bark. The water is pumped in at the container’s bottom, rising through the bark mass to exit at the top. This approach ensures an even flow through all of the bark mass, as opposed to a trickle-down approach whose flow might be erratic.

“Besides being more effective, easier to deal with and less expensive than other approaches,” Harman says, “the bark binds the pollutants very tightly — they won’t wash out. It’s ‘green’ to start with — it uses natural waste products — and it ends in ‘green’ results — the water is remediated and the remediating material used can be treated as normal landfill, not as hazardous waste.

“It can have a significant impact on environmental cleanup efforts, with nothing but positive outcomes. It’s very gratifying to have something to do with that.”

— *Ralph N. Fuller*



**Purdue University, West Lafayette, Ind.**

## Broadband Communications System Deploys Rapidly for Disaster Recovery

When the winds scream, the earth shakes and the tsunami moves inland, communications systems typically are among the first casualties. Yet communications are critically in demand when disaster strikes — initially to summon help and coordinate first responders. Then, as rescue efforts kick into high gear, broadband communications links are needed to handle a torrent of information: requests for equipment and personnel, detailed situation reports, lists of casualties, streaming video and so forth.



BATS provided a logistically flexible, quick-deploy solution for the high-security environment at the G-20 Summit in Toronto.

It's a conundrum: How do you get broadband communications up and running in a disaster situation when they've just been wiped out?

Thanks to a chance remark at a meeting at Purdue University, a company in Indianapolis, Ind., has the answer.

### **Mind What You Say, an Invention Might Happen**

In 2005, Professor Lonnie Bentley in the Department of Computer and Information Technology at Purdue University was collaborating on a project with Anthony Smith, also a professor in the same department. At a project meeting, Smith arrived late complaining about an unrelated topic: "I just spent five hours on a tower trying to aim a microwave broadband antenna. There has got to be a better way!"

Bentley said, "Can't you automate that?" Smith replied, "I think maybe I can." Bentley considered this for a moment, then said, "Do you want to scrap the other project and work together on this instead?" Smith agreed and began explaining why aiming broadband wireless antennas is so difficult. And with that, an idea, a collaboration and, ultimately, a company was born.

The heart of the problem is twofold. First, broadband wireless systems generally employ a unidirectional antenna at each end to establish a communication link. Each station's antenna must be accurately aimed at the other station's antenna for the broadband link to work properly.

Second, at the microwave frequencies at which broadband wireless systems operate, the beam width of unidirectional antennas is incredibly narrow, on the order of .4 degrees. It can be like aiming a laser at a target antenna that may be 35 miles



away and only 2 feet to 3 feet in diameter. Until now, aiming the antenna required climbing the antenna tower and manually adjusting it, a time-consuming and frustrating procedure.

Further, current technology is vulnerable to failure. Because the beam width is so narrow, it doesn't take much — high wind, an aftershock — to move the antennas out of alignment and break the communications link, which requires another manual antenna alignment procedure.

### The Light Bulb Comes On

Bentley and Smith, working with Michael Kane, Ph.D., and Raymond Hansen did, indeed, come up with a better idea. "With funding from the state of Indiana, we automated the system," Bentley says. "We created a computer algorithm that automatically aims the antenna for optimal communications. It controls the antenna rotation and tilt while measuring signal strength and other factors to determine when the antenna is properly aimed."

The system is not only automated, it's incredibly fast. Bentley says, "Typically, it takes half a day to manually align an antenna. Our system routinely locates the target and connects in less than a minute."

By 2008, they wanted to start a company.

### Licensing the Technology

The new antenna-aiming technology was licensed exclusively by the Purdue Research Foundation to a new venture spinoff: Broadband Antenna Tracking Systems Inc. (BATS). "Purdue University has a long and excellent history of tech transfer," says Hilton Turner, project manager, Office of Technology Commercialization, Purdue University Foundation. "Senator Birch Bayh, of the Bayh-Dole Act, is a Purdue University graduate. Right now, we have 67 faculty members who are directly involved with startup companies."

In keeping with Purdue's policy of encouraging spinoffs, the

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actual licensing process took about 30 days. The Purdue Research Foundation filed a provisional patent application, the inventors obtained permission from Purdue to engage in an outside activity, the company was incorporated and the technology license was granted. "It was easy," Turner says. "All the participants knew what they wanted to do, and this was their opportunity to do it."

### Triple-Digit Growth

BATS hit the ground running and has been expanding quickly ever since. "We incorporated in March 2008, and had our first sale in June," says Bob Peterson, CEO of BATS. "Our first customer wanted us to establish the broadband link in less than an hour, as a condition of the sale. We obtained the signal and optimized it in 45 seconds. The next question from the customer was: 'How fast can we get it?' And it's been like that ever since."

BATS sales rose 500 percent from 2009 to 2010, and Peterson expects sales to double again in 2011. The company, which became profitable in 2010, now has stock integrated hardware and software systems available for most of the major radio brands and distributors and value-added resellers to cover



much of the world. “We give vendors something new to sell their customers, an enabling technology. When customers see what it can do, the checkbooks come out,” Peterson says.

### Powerful Capabilities

Beyond its speed, the strength of the BATS antenna aiming system is that it automatically seeks the best signal quality, regardless of the source. Because microwave signals can bounce off objects and behave in unexpected ways, this can lead to unusual solutions to problems. An oil refinery wanted to establish a temporary secure network during a shutdown for maintenance and overhaul. Numerous storage tanks dot the landscape, making line-of-sight communication difficult. A BATS system quickly found the highest quality signal path could be achieved by bouncing the signal off a storage tank. “It would have taken human operators a week to find that communications path, if they found it at all,” Peterson says.

In another instance, at the 2010 G-20 Toronto Summit, a BATS system provided secure and flexible broadband communications between a mobile command post and a fixed unit on the top of the U.S. delegates’ hotel. The BATS system, which performed flawlessly throughout the conference, eliminated the need to re-aim the antennas whenever the mobile command post was deployed or moved.

### More Tricks up BATS’ Technological Sleeve

Not content merely to offer the fastest broadband antenna aiming system, the technical team at BATS continued to refine the system until it could provide broadband communications with a mobile target by tracking it as it moved. “We did the first ever ship-to-shore high-speed wireless communication where the ship was in motion,” Peterson says.

Recently BATS systems permitted an entire fleet to stay in broadband communication while under way, and BATS technology enabled vessel-to-vessel broadband communications for greater efficiency in seismic oil mapping. In a technological *tour de force*, BATS was able to maintain broadband communica-

tions with an aircraft from takeoff to 30,000 feet — at a distance of 200 nautical miles.

“With capabilities like these, it’s little surprise that our primary markets at present are the military, the oil and gas industries, and emergency responders,” Peterson says.

### BATS to the Rescue

When a Louisiana parish wanted a rapidly deployable mobile command center to provide onsite command and control at disaster sites and to act as a redundant 911 call center, emergency managers turned to BATS for a solution. They wanted to be able to quickly deploy the mobile command center to any location across the 270-square-mile parish and initiate communications — by nontechnical personnel — within 10 minutes.

By installing automated antenna aiming systems on the mobile command post and on each of the four towers that cover the area, BATS systems provide uninterrupted communications throughout the entire area, with integrated voice, video and data transmissions among all public safety organizations simultaneously. This is disaster response communications on steroids. Now, whether there is a hurricane, chemical spill or plane crash, the parish is enabled to respond as quickly as possible while maintaining seamless communications among all emergency response resources.

Thanks to a great idea from professors Bentley and Smith, development by the Purdue team and rapid technology transfer by the Purdue Research Foundation, BATS systems promise to revolutionize broadband usage in situations where communications links are hard to establish and difficult to maintain. Now, when disaster strikes — such as tsunami, earthquake or hurricane — rapidly deployable BATS systems offer new hope for responding to those in peril and in need faster and better than ever before.

— Jock Elliott



University of Connecticut, Storrs, Conn.

## Innovative Chemical Cleanup Techniques Help Restore the Earth

Long before George Hoag took an academic interest in the environment, he forged a personal connection with it. “As a child, I just loved being outdoors,” he says. “Camping, skiing, biking, you name it.” Hoag, an avid hiker, later realized the human race didn’t always tread lightly on the planet. That steered him toward a career path dedicated to cleaning up the chemical mess industry can leave in its wake, wreaking havoc on soil and water.

In 1983, Hoag earned a doctorate in environmental engineering from the University of Connecticut in Storrs, Conn., and applied his knowledge to methods that could help rid the environment of contaminants. He wasn’t impressed with conventional methods used to accomplish that goal. Typically, the technique used on contaminated sites involved pumping chemicals out of the ground and disposing of them as a hazardous waste or digging them up and hauling them to landfills.

“I just didn’t think moving contamination from one place to another was the best way for our society to manage the problem,” he says. Instead, Hoag discovered a new cleanup method that targets contamination at its source. So far, it’s helped restore soil and water quality at hundreds of sites around the world.

### Trouble with Chlorinated Solvents

While Hoag was immersed in his doctoral studies, the U.S. federal government was also taking a closer look at environmental issues. That included the creation of Superfund, the Environmental Protection Agency’s (EPA) program to clean up hazardous waste areas. According to the EPA, the program has helped restore nearly 1.3 million acres of land for productive use during the past 30 years, ranging from bird sanctuaries to golf courses. But there’s still much work left to be done. As of April 2011, the EPA had 1,290 contaminated sites on its priority



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list of Superfund sites.

In the 1990s, Hoag became interested in a pervasive toxic culprit — a type of chemical compound called chlorinated solvents. About 80 percent of all Superfund sites with groundwater contamination have chlorinated solvents, according to Strategic Environmental Research and Development Program, the U.S. Department of Defense’s environmental science and technology program. An example is perchloroethylene, the chlorinated solvent most widely used by dry cleaners. It’s a suspected carcinogen and has been detected in soil and groundwater near some dry cleaning facilities. If left untreated, the effects of chlorinated solvents can linger for many decades.

United Technologies Corp. (UTC), based in Hartford, Conn., had concerns about those long-term problems. Like many



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Most people think of free radicals as something to avoid, and rightfully so. Free radicals can destroy cells and cause disease. But the properties that make free radicals harmful in people also make them function as a helpful, hard-working cleanup crew. “The free radicals from hydrogen peroxide are phenomenally good at destroying a broad range of organic chemicals in water, like pesticides, herbicides and PCBs,” says Hoag.

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other large manufacturers, it had chlorinated solvents on its property. In 1997, UTC turned to Hoag for help. The company needed to clean up sites contaminated with trichloroethylene, a chlorinated solvent commonly used to clean industrial machinery. One of the decontamination methods available at the time entailed pumping out polluted water and then treating it. It was a costly approach and not a particularly effective one. While the pump-and-treat method does clean affected water, it often fails to neutralize the pollution’s origin, which can lurk underground for decades. Seeking a better solution, UTC funded Hoag’s research at University of Connecticut laboratory to find new methods that could target the contaminant source.

### Putting Free Radicals to Work

To accomplish this daunting task, Hoag researched a group of substances called chemical oxidants. When injected into the ground, chemical oxidants can convert hazardous contaminants to less toxic compounds.

One of the initial chemical oxidants Hoag studied was potassium permanganate — but it was only effective on a limited spectrum of compounds. He also tested the effects of hydrogen peroxide, after adding a catalyst and prompting it to make free radicals.

Most people think of free radicals as something to avoid, and rightfully so. Free radicals can destroy cells and cause disease. But the properties that make free radicals harmful in people also make them function as a helpful, hard-working cleanup crew. “The free radicals from hydrogen peroxide are phenomenally good at destroying a broad range of organic chemicals in water, like pesticides, herbicides and PCBs,” says Hoag.

But the catalyzed hydrogen peroxide had a significant shortcoming. When injected into soil, it decomposed much too quickly. That prevented the helpful free radicals from reaching the contamination source.

“So I asked myself the question, is there anything else that makes free radicals and could potentially be used in the ground?” says Hoag. With the help of colleagues — Pradeep Chheda, Ph.D., a postdoctoral fellow at the University of Connecticut; and Bernard Woody, M.Sc., and Gregory Dobbs, Ph.D., both from United Technologies Research Center — he found the answer in a chemical oxidant called sodium persulfate.

Specifically, the researchers studied activated sodium persulfate — which means it’s exposed to a catalyst, like heat or iron. When injected into the ground, activated sodium persulfate lasted longer and traveled farther than hydrogen peroxide and was practically as good at making free radicals.

“This technology has a lower carbon footprint than, say, digging things up,” says Hoag. Plus, it could neutralize a wider array of contaminants than potassium permanganate: In addition to cleaning up chlorinated solvents, sodium persulfate could handle petroleum-based contaminants.

UTC’s funding for Hoag’s work included treating a site owned



by the company. During the field trial to destroy contamination at the site, Hoag learned persulfate could travel up to 50 feet in ground water.

The field trial revealed a surprise, too: The technology worked even better than Hoag had suspected. That's because the persulfate stimulated naturally occurring bacteria in the soil, which were able to help break down contaminants (chlorinated compounds and petroleum compounds) present at the site.

"That was very exciting to find out," says Hoag.

### Commercializing the Cleanup Technology

The university's technology transfer office — the Center for Science and Technology Commercialization (CSTC) — guided the patent process for Hoag's discovery. The CSTC also coordinated efforts to introduce the new cleanup technique in the marketplace.

Some of those initial discussions included the possibility of creating a spin-off company. But years ago, Hoag had worked on a spin-off company for another technology — and he wasn't eager to revisit that experience. "It took an awful lot of time and energy," he says.

Instead, the university chose a licensing approach. "The technology transfer office really helped a lot, in terms of working through that process," says Hoag. "They identified companies to license it to."

In 2000, the CSTC began arranging nonexclusive licenses with about a half-dozen environmental remediation companies. At first, adoption of the new technology fell short of expectations. Says Michael Newborg, Ph.D., executive director of the university's CSTC: "The licenses we had in place weren't generating a whole lot of income, which implied that this particular technology wasn't being broadly used."

That changed in 2005, when the technology caught the attention

of FMC Corp., a chemical company. FMC is the world's largest manufacturer of sodium persulfate, and the only company that produces it in North America. At the time, FMC already sold persulfate for many applications, from manufacturing printed circuit boards to bleaching hair in salons. Philip Block, Ph.D., remediation technology manager at FMC, heard about Hoag's work and saw the potential to expand that range of use.

"I was looking for new applications, so when I saw University of Connecticut had done a fair amount of work on the use of persulfate in the environmental market, I found that quite exciting," says Block.

The university negotiated an agreement with FMC in 2006 to give the company licensing rights for using activated persulfate in environmental cleanup projects. "It was definitely a pleasure working with the University of Connecticut," says Block. "I think the relationship has been financially beneficial to both organizations."

FMC now markets the product under the name Klorur Activated Persulfate. Whenever the company sells persulfate for environmental cleanup that uses Hoag's technique, FMC is able to grant a sublicense for use of the technology. In return, the university receives a royalty on the amount of Klorur sold by FMC. That's not the only advantage of the agreement. "Many more companies are using the technology now, compared to those we had licenses with initially," says Newborg. That broader adoption gives the technology a better chance to prove its effectiveness.

### A Novel Approach Becomes an Industry Standard

Before FMC established the licensing agreement with the university, the company had a very small environmental group. Now that business is burgeoning, says Block. Since the launch of Klorur Activated Persulfate, revenue for its environmental group has reached double-digit growth each year. Block notes that in the United States, the two driving forces behind environmental projects are regulatory requirements and real estate (properties





that must be decontaminated before they can be sold and re-developed). Even when real estate projects took a hit, demand stayed strong in other areas. Groundwater protection, for example, isn't influenced by the U.S. economy. "The EPA is going to make you clean up the site, regardless," says Block.

Persulfate's ability to target a range of hazards — chlorinated solvents as well as petroleum-based substances — gives it an advantage over many other technologies, says Block. He's observed several indicators that underscore the effectiveness of this particular decontamination technique. For starters, FMC has received many repeat customers for Kloxur Activated Persulfate. Not only has the number of cleanup projects increased significantly, but the size of those projects has grown too. About five years ago, the average persulfate environmental project used about 10,000 pounds of Kloxur Activated Persulfate. Today, that number can exceed 100,000 pounds for an average cleanup site, says Block: "That's a good measure of success."

The decontamination technique has come a long way in just a few years. At a major environmental conference in 2004, Block recalls only one persulfate presentation on the schedule. "In 2010, at the same conference, there were whole sections devoted to persulfate-related talks," says Block. "It's now considered one of the industry standards."

In the United States alone, Kloxur Activated Persulfate has been used in more than 600 decontamination projects, including large Department of Defense and Department of Energy sites. International demand for the product is rising too. FMC currently sells it in 16 countries, and customers outside the United States account for 20 percent of sales for Kloxur Activated Persulfate.

### More Innovation on the Horizon

"There have probably been a minimum of 100 journal articles written on different aspects of using this technology," says Hoag. "I'm very pleased a technology I discovered has had the widespread positive environmental impact that it has." That doesn't mean he plans to kick back and bask in the glow of success. "People who know me know that I'm very passionate about this field," says Hoag, who founded and directed the University of Connecticut's Environmental Research Institute. "I'm very committed to applying technology to obtaining a cleaner planet."

Hoag left the university in 2003 to do consulting work, helping companies apply his new persulfate method. In 2005, he channeled that entrepreneurial spirit into the co-founding of VeruTEK Technologies Inc., a Bloomfield, Conn., company that develops environmentally friendly decontamination technologies using green chemistry. His company funds the research of a few University of Connecticut chemistry faculty members and doctoral students. (VeruTEK jointly holds patents with the university for inventions by some of those faculty and students too.)

"We're working on licensing from the university some of the new technologies we've developed, some of which are an outgrowth of the original work I did on sodium persulfate," says Hoag.

He notes that more innovation is needed to keep up with hazardous waste. That's especially true for the chemical pollutants that proliferate in rapidly industrializing countries with lax environmental regulations. Still, Hoag has faith in the problem-solving power of science. "There's a lot of great work being done in this field," he says. The persulfate technique represents an important part of those ongoing efforts. By cleaning up contamination at its source, Hoag's discovery can do good things for the great outdoors.

— Sandra A. Swanson



# Technologies to Enhance Food Sources



North Carolina State University, Raleigh, N.C.

## A Seasoned Discovery Helps Keep Crops Fresh and 'Unweathered'



Invinsa helps crops manage heat and drought stress.



AgroFresh Inc.

Contrary to the image of scientists having sudden, stunning insights that abruptly change the world, most scientific advances occur in progressive steps over time, one stage building on another through years of systematic research.

A case in point: A synthetic compound called 1-methylcyclopropene (1-MCP). As SmartFresh, it helps keep apples, kiwis and other fruits fresh and crisp for consumers to purchase and eat long after they've been harvested. As EthylBloc, it's used by flower wholesalers to prolong freshness in their floral products.

Developed by biochemist Edward Sisler, Ph.D., and horticulturist Sylvia Blankenship, Ph.D., at North Carolina State University (NC State), 1-MCP's discovery followed dogged work in the 1980s-1990s on the role of the organic compound ethylene in plant growth.

In 2011, advances by other scientists are adding a new role to 1-MCP's capabilities: Helping an array of growing crops remain productive through the stress of drought or extreme heat. Sprayed on plants facing a stretch of hostile conditions, the new Invinsa technology helps them weather the unfriendly conditions by preventing their normal response — wilting and shutting down.

It has the potential to help boost food production around the world — whether by rice farmers in Asia or corn growers in Iowa — improving crop yields in third-world countries where food supplies can be marginal and helping blunt price spikes for consumers in affluent societies.

Further, government tests on 1-MCP in the United States and other countries have found it safe for consumption and without

impact on the environment.

Blankenship, now a professor of horticulture and an associate dean at NC State's College of Agriculture and Life Sciences, hasn't been involved in the latest developments. But she's pleased to see her foundational work still moving forward.

"I think it's wonderful," she says. "To know your work continues to evolve and to make a difference is a great feeling."

### Finding SmartFresh

Both Sisler and Blankenship spent their careers studying the physiology and biochemistry of ethylene. The vapor-borne plant hormone plays multiple roles in plants' lives, from stimulating shoot growth, root formation and flower opening to triggering flower and leaf decay and fruit ripening. For Sisler, an early research goal was to find a way to speed up tobacco leaves' color changes in curing sheds.

A focus was ethylene's interaction with receptors on plants. It was a complicated process that included discovery of one substance (diazocyclopentadiene or DACP) that did inhibit ethylene. Although they patented it in 1993, DACP proved impractical for several reasons, including flammability.

"Eventually, we identified components of DACP that proved to be potent ethylene inhibitors," Blankenship says. "1-MCP was synthesized. It was remarkable in its ability to retard ripening. You could put an apple on a counter for a month and pick it up and eat it and it would be fresh. It worked on fruit, cut flowers, tomatoes."

Blankenship compares a plant's ethylene receptors to a lock — ethylene is the key that opens the lock and tells the plant to begin shutting down and the fruit to begin ripening.

"1-MCP is also a key, but not exactly the right key," she says. "You can insert it into the lock but can't turn it. Once it's there, it blocks the ethylene from acting."

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**Blankenship compares a plant's ethylene receptors to a lock — ethylene is the key that opens the lock and tells the plant to begin shutting down and the fruit to begin ripening.**

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Once Sisler and Blankenship had their key, the next step was almost as formidable as the research. "Ed and I are classic scientists," Blankenship says. "We didn't know what to do next. In those days, you got on the university website, found a form for reporting patentable discoveries and sent it in. Then someone in the technology transfer office called and explained what you could and could not do."

"After the university secured patent protection in 1996," notes Kelly Sexton, Ph.D., assistant director for outreach and new ventures in NC State's Office of Technology Transfer, "the challenge was to get the technology commercialized. The Office of Technology Transfer and the inventors approached a number of food companies they thought might be interested, but without success.

"Finally, they decided to approach businesses in the flower industry. A small, family-owned company, Floralife responded." Sexton notes that both Floralife's tweak of 1-MCP into a floral product and its subsequent life as a fruit preservative were covered by NC State's patents. And although Sisler and Blankenship had no part in the latest product development work on Invinsa, NC State's patents for their foundational work apply to that as well.

Sisler's and Blankenship's original research was supported with research funding from the U.S. Department of Agriculture and the North Carolina Agricultural Research Service. After Floralife became involved, corporate funding underwrote further developments.

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“By extending freshness, this compound gives growers, packers and wholesalers much more flexibility in taking their products to market, increases yields and reduces losses to waste,” Lopez says. “Most of all it gives consumers access to crisp, fresh fruit almost year-round. When SmartFresh is used in combination with other storage technologies — such as controlled atmosphere — you get the best piece of fruit you can buy in the store.”

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At Floralife, chemist Jim Daly formulated it into a powder that could be mixed with water — when 1-MCP was then released into the air, it slowed the aging of the flowers. The product became a staple for the wholesalers who bring those flowers to market.

Since edible products weren’t involved, there were only minimal regulatory requirements to be dealt with. But as Floralife scientists worked on their new technology, they recognized its potential for food preservation. In the late 1990s the small family-owned business approached the global technology company Rohm and Haas, which organized trials on apples. In 1999 it founded AgroFresh Inc. to commercialize the product they called SmartFresh. In 2009, Rohm and Haas — and AgroFresh — were purchased by the Dow Chemical Co. as wholly owned subsidiaries.

### Worldwide Usage

“Today, SmartFresh is used around the world, from Europe

to South Africa, New Zealand and China,” notes Gerry Lopez, AgroFresh’s vice president and director for agronomic crops. “SmartFresh is used to slow the ripening of about 50 percent of all apples harvested in the United States.”

Apples are SmartFresh’s No. 1 product, but it’s also applied to fruits like pears, kiwis, plums and avocados. It’s been tried for crops like tomatoes, as well, but since fresh tomatoes are available year-round, the economics are different. The product best serves single-harvest crops.

SmartFresh is a treatment that the fruit is exposed to, applied in enclosed spaces such as cold rooms. Simply introduced into the atmosphere within the enclosed space, it’s absorbed by the fruits from the air.

“By extending freshness, this compound gives growers, packers and wholesalers much more flexibility in taking their products to market, increases yields and reduces losses to waste,” Lopez says. “Most of all it gives consumers access to crisp, fresh fruit almost year-round. When SmartFresh is used in combination with other storage technologies — such as controlled atmosphere — you get the best piece of fruit you can buy in the store.”

### The Invinsa Factor

Still, in its 10-year life as a product, SmartFresh has been used only on fruit already harvested. AgroFresh’s staff wondered if there was a way to extend its benefits to living plants — which would require applying it in the open air. In 2008, the company entered into a partnership with agricultural giant Syngenta to develop Invinsa. Scientists at nine universities throughout the United States and in Argentina contributed to research on forms — primarily sprays — that could be used outdoors.

“We started with flowers because we knew the kind of biological responses to look for,” Lopez says. “Once we knew meaningful results were possible, we tried it on field crops — corn, soybeans, rice, wheat, cotton. Cotton responds extremely well. One



benefit that emerged was its ability to help crops avoid their normal stress response.”

Essentially, when besieged by drought or hot spells, growing plants respond by shutting down — allowing their flowers to wilt and their leaves to curl — and generating seeds to reproduce themselves. By blocking their ethylene receptors with Invinsa, the farmer has a way to prevent the stress response.

“Generally,” Lopez says, “Invinsa increases plants’ photosynthetic activity during stress and increases plant robustness. For corn, as an example, it produces larger ears with better kernel fill at the end of the ear. For cotton, it fosters early boll retention and limits ethylene boll abortion due to insect damage.” The multiple-university studies have demonstrated that an Invinsa crop’s yield will increase 5 to 15 percent compared to the normal yield in a stressed crop. Lopez expects the new product to reach market within the next several years.

But he adds a caveat: “This technology has a specific role. It’s effective in defeating transient stress but it won’t resolve the hazards of prolonged stress. If the farmer knows the drought or extreme heat is going to break in seven to 10 days, Invinsa will help bridge the crisis and provide a better yield at the end of the year.”

Invinsa’s first target market is likely to be rice crops in Asia, Lopez suggests — the stress of hot climates is more predictable than in more temperate climates. One challenge is the need to develop a range of appropriate delivery techniques — in the United States it might be applied to corn as a spray from a trailer pulled by a tractor and to rice by aerial spraying. In Asia, it’s most likely to be administered by hand, suggesting multiple applications in a granular form.

“This is a superb example of the way that science continually builds upon itself,” Lopez suggests. “It started with the laboratory research development of 1-MCP. It was a wonderful discovery. Scientists around the world have written hundreds of papers on its potential uses.

“EthylBloc and SmartFresh have had enormous impacts on people’s quality of life. We think Invinsa has the potential to help support a sustainable food supply for a burgeoning world population.”

— *Ralph N. Fuller*

North Dakota State University, Fargo, N.D.

## For Amber Waves of Grain: High-Yield Wheat Stretches Around the World



Breeder Mohamed Mergoum, Ph.D., (left) and Research Specialist James Faller clean hard red spring wheat in Casselton, N.D., in August 2005.

Developing a new variety of wheat takes time — as much as 10 years. So James Faller, a research specialist who worked in the hard red spring wheat breeding program at North Dakota State University (NDSU) for more than 30 years, knew it might be a decade until his hard work bore fruit.

But sadly, Faller died in 2006 — before some of the projects he was working on had come to fruition. In honor of Faller's contributions, Mohamed Mergoum, Ph.D., the breeder Faller worked with, dubbed one of the wheat varieties "Faller" in his honor.

Because of its high yield, the wheat developed in Fargo, N.D., called Faller hard red spring wheat, can make its mark far beyond the state's boundaries. The United States exports hard red spring wheat varieties — which mainly grow in North Dakota,

Minnesota, South Dakota and Montana — to Europe, Asia and South America. In fact, the United States exports about 50 percent of its hard red spring wheat, according to Mergoum.

This is good news for other countries, especially those that have suffered severe drought. Such countries can help meet local demand for wheat by importing the high-yielding Faller variety and mixing it with lower-quality wheat. Thus, the variety that Jim Faller helped develop might show up in a meal in Egypt or South Africa.

Faller wheat is noted for its elasticity, which makes it especially suitable for products such as pizza dough. But this adaptable wheat variety not only shows up in pizza. It also serves as the main ingredient in baked goods such as bread and cookies. Naming this hardy, high-yield wheat after Faller seems a fitting tribute to a researcher whose colleagues describe him as very hard-working.

Nowadays, Faller's name lives on, both in the wheat variety named after him and in the form of his son Jay, who is involved in the barley-breeding program at NDSU.

Considering Jim Faller's legacies to the agricultural community — and his contribution to meeting the increasing demand for wheat around the world — somehow that seems fitting.

— Kirsten Lambert

University of Georgia, Athens, Ga.

## Crop Protection Gets a Boost with Biotechnology

Big problems can come in small packages. Case in point: The insect pests that feed on crops. Each year, these tiny creatures cause large-scale agricultural devastation around the world. For farmers, that erodes revenue worth billions of dollars and also contributes to steeper food prices. This poses a particularly worrisome trend in developing nations, where growing populations already struggle to afford the sustenance they need.

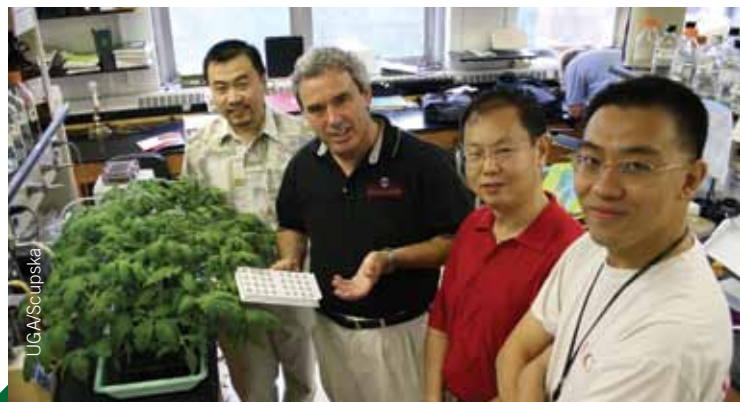
InsectiGen Inc. plans to help squash that bug problem. The Athens, Ga.-based startup has marketed a scientific discovery that increases the effectiveness of widely used biopesticides and genetically modified crops — without damaging the environment.

### On the Farm, Bacteria Lend a Hand

To understand how InsectiGen's product, *BtBooster*, can improve insect control, it helps to know a little about the type of pesticide it enhances: *Bacillus thuringiensis*, or *Bt*.

*Bt* is a form of bacteria commonly found in soil. Thousands of *Bt* strains exist today, and these bacteria have a valuable property. When eaten by certain insect larvae, *Bt* proteins turn toxic, killing the larvae within a couple days. That function was discovered a century ago, and farmers have used *Bt* toxins to help protect their crops for decades. Worldwide, it represents the most commonly used biopesticide. Considering the benefits *Bt* offers, it's easy to understand why.

Unlike some pesticides, *Bt* doesn't kill haphazardly. That's because each *Bt* strain works like a lock and key, matching up with gut receptors in different insect larvae. As a result, it can target specific pests and let helpful insects thrive. *Bt* is also biodegradable, so it avoids problems linked to conventional chemical pesticides, such as potential harm to nearby livestock or wildlife or contamination of soil and water.



Researchers (left to right) Mohd Amir Abdullah, Ph.D.; Michael Adang, Ph.D.; Gang Hua, Ph.D.; and Jiang Chen protect crops and could eventually help humans fight insect scourges such as malaria.

In the mid-1990s, farmers began planting cotton and corn crops that contained the *Bt* gene. These genetically modified plants produce the *Bt* protein that kills insect larvae. Since the introduction of *Bt* plants, their use has grown dramatically. In 1997, *Bt* crops represented 8 percent of U.S. corn acreage and 15 percent of U.S. cotton acreage, according to the U.S. Department of Agriculture. By 2010, those figures had surged to 63 percent for corn and 73 percent for cotton.

### Giving *Bt* a Much-Needed Boost

While *Bt* has significant benefits — like the ability to selectively kill insects — it hasn't eradicated agriculture pests. To glimpse the problem's enormity, consider that for U.S. farmers, the cost of insect treatments and crop loss due to the corn rootworm can reach \$1 billion annually, according to a *Journal of Economic Entomology* article. And that's just the toll taken by one insect species, in one country.

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Several shortcomings have kept *Bt* from making a bigger dent in the pest problem. It works well on some insects but has little effect on others. Concerns about *Bt*'s effectiveness have grown, as insects show signs of building resistance (one recent documented case is the fall armyworm, a well-known corn and cotton pest). Plus, *Bt* is a relatively expensive biopesticide, so it's costly for farmers.

InsectiGen addresses those challenges with *Bt*Booster. The aptly named product gives a boost to *Bt*'s effectiveness, in both spray form and genetically modified crops. According to InsectiGen, tests have demonstrated *Bt*Booster's ability to increase *Bt*'s potency by 20-fold or more. This creates several advantages for insect control. The heightened potency allows current *Bt* products to more effectively kill the insects they target. It also allows the development of new *Bt* products aimed at a wider range of pests.

What's more, the extra-potent *Bt* diminishes insects' ability to develop resistance to it — and farmers can use smaller amounts of *Bt* when it's paired with InsectiGen's product. As a result,

*Bt*Booster provides a twofold benefit for agriculture: It not only makes *Bt* more effective, but less costly too.

All of those advancements sprang from a happy accident — basically, a failed hypothesis that led to a scientific breakthrough.

### A Path to Serendipity

"In the lab, you learn to look for 'eureka' moments," says Michael Adang, Ph.D, professor of entomology and biochemistry and molecular biology at University of Georgia in Athens. That's exactly what he found in October 2003.

At the time, Adang sought answers to a fundamental question: What makes certain *Bt* toxins kill one caterpillar and not another? With several patents for genetically modified *Bt* plants and more than 25 years of research, Adang was already well-versed in the science of *Bt*. But he needed to dig deeper.

To that end, Adang and his colleagues did an experiment using fragments of an insect's receptor for *Bt* toxin. They took the fragments, mixed them with *Bt* toxin, and fed it to larvae. The researchers thought the fragments would neutralize *Bt*'s effects and block the toxin from binding to the insect's gut. Instead, they got a startling result that defied their expectations. The receptor fragment didn't protect the insects at all — it caused them to die from lower-than-usual doses of *Bt* toxin.

"We thought, 'This is really unusual,'" says Adang. "At first we didn't believe it." Adang and his team — Gang Hua, Ph.D, Jiang Chen, and Mohd Amir Abdullah, Ph.D — repeated the experiment several times. When they got the same results again and again, they started believing. "We said, 'This is real.' It was a serendipitous discovery."

### A Business Takes Root

To commercialize that happy accident, Adang co-founded InsectiGen in 2003 with Clifton Baile, Ph.D. With *Bt*Booster, they envisioned a new strategy for insect control: A product that doesn't replace *Bt*, but augments it. "The *Bt*Booster has no



toxicity itself because it's just part of an insect protein. It binds to the *Bt*, and preserves its bioactivity," says Baile, InsectiGen's CEO. Previously, he served as a director of research and development at Monsanto, one of the largest agricultural biotech companies in the world. But he's no stranger to the struggles of a small business. Before InsectiGen, Baile helped launch nine other biotech startups.

When InsectiGen needed to create a business plan, the not-for-profit Georgia Research Alliance helped pay for a professional to write it. Funding from the U.S. Department of Agriculture and the National Institutes of Health helped Adang conduct research to further develop the company's nontoxic protein. In 2003, InsectiGen licensed *BtBooster*'s initial technology from University of Georgia Research Foundation, the university's technology transfer group. Since then, Adang's lab has done additional patent-worthy research for *BtBooster*. "We jointly own some of the patents with InsectiGen, which is a little bit unusual," says Rachael Reiman Widener, Ph.D, technology manager at the University of Georgia Research Foundation.

The company has close ties to the university; InsectiGen is currently based on campus at the university's BioBusiness Center, which serves as an incubator for faculty startups. Widener notes that not all academics are natural entrepreneurs — and that sets InsectiGen apart from other startups she's observed.

"It is not unusual to have struggles with faculty startup companies," she says. That hasn't been the case with InsectiGen. "They make it easy," says Widener. "Mike and Cliff have a good sense of what it means to run a company, versus running a lab. So we've been able to work with them without any hiccups."

Even before his *BtBooster* invention, Adang says the University of Georgia Research Foundation played a helpful role. "I've filed other patent applications previously, and our technology transfer group here is very faculty friendly," he says. "They're supportive of faculty that have entrepreneurial ambitions." He also appreciates the level of trust shown by the technology



Michael Adang, Ph.D., researches biopesticides that protect crops and could eventually help humans fight insect scourges such as malaria.

transfer group. "When I asked to work with a patent attorney I've known for more than 15 years, they said 'Great, go with it,'" says Adang. "They could have insisted on using a local attorney, but they didn't."

Baile echoes those sentiments regarding the technology transfer group's support. "We consider them members of the team," says Baile, who is also a professor in University of Georgia's Departments of Animal and Dairy Science and Foods and Nutrition. "They've been very good in nourishing the commercialization activity of the company."

### InsectiGen's Next Steps

Soon, the company plans to take *BtBooster*'s commercialization a step further. It's working toward registering the product with the Environmental Protection Agency. "We've been doing field trials for several years on combinations of *BtBooster* with *Bt* biopesticides," says Adang. "I think we could have it registered in the next two or three years."

The product has already caught the attention of large companies. A subsidiary of DuPont, Pioneer Hi-Bred, is using

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“We thought, ‘This is really unusual,’” says Adang. “At first we didn’t believe it.” Adang and his team — Gang Hua, Ph.D, Jiang Chen, and Mohd Amir Abdullah, Ph.D — repeated the experiment several times. When they got the same results again and again, they started believing. “We said, ‘This is real.’ It was a serendipitous discovery.”

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*BtBooster* under a licensing agreement to develop better genetically engineering *Bt* crops. “It’s the only one we have publicly announced, but we have other agreements with companies,” says Baile.

In its present form, *BtBooster* is designed to thwart agriculture infestations, but InsectiGen won’t stop there. Ultimately, Adang wants to broaden the scope of insects that *Bt* kills — and not just pests that damage crops. His current research includes *BtBooster*’s effect on the darkling beetle, which can transmit *Salmonella* in commercial poultry houses. He has other pests in the crosshairs too.

“Some of our more interesting work is trying to find a more effective way to make biopesticides for mosquito control,” says Adang. He has applied for a National Institutes of Health grant to conduct field trials in this area. If he’s able to curb mosquito populations with *BtBooster*, it could have widespread effects on world health issues by preventing the spread of lethal diseases. Malaria is one example — according to the World Health Organization, at least 1 million people die each year from malaria transmitted by mosquitoes.

Adang knows the rewards of taking a discovery from the lab to the marketplace. Each year, he helps plant that seed in students’ heads by teaching a biotechnology course at University of Georgia (one of the guest lecturers the patent attorney who works on *BtBooster*). “I think he’s really able to get the point across to students that there is another world beyond academia,” says Widener.

*BtBooster* has officially entered that other world. It evolved from a “eureka” moment in the lab to a product that could dramatically improve pest control.

“It’s very gratifying,” says Adang. “But this isn’t the first time I’ve had this experience.” In 1982, he started developing technology for engineering *Bt* genes into plants. InsectiGen continues to build on those decades of research. With a boost in potency, *Bt* toxins can help reduce the damage insects do to plants, and the disease they cause in humans. The potential significance isn’t lost on Adang. “It’s a motivating force in my career,” he says, “that you can continue to make discoveries that will have value for society.”

— Sandra A. Swanson

University of Georgia, Athens, Ga.

## A Labor of Love: Designing Devices for Africa's Rural Poor

In industrialized countries, a milk cooler is where shoppers grab a gallon of milk at the grocery store. A nutcracker is something people use to pry open a pecan.

But in developing countries, those two devices can look quite different. In some countries, a milk cooler is something a dairy farmer uses to keep his cows' milk from spoiling. A nutcracker is a person with a rock.

Thanks to William Kisaalita, Ph.D., a professor and tissue engineer at the University of Georgia (UGA) in Athens, storing and harvesting food has become much easier for farmers in Uganda and Morocco. The milk cooler and nutcracker he developed give an economic boost to those who struggle to make a living.

The Uganda-born Kisaalita worked with UGA engineering students to develop these two devices. And though the innovations may be made of metal, a lot of heart goes into the invention process.

The professor, who grew up just outside Kampala, Uganda, is now a U.S. citizen. He and his wife, an accountant, have four children who are healthy and successful. His current surroundings are a stark contrast to the place where he grew up: a house made of reeds and mud, lit by kerosene and heated with wood.

Kisaalita left Uganda, earned his doctoral degree in Canada, and joined UGA's College of Agricultural and Environmental Sciences in 1991. After asking himself what he could do to help people like those he had grown up with, he set up a program in which engineering students can go overseas and design products to help the poor.

The first product they came up with was a milk cooler about the size of a dishwasher. Farmers along Uganda's "cattle corridor,"



a 50,000-square-mile dry-land area stretching north to south, are now using that cooler.

That region is home to more than 2.5 million dairy farms. Most farmers have between two and five cows. Farmers milk the cows, which produce an average of 50 liters of milk a day, in the morning and evening.

During the day, farmers sell the milk to local vendors who transport the milk to cooling stations. But those markets are closed in the evening. So, in the past, farmers had no way to cool the milk produced in the evening. The lack of refrigeration forced them to pour about 40 percent of their income potential down the drain each night.

So Kisaalita and 15 of his undergraduate students came up with a power-independent cooler for short-term milk storage. The cooler uses a vacuum system and a mineral called zeolite to help keep the milk cold.

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**But instead of resting on his laurels, Kisaalita has continued to engineer practical, simple solutions for Africa's rural poor. So when a colleague approached him in 2005 on behalf of people in rural Morocco, Kisaalita took up the challenge.**

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Research funding came from a number of sources: the University of Georgia Research Foundation Inc., the World Bank, U.S. National Science Foundation, U.S. Department of Agriculture and U.S. Environmental Protection Agency.

After the first prototype of the cooler didn't work well enough to market, Kisaalita found an unlikely partner: a German company called Cool-System KEG GmbH, which had designed a self-cooling keg for beer drinkers. After some redesign, Cool-System produced a cooler called CoolChurn. The kegl-like cooler chills 15 liters of milk within three or four hours, and keeps it cold for a full day.

But instead of resting on his laurels, Kisaalita has continued to engineer practical, simple solutions for Africa's rural poor. So when a colleague approached him in 2005 on behalf of people in rural Morocco, Kisaalita took up the challenge.

The professor and his students were determined to crack the mystery of how to help the Moroccans. Women and children in Morocco used rocks to manually open argan nuts, which contain oil-rich seeds. When cracked open, those seeds yield argan oil, which gourmands around the world use as a cooking ingredient. The oil also serves as a rich source of vitamin E for cosmetics.

Cracking those nuts using rocks was not only labor-intensive, it was unsafe. Workers engaged in this work sometimes broke fingers.

Sustaining such an injury meant women and children faced periods of inactivity and lost income from one of the few economic activities available to them. Given the lack of proper medical care, those broken fingers often resulted in poorly healed bones. That could lead to hand or finger deformity — even permanent injury.

So Kisaalita and students Max Neu, Meghan Samberg, Jonathan Dunn and Phillip Jones designed a simple metal-and-wood structure that cracks one nut at a time and is three times faster than cracking with rocks. The device is much sturdier than a nutcracker a consumer in the United States might use for something like an almond because argan nuts are incredibly hard to crack. Kisaalita's nutcracker maximizes safety, thereby eliminating injuries while greatly increasing productivity and income.

The University of Georgia Research Foundation Inc. and the University of Georgia Office of the Vice President for Public Service and Outreach both funded the technology, which is now in use in Morocco.

Someone who lives in an industrialized country may not always think about where the food comes from before it arrives on a dinner plate. But for William Kisaalita and his students, the question of how farmers will get food on the table is one they won't be forgetting anytime soon.

— Kirsten Lambert



# Technologies to Further the Green Movement



**Indiana University, Indianapolis, Ind.**

## Altered Yeast Strains Hold the Promise of Expanded Biofuel Supplies



Shutterstock: Hywit Dimyadi

Most people don't spend a lot of time thinking about yeast, but in fact, it plays extremely important roles in our lives. A single-celled fungi with hundreds of variations, it digests sugars in plant materials, in the process leavening flours into breads and fermenting grapes into wine, grains into beer and hard alcoholic beverages.

And, as it turns out, helping deal with the world's energy crisis. It's an essential component in the manufacture of ethanol, the biofuel made from renewable crops and added to gasoline to reduce the nation's dependence on oil.

If Mark Goebel, Ph.D., has his way, the genetically modified yeasts he's developed will dramatically expand the availability of ethanol. A professor of biochemistry and molecular biology at

the Indiana University (IU) School of Medicine, he and several colleagues founded Xylogenics Inc. in Indianapolis to develop the technology.

"Right now," he says, "we're focused on helping corn ethanol manufacturers expand their production. In the long run, we see ourselves providing the missing element — more efficient yeast — that will make manufacturing cellulosic ethanol practical for biofuel companies. This will significantly increase the amount of ethanol that can be created."

Ethanol, the most common type of biofuel, is an alcohol obtained by fermenting sugars and starches in plant materials. Although nearly all gasoline sold in the United States today is 10 percent ethanol, it's corn ethanol, made from the starch in corn kernels, a limited source. The cob, stalks, leaves and other cellulosic material are often left on the ground as waste.

To Goebel, those cellulosic "waste" materials represent the opportunity to create new and much more abundant sources of ethanol. But it's not practical yet.

"People we've talked to say the missing piece in cellulosic ethanol production is the yeast," says Xylogenics Founder Mike Neibler. "The strains of yeast that are currently available work on the starch in corn kernels but not on the cellulosic material in other parts of the plant in a way that makes it financially feasible."

"And cellulosic ethanol is much harder to make than corn ethanol," he adds. "You have to pretreat it, expose it to expensive enzymes to convert it to sugar and then add yeast to ferment it. Currently, yields are low — 7 to 8 percent."

“We expect our technology to help make it workable by increasing the production yield, speeding up the process and reducing enzyme needs.”

### Understanding Yeast

As a cancer researcher, Goebel’s focus on cell division would seem to be far away from the subject of biofuels. However, yeast connects the two.

“Yeast is one of those organisms, like fruit flies, that constitutes a model system for studying biological processes, such as how cells grow and divide,” he says. “As we worked with yeast for biological insights, we began to understand the things that yeast cells eat — and that one of those things could be cellulose.

“Once we found that, we realized that it could be important for nonmedical uses. We kept studying it.”

We is Goebel and three graduate assistants working with him in 2005-06: Ross Cocklin, Josh Heyen and Cary Woods. The issue is that yeast has an overwhelming preference for the simple sugar glucose — when it eats, it uses up every bit of glucose available before moving on to other sugars, even abundant ones like those in other plant materials. By working with the genome, they found that removing specific genes made cells able to use xylose and other key sugars in cellulosic materials at the same time as glucose. And, they found that the enzymes breaking down the complex sugars also became much more efficient.

“It took a while to understand, but once we did, making it happen wasn’t hard,” Goebel says. “The key part was figuring it out.” Notes David Wilhite, M.B.A., senior technology manager in IU’s Office of Technology Commercialization, “One day, Mark and his team were looking over their data and one of them had the thought that perhaps they ought to patent their findings.

“They brought their results to the technology office and we applied for the patent,” he says. “Forming a company made sense as a way to develop the technology as quickly as possible.”

The company was established in late 2008 with Goebel and his assistants as founding partners, and the technology licensed to it in mid-2009.

Goebel lauds Wilhite for his assistance. “David was instrumental in making our company happen, helping us through the legal steps, finding the right people, developing a business plan.” They named it Xylogenics for xylose, the second most abundant sugar in cellulosic material.

Goebel’s original research and his biofuel offshoot received support from the National Science Foundation. Ongoing research was supported by money raised once Xylogenics was formed.

### Building a Company

“We established the company at the worst time possible — the height of the recession,” notes Neibler, a chemical engineer by training whose background includes expertise in startup companies — Xylogenics is his sixth.

“My first job was to get funding,” he says. “I had a list of 200 prospects. It’s amazing how many nos I heard, that, ‘The technology looks good, the business plan looks good, we’re not investing right now.’

“We couldn’t have survived if we hadn’t gotten seed money from the School of Medicine. We finally got some funding from the Irish Angels, a group of Notre Dame University alumni.”

Initially, the new company was based at the School of Medicine, with Neibler the only employee. Goebel describes himself as “either one of the owners, or a volunteer.” Heyen, having earned his doctorate, has joined the company as a full-time employee, and the organization has moved into offices in IU’s incubator, the Emerging Technology Center. Cocklin is pursuing postdoctoral studies in plant genomics and Woods is finishing up his doctorate.

“Our strategy is to be a research and development company,

to sublicense intellectual property,” Neibler says. “We’ve had people in Indiana, seeing the prospect of jobs, urge us to establish a manufacturing operation. But we don’t feel it would be economically feasible. It would change the nature of what we’re trying to do, and it would certainly delay introduction of our product for several years.”

Instead, the company sought to form an alliance with one of the largest companies that serve the global yeast market. In mid-2010 they finalized an agreement with Milwaukee-based Lallemand Ethanol Technology to work on commercializing genetically enhanced ethanol-producing yeasts. Their first efforts will focus on new corn ethanol technology. Lallemand will utilize Xylogenics technology to manufacture and market modified yeast.

### Cellulosic Ethanol Still in the Future

“When we started out, our vision was about the next generation of ethanol, cellulosic ethanol,” Neibler notes. “It still is, but, in the short-term, we found we could make a contribution to the production of corn ethanol.

“We went to a couple of corn ethanol manufacturers and talked to them. After looking at their operations, we saw ways we could increase their production by 3 to 5 percent. We didn’t consider it a huge number, but when we told them they practically fell out of their chairs. For them, it was a big deal.”

Specifically, Goebel points out, they saw a way to speed production time with Xylogenics yeast by 25 percent while using less enzyme. It’s a savings that turns a 40-million-gallon capacity into a 50-million-gallon capacity.

Since currently there are some 200 manufacturers producing corn ethanol and none at all producing cellulosic ethanol, focusing on corn ethanol makes sense. Revenue from that business can support research on cellulosic ethanol technology, with the expectation that the cellulosic industry will come of age in the foreseeable future. Several large corporations are presently constructing cellulosic manufacturing plants, anticipating

cellulosic ethanol becoming a profitable product in the future and prepared to live with losses while the technology develops.

To Goebel, the ability to process sugars other than glucose is essential in making ethanol a practical reality. Brazil, which relies heavily on glucose in sugarcane for ethanol production, can’t produce enough of it. The United States has just approved usage of 15 percent ethanol for cars made since 2003, a 50 percent increase over the current level.

Goebel sees xylose as an important part of the future. Unused in corn ethanol production, it constitutes 25 percent of the sugars in corn stalks and leaves — currently treated as waste in corn ethanol agriculture — and represents an opportunity to significantly expand ethanol production. Neibler notes that corn kernels constitute a somewhat limited source for ethanol in its current form, since space to plant new corn acreage is limited, he says.

The Xylogenics team isn’t solely committed to corn waste — sorghum, wheat and rye are all potential sources. Neibler speaks admiringly of switchgrass, the native grass that once covered the Midwestern prairies, which grows well, can be harvested twice a year, doesn’t need pesticides or insecticides and is a great absorber of carbon dioxide.

For that matter, while ethanol occupies its attention at present, the company is looking at other potential yeast-related opportunities — including baking, brewing, distilling, and biochemical and biopharma production.

In the meantime, Neibler notes, the benefits of a shift to cellulosic ethanol will be enormous, including reduced dependence on foreign oil, lower carbon dioxide emissions, job creation and stimulation for the economy.

“The industry is waiting for advances in the fermentation process. That’s us. We feel we can be a game changer.”

— Ralph N. Fuller





**Nelson Mandela Metropolitan University, Port Elizabeth, South Africa**

## An Environmentally Friendly Process Helps Tires Tread More Lightly

It's hard to imagine a world without rubber. From automobile tires to washing-machine gaskets, rubber pervades modern life. Unfortunately, it also carries an unwelcome tradeoff. For decades, rubber manufacturing has used a compound — zinc oxide — that harms the environment. The solution to that big problem may rest with a small South African company called Rubber Nano Products. It has unveiled a manufacturing process that eliminates the need for zinc oxide — making rubber production greener and also more efficient.

### Rubber's Prevalence and Problems

Current industry trends underscore the need for more environmentally friendly production. According to the International Rubber Study Group, an intergovernmental organization, global rubber consumption reached 24.4 million tonnes in 2010 — a nearly 15 percent increase over 2009. That demand won't abate anytime soon. Forecasts from the International Rubber Study Group suggest those figures will grow to 26.1 million tonnes in 2011. By 2012, they may hit 27.5 million tonnes. And as rubber consumption grows, so does the use of zinc oxide.

Zinc isn't always harmful; in fact, organisms need it to function properly. But in concentrated amounts, it can have devastating effects. When elevated levels of zinc oxide accumulate in water, for example, it can prove toxic for fish, crustaceans and other aquatic life. Those concerns have caught the attention of nations worldwide. The European Union classified zinc oxide as “dangerous for the environment” and “very toxic to aquatic organisms,” and the U.S. Environmental Protection Agency has listed zinc as a pollutant to closely monitor to ensure water quality.

Rubber manufacturers don't want to harm the environment — but lacking other viable, affordable options, they've adhered



Jacqueline Barnett, M.Sc.Eng., MBA, director of Innovation Support and Technology Transfer at Nelson Mandela Metropolitan University, (left) worked with innovator Robert Bosch, M.Sc., to commercialize a more eco-friendly approach to rubber manufacturing.

to zinc-oxide processes for many decades. With its zinc-free approach to rubber production, Rubber Nano Products hopes that will soon change.

### Enhancing the Ingredients

It takes more than good intentions to convince large manufacturers to swap deeply ingrained production methods for something greener. “One of the issues in rubber manufacturing is that it's pretty much been made the same way for 100 years,” says Jacqueline Barnett, M.Sc.Eng., MBA, director of Innovation Support and Technology Transfer at Nelson Mandela Metropolitan University (NMMU) in Port Elizabeth, South Africa. “To actually change the way people do things is rather problematic.”

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What's more, this zinc-oxide replacement has benefits beyond its environmental impact. By altering the chemical reactions of manufacturing, it reduces the cure time for rubber. This means manufacturers could use less energy to produce the same quality product. While still a university student, Bosch founded Rubber Nano Products to market the new process, currently named ZR-6.

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While attending graduate school at Nelson Mandela Metropolitan University several years ago, Robert Bosch, M.Sc., chose to tackle that challenge. As a field of study, rubber appealed to him because of its "inherent unknowingness." Says Bosch: "There was a massive amount of things going on in rubber that scientists don't understand." That includes more detailed knowledge of the chemical reactions in rubber manufacturing.

For years, the basic components have worked like this: By adding sulfur to natural rubber, chains of large rubber molecules (called polymers) bond to each other, creating a durable material. Chemicals called accelerators help speed up the process, and zinc oxide serves as the activator that tells those reactions when to start.

"It's almost the same as baking, chemically," says Bosch. As with baking, rubber manufacturing means more than mixing the right ingredients. The process requires heat to cure the rubber — making it harder and reliable enough to produce automobile tires that work safely for thousands of kilometers.

While at Nelson Mandela Metropolitan University, Bosch discovered a new twist on that traditional approach to rubber manufacturing, with the help of his supervisors, Chris Woolard, Ph.D., and Katherine Garde, Ph.D. In 2008, the researchers identified a biodegradable substance that does the work of zinc oxide. What's more, this zinc-oxide replacement has benefits beyond its environmental impact. By altering the chemical reactions of manufacturing, it reduces the cure time for rubber. This means manufacturers could use less energy to produce the same quality product. While still a university student, Bosch founded Rubber Nano Products to market the new process, currently named ZR-6.

### Easing the Growing Pains

To help build momentum for the discovery, South Africa's National Research Foundation and the Nelson Mandela Metropolitan University funded the early stage research. Bosch also enticed two experienced industry people from rubber chemical distributors to join the business, as managing/financial director and marketing director. Financing for late-stage development came from Bosch's friends, family and business connections, as well as from Nelson Mandela Metropolitan University.

The university's support didn't stop there. Of the three patents currently held by Rubber Nano Products, two used to belong to the university. In her role as head of the university's technology transfer office, Barnett facilitated the patent's ownership change to Rubber Nano Products. As a result, the university became a shareholder in the company, and Barnett now serves as a director. When Rubber Nano Products faces cash-flow issues for patent costs, she ensures the university covers those costs so the company doesn't lose the patents.

Barnett also assists the startup company by identifying the right lawyers to provide legal advice and ensuring Bosch has the proper equipment to help refine his company's product. That's because the university allows Bosch to use its laboratory facilities, even though he's no longer a student there. "Things can get stuck in university bureaucracy if there's not an office

to drive things forward,” says Barnett. That access has been crucial for the company.

Bosch agrees.

“NMMU has been very cooperative in the manner it handled the transfer of the intellectual property into the commercial entity as well as very accommodating in allowing some of the business R&D to occur in their labs,” says Bosch. “This has saved valuable resources for the business.”

Like most technologies that emerge from universities, Bosch’s discovery needed significant development work before it reached market-ready status. So far, the product has gone through six updated versions.

After overcoming technical challenges with product formulation, the company faced a formidable hurdle: How do you craft a sales pitch compelling enough to revolutionize an entire industry? “You say, ‘Forget what you’ve learned, there’s a new set of rules,’” says Georg Cronje, managing director of Rubber Nano Products. “And they look at you as if you’ve come from Mars.”

At first, Cronje and his colleagues assumed the product’s environmental merits would be enough to win over manufacturers. They soon learned companies like to talk about going green but won’t act without a stronger business incentive. So they changed their pitch and focused instead on Rubber Nano Products’ ability to provide a more efficient curing process — while touting the greener approach as a bonus.

ZR-6 can shorten rubber’s cure time by about 15 percent, and it also allows that process to happen at a lower temperature. The reduction in both time and energy costs has resonated with manufacturers.

“If they were making 60,000 tires a day, now they have the ability to manufacture an additional 12,000 tires, without investing

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**ZR-6 can shorten rubber’s cure time by about 15 percent, and it also allows that process to happen at a lower temperature. The reduction in both time and energy costs has resonated with manufacturers.**

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in additional mechanical equipment,” says Cronje. “Suddenly it becomes a lot more attractive.”

That also makes a persuasive sales pitch in developing nations, where environmental concerns play an even smaller role, says Cronje. “Let’s face it, if we go knocking on their doors, saying, ‘Look, we’ve got a biodegradable, environmentally friendly alternative to zinc oxide,’ nobody is really going to fall over.”

Already, the greener process has gained acceptance in a wide range of industrial products, including conveyor belts, shoes, gaskets, hoses and other non-tire-related rubber applications. (Bosch is even working on a rubber horseshoe to provide a more comfortable experience for horses.) In this case, “acceptance” means manufacturers have started using ZR-6 in industrial trials. Some have taken the next step and placed commercial orders to use ZR-6 in their rubber process.

Rubber Nano Products manufactures its product locally, but that will change as the company focuses more on international markets. The company has already established a partnership with a European distributor, and plans to do the same in Asia, the United States and other regions.

### **Making Inroads with Tires**

ZR-6 has made inroads within nontire rubber manufacturing because those products have easier criteria to meet, notes Bosch. But the greener process will make the biggest impact when tire manufacturers adopt it. Zinc oxide can represent



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That's just the beginning. Rubber Nano Products has hardly tapped the potential to transform rubber manufacturing into a greener industry. Cronje estimates the worldwide market share for ZR-6 could ultimate reach about 120 kilotonnes. "Even if we achieve 10 percent of that, it would be a good start," he says.

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as much as 5 percent of a tire's mass. In terms of zinc-oxide sources that pollute the environment, tires rank highest.

Several tire manufacturers have started trials using ZR-6, but the approval process will take time. "Tires are a life-bearing device," says Bosch. New tire development can take up to five years, he says, so he doesn't expect to see ZR-6 accepted in the tire industry for another two or three years.

However, the tire retreading industry has potential for earlier adoption. "Some of our biggest approvals have actually come from retreading companies," says Bosch. "The core of the tire is the same — we just need to prove our product is as strong as the tread that's being replaced."

That's just the beginning. Rubber Nano Products has hardly tapped the potential to transform rubber manufacturing into a greener industry. Cronje estimates the worldwide market share for ZR-6 could ultimate reach about 120 kilotonnes. "Even if we achieve 10 percent of that, it would be a good start," he says.

As adoption of this new process increases, it signifies the best of both worlds for the rubber manufacturing industry. Those companies can now rethink the way they make products that enhance quality of life — and do so more efficiently, without short-changing the environment.

— Sandra A. Swanson



**University of Illinois, Urbana-Champaign, Ill.**

## From Tamales to Skateboards: A Green Idea Harvested from the Corn Belt

Professor Scott White, Ph.D., had a regular weekly lunch date with two colleagues in the early 1990s who, like him, had recently been hired at the University of Illinois. They had similar backgrounds in designing composite materials, so they started brainstorming over their lunches about a project they could work on together.

White, who is a professor in the aerospace engineering department and in the school's Beckman Institute for Advanced Science and Technology, added another challenge: They should come up with a material that had a distinct Illinois feel. It didn't take long to figure out how to infuse a Midwestern ethos into their project.

"Every day when driving into work we'd pass acres and acres of cornfields," White remembers. Thus their idea was born. The group would turn corn waste into a plywood-like building material.

Nearly two decades later, their innovation is out on the market in the form of skateboards and, soon, outdoor furniture produced by a company in Texas that licensed the university's technology. The product, called CornBoard, helps the environment in two main ways. It sequesters carbon in the boards instead of allowing the cornhusks and stalks to decompose in farmers' fields. This saves 1.5 tons of carbon dioxide (CO<sub>2</sub>) emissions per acre, according to the company now manufacturing CornBoard. And it's a renewable resource that reduces the number of trees that need to be cut to use as lumber.

"I thought that was a pretty cool aspect," White says of their quest to create a corn-based material, even though the idea of green technology wasn't as pressing an issue as it is today.



CornBoard Manufacturing Inc., the Texas company that has licensed the CornBoard technology, produced the Stalk It Longboard as its first product. After setting a Guinness World Record for fastest speed on a towed skateboard, the Stalk It was inducted into the Smithsonian.





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**Segerstrom's CornBoard Manufacturing Inc. in McKinney, Texas, created the Stalk It Longboard, a skateboard that has been endorsed by professional skaters and surfers. Last year he had a truck tow him on a Stalk It board down an airport runway. At 78.1 mph, he broke the Guinness World Record for speed on a towed skateboard. That board is scheduled to be officially inducted into the Smithsonian in August.**

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Since then, the world has learned a lot about the need for environmentally sensitive products.

"It's very, very satisfying," White says of the realization that his innovation could help the planet. "It's a huge problem now, and it's nice to have already tackled that to some degree."

### **Trips to the Grocery Store and Testing in the Lab**

White, along with colleagues Nancy Sottos, Ph.D., and Thomas Mackin, Ph.D., began his efforts to turn corn into a composite material by going to the grocery store and buying a bunch of tamale wrappers. After all, they were just cornhusks that someone else had taken the time to clean and dry.

They used the outer sheath of the corncob because it's constructed of fibers embedded in a matrix. A matrix is the key component in composite materials because it gives the material its structural integrity. The trio played around with the matrix to find just the right architecture for the fibers and laminated the test material in hot presses. (They soon graduated from tamale wrappers to carloads of corn waste, known as stover, that a

student volunteered to drive in from his parents' farm.)

"The kinds of material we were using for CornBoard were basically left on the field and had no value at all," White says. "You're taking something that was basically useless and making something valuable out of it."

And it worked.

"It became pretty clear very early on that this stuff was kind of neat," White says. "It looked cool, it felt like a material, it looked like a material."

They got a grant from the United States Department of Agriculture, which they used to perfect their material. The next step was to bring it to market by licensing the technology.

### **A Setback and Then Success**

White, Sottos and Mackin got a patent in 1998 with the help of the university's Office of Technology Management (OTM). Several years later, in 2005, the office signed an agreement with a company to develop the product.

Then nothing happened.

The licensee essentially disappeared, explains Steven Wille, assistant director of marketing and senior technology manager at the OTM. This was frustrating for everyone since that company had an exclusive license to the technology. "We want to make sure technology is out there in the world and not sitting on the shelf somewhere gathering dust," he says.

It took four years for that dust to get brushed off, and it happened through a fortuitous meeting on a Texas beach.

Lane Segerstrom, a Texas entrepreneur, was on South Padre Island in 2008 when he met a friend of a friend who had been involved with CornBoard. The man represented several investors in the original licensing company who were upset that they



hadn't recouped their money. He asked Segerstrom to look into the defunct company's technologies to see if any of them had legs.

"One jumped out, and it was the University of Illinois technology," Segerstrom remembers. "Being a farm boy from Iowa, I thought that one had some possibilities."

While he was researching, one of the investors called to ask if Segerstrom would investigate bringing CornBoard to market. Segerstrom agreed and spent several months on the project.

He was struck by the abundance of corn stover in the country. "It's just ridiculous," he says, citing a stat that if one year's worth of American stover was rolled into 1,000-pound bales it would stretch around the Earth 21 times. "All we had to do is get just a little bit of it."

Despite his excitement, the man who hired him wouldn't return his phone calls. Segerstrom was angry and felt like he'd been used — he never got his final paycheck — and decided to channel that frustration into turning CornBoard into his own endeavor.

"I felt like I was going to the pound and rescuing this championship dog that somebody left abandoned," he says.

He called the OTM and asked if he could get a new exclusive license to the technology. They agreed, and by 2009 were able to void the original license and grant Segerstrom his own, a process that is highly unusual, Wille says.

Unusual, but beneficial, says Wille, who calls Segerstrom a model commercialization partner. He respects the professors, had a clear, focused plan to commercialize the product, and "the man understands marketing."

### CornBoard Goes to the Smithsonian

Part of that marketing push was to make CornBoard sexy. Segerstrom likens it to the fact that everyone knows what Kevlar



Lane Segerstrom founded CornBoard Manufacturing Inc. in McKinney, Texas, to commercialize the technology that came out of the University of Illinois.

is because it's in bullet-proof vests. So when people hear that Kevlar is in other products, like rope, consumers immediately respect those products.

"What can we put CornBoard in that's a sexy product, a wow product?" Segerstrom wondered at the time. The answer: skateboards.

Segerstrom's CornBoard Manufacturing Inc. in McKinney, Texas, created the Stalk It Longboard, a skateboard that has been endorsed by professional skaters and surfers. Last year he had a truck tow him on a Stalk It board down an airport runway. At 78.1 mph, he broke the Guinness World Record for speed on a towed skateboard. That board is scheduled to be officially inducted into the Smithsonian in August. The boards are for sale through the company's website and, as of this writing, slated to be in retail stores in 2011, eventually being sold in 11 cities worldwide.

Next up is a line of modular outdoor furniture that will be out this year. CornBoard also plans to produce a green version of wood shipping pallets. According to the company, more than 2 billion wooden pallets are used every year in the United States



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alone — the equivalent of approximately 1 million acres of hardwood forest.

Cabinets and other products will follow. Segerstrom's first plant is currently being built in the Texas panhandle near corn farmers who are happy to have their waste bought and towed away. Segerstrom plans to build more plants as demand increases in small, Corn Belt towns around the country. Any money the farmers make on their stover is a bonus, since most leave it in their fields to decompose and be tilled into the soil the following spring.

Segerstrom believes his company will be able to produce CornBoard in a carbon negative way, meaning it will sequester more CO<sub>2</sub> than it uses to produce its products. Plus, he says, “every bit of board we make reduces board that comes from a tree. That's less trees that need to be cut down.”

He knows that consumers are eager to purchase green, but the main stumbling block is that environmentally friendly products often cost more than their less-green counterparts. Because CornBoard is being custom engineered for the specific product

it will become — the skateboard boards are designed specifically to become skateboards, the furniture boards to become furniture, etc. — they are a superior product than other pressed wood boards, Segerstrom says. And the company will ensure that their products never cost more than the same items made out of conventional materials.

“If we can deliver to the consumer at the same price a product that is better designed and better quality, then somebody is going to buy green over not green,” he says.

— Emily Stone



**University of Virginia, Charlottesville, Va.**

## Affordable, Green Buildings Hit Home for Students and the Community

For most of its 50-plus year history in the United States, the prefabricated or prefab home has been the ugly stepsister of the housing industry, disparaged for substandard quality and lack of design aesthetic. But a confluence of factors — from the advent of green building technologies and a natural disaster to the latest financial crisis — has prompted innovative architects to take a second look at the modular home.

After building an award-winning prefab home with a small army of students, John Quale, associate professor at the University of Virginia (UVA) School of Architecture, realized the modest modular offered him a wealth of opportunity: Building prefab homes in collaboration with the community would allow him to create environmentally conscious, energy-efficient and affordable housing — while providing a unique, hands-on learning experience for students.

### Winding His Way to Sustainable Housing

Quale never intended to teach architecture or pioneer sustainable building practices in the modular housing industry. His is one of those circuitous career paths that in retrospect, seems to make perfect sense.

As an undergrad at the American University School of International Service, he concentrated on international development and Asian studies. He spent time as a magazine photo editor before enrolling in the master of architecture program at UVA. After graduation, he worked on fantastic high-end residential and commercial projects for prestigious architecture firms, all the while looking for an opportunity to practice sustainable design.

“The ‘90s was the era of the ‘starchitect,’ and there wasn’t



Scott Smith Photography

University of Virginia students and faculty designed this house in Charlottesville, Va., to show that good, responsible design is achievable at low cost.

anyone with a design agenda that included sustainability,” says Quale, who is a Leadership in Energy & Environmental Design (LEED) accredited professional.

### Building a Solar-Powered Trojan Goat

Soon after Quale began teaching at his alma mater, a longtime UVA professor of electrical and computer engineering, P. Paxton



As an electrical engineer keenly aware of the country's energy issues, Marshall shared his colleague's concerns.

"The green movement caught on in the building industry, but affordable housing lagged behind, which meant those who could least afford it were saddled with higher utility bills," he says.

### ecoMOD: Build, Design, Evaluate

In 2004, the two professors established ecoMOD as a partnership between UVA's School of Architecture and School of Engineering and Applied Science and began looking for housing partners to collaborate on future building projects.

The goal of the design, build, evaluate project — which is fully integrated into both schools' curricula — is to create prefab, affordable housing units using rigorous standards for sustainable design. Guided by Quale and Marshall and various other faculty members and outside advisers, students from the architecture and engineering schools would spend a year designing the modular home, build over the summer, and then monitor and evaluate the finished product for an entire year.

"The University of Virginia's ecoMOD project is a terrific example of what can be accomplished when researchers from different fields of study come together to solve the world's problems," says W. Mark Crowell, executive director and associate vice president for innovation partnerships and commercialization at UVA. "Through this project, the University of Virginia's architects and engineers are pushing the boundaries of sustainable design to create affordable housing solutions, for our community and yours."

### ecoMOD1: The OUTin

Using a decommissioned airplane hangar owned by UVA, the first ecoMOD team started constructing its inaugural project: the OUTin, a two-unit condominium to be placed in a Charlottesville neighborhood. The condominiums, funded by the Piedmont Housing Alliance, became home to two of the housing organization's clients.

Marshall, Ph.D., came looking for a member of the architecture faculty to help build a home for the inaugural Solar Decathlon. The annual event, sponsored by the U.S. Department of Energy, challenges collegiate teams to design, build and operate cost-effective and energy-efficient houses totally powered by the sun.

Their collaboration produced the Trojan Goat, a 750-square-foot, solar-powered modular home designed and built by architecture and engineering students on the UVA campus and transported to the National Mall in Washington, D.C. Energized by the experience — the Trojan Goat won first place for design and livability and second place overall — Quale saw an opportunity to apply what they had learned from the competition to the affordable housing market.

"The Trojan Goat wasn't something that could be replicated in the real world," he says of the home, which cost more than \$350,000 to build. "I realized I wanted to do something similar, but with a social conscience."



“John was convinced there were economies of scale in off-site construction, where you have all your tools and labor there and you’re sheltered from weather,” says Marshall.

The OUTin condo was designed to merge the inside and outside, making the entire site habitable and usable. The condo project also included the area’s first potable rainwater collection system, a solar hot water panel and sustainably forested wood flooring from Virginia.

### A New Semester, a New House

Since the OUTin condo was completed in 2005, ecoMOD has built a total of six housing units, collecting a slew of awards and major press coverage in magazines such as *Metropolis*, *Dwell* and *Architectural Record*.

Each project is different from the last: one ecoMOD home was transported to Mississippi, where the local housing industry was hobbled by Hurricane Katrina; others have been strategically sited to aid in neighborhood redevelopment. Another was built as an accessory dwelling unit (ADU), behind an existing home. At 398 square feet, the ADU is the smallest building in the world certified by LEED, the internationally recognized green building certification system.

Quale says response from the community has been overwhelmingly positive — a large number of builders and other businesses have served as advisers and donated resources. When it makes sense, ecoMOD teams have pursued grant funding and the expertise of UVA faculty from other disciplines — such as landscape architecture and historic preservation.

“Ten years ago, very few architecture schools offered hands-on building opportunities like ecoMOD,” says Quale. “And although there are programs like ours around today, the collaborative nature of ecoMOD and the evaluation component set us apart.”



In the evaluation phase, team members analyze the home’s environmental impact, energy performance and comfort levels.

### Systems Testing and Homeowner Feedback

In the evaluation phase, students analyze the home’s environmental impact, energy performance and comfort levels, among other factors. Homeowner feedback as well as air temperature, humidity and utility-usage information gathered by a monitoring system installed in each ecoMOD home are also part of the comprehensive process.

Energy-efficient construction methods employed for ecoMOD1, such as the use of high-performance structural insulated panels, help the condominium outperform a comparable conventional home of the same size by 65 percent to 70 percent.

“I think we’ve done the best with insulation and sealing our homes,” says Marshall. “Our homes are very well-insulated and tight.”

### ecoMOD4: Going for Gold

The ecoMOD4 project, a townhouse built in partnership with

Habitat for Humanity of Greater Charlottesville, is likely to be the design that comes closest to net-zero energy usage. The hope is that the home, which features geothermal heating and cooling combined with solar panels, will also be certified gold or platinum through LEED.

“We’ve made good progress designing an energy-efficient home, lowering upfront costs and the cost of operating the home, and incorporating advanced technology but still creating affordable housing,” says Marshall.

At \$125 or less per square foot, the cost to build an ecoMOD home is well below the national average for a stick-built home and within the budgets of housing organizations such as Habitat for Humanity. Even more importantly, the utility costs for ecoMOD homes are also significantly decreased.

“The homeowner who lives in our ADU is our best spokesperson because he loves living there and tells everyone how about how low the utility bills are,” says Quale. “That’s what’s most rewarding, to see students go through the process from design to build to the homeowner moving in. And once homeowners live in [our homes], they really understand and appreciate what we were trying to do with the design. They get it.”

### The Student Experience

To date, more than 300 students have participated in ecoMOD, many of whom have been inspired to embark on careers that include a dedication to sustainability.

“I’m particularly proud of the value of this project for student education,” says Marshall. “There’s nothing else that provides students with a holistic experience like working on an ecoMOD team.”

The University of Virginia Patent Foundation has licensed its copyrighted designs to affordable housing organizations and continues to pursue nationwide commercialization channels so

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that ecoMOD designs may be built across the country.

“It’s all about getting the designs and the concept of sustainability out there,” says Quale.

ecoMOD continues to vigorously partner with organizations in the nonprofit sector, providing students with real-world project experience and a service-learning opportunity — while contributing to the inventory of affordable, sustainable housing.

“I’ve learned that students can accomplish a lot more than I ever believed possible,” says Marshall. “They can be out addressing the real problems of society.”

— Mary Roberts Henderson



A close-up photograph of a woman with dark skin, wearing a red headwrap with a white and yellow geometric pattern. She is holding a baby who is wearing a pink long-sleeved shirt and a white headband. The woman is looking down at the baby with a gentle expression. The background is a light-colored, textured wall, possibly made of wood or plaster.

## Technologies to Improve Health



École de technologie supérieure, Montreal, Quebec, Canada

## Device Helps Knee-Pain Sufferers Get Back on Their Feet



A technician affixes the exoskeleton of the KneeKG to a patient's leg.

Most drivers hate red lights. But motorists with knee pain might want to reconsider. Thanks to a chance meeting at a stoplight, patients can now get more accurate diagnosis and treatment for their conditions.

The key is a motion-capture-and-analysis device called Knee Kinematics Graphs, or KneeKG. KneeKG allows health care professionals to test a patient's knee function while the patient walks on a treadmill. X-rays and MRIs can only take images of the knee while it is still.

What's more, KneeKG costs less than X-ray or MRI machines. And, with the help of two Canadian technology transfer organizations, the device is on the market in Canada and approved for

use in the United States.

The technology benefits anyone with knee pain — both professional athletes and the general population. That includes workers whose jobs are hard on their knees, such as mail carriers and rug installers. In countries with aging populations, osteoarthritis is the most common cause of knee pain in people who reach middle age, no matter what a patient's profession.

In fact, American patients visit their doctors about 19 million times a year for knee problems, according to the American Academy of Orthopaedic Surgeons. Knee pain and other bone and joint problems represent the most disabling and costly medical issues in countries such as the United States.

### The Questions That Led to a 20-Year Project

The story of how the device came to market is almost as complex as the knee it was designed to analyze. It offers a clear picture of how technology can help those who need it, thanks to more than 20 researchers, three universities and multiple funding agencies.

Back in 1990, an orthopedic surgeon came to Jacques de Guise, Ph.D., with two questions: How could he limit harmful stresses on a patient's knee ligaments? And was there an optimum position in which the stresses were minimal for the ligament in the knee?

The orthopedist was performing knee surgery on patients with injuries to ligaments such as the anterior cruciate ligament, or ACL. An ACL tear, an injury familiar to many athletes, can be debilitating. Surgery does not always restore a patient's knee to its pre-injury function.





De Guise quickly realized that, to get answers to his questions, the doctor would need to be able to provide a 3-D image of the knee in motion. Unlike an X-ray or MRI, which provides a two-dimensional picture of the knee, the device de Guise envisioned would capture the knee's motion and present it as a 3-D image. However, no existing device could provide such information.

Besides that, getting a portrait of the joint would not be easy because the knee's movement is quite complex. The only way to capture such data was to surgically implant pins into the knee, with wiring leading to a motion-capture device that would compute the data.

### Why Did the Professor Cross the Road?

At the time, de Guise was a professor of biomedical engineering at the École de technologie supérieure (ETS) in Montreal. But, the engineering school did not have any medical faculty, something de Guise needed in order to work with a physician.

So de Guise went across the road to the University of Montreal and took a position as an adjunct professor at the faculty of medicine and as a researcher at the University of Montreal Hospital Centre, or CHUM. He continues his work at both institutions today, with multiple roles at each organization.

"My left arm is at the ETS, and the right arm is at the University of Montreal," de Guise jokes. "My head is in between."

With his appointment at the University of Montreal, de Guise was able to install an ETS lab at the CHUM Research Center, the Imaging and Orthopedics Research Laboratory (LIO). At the LIO, he and his students began investigating different options for obtaining data about the knee.

First they reviewed medical literature to see if other researchers had already found a technique for capturing movement with motion sensors. The group did not find anything, so they brainstormed solutions and did an anatomical study of the knee's structure.

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De Guise was riding his bicycle one day in 2000 when a former engineering classmate, Francois Bastien, pulled up next to him in a car at a red light. When Bastien asked what he was up to, de Guise told his former classmate about his research. Bastien asked de Guise why he hadn't commercialized the invention.

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The idea that emerged from those efforts involved a special motion-sensor attachment system — a knee brace that allowed the quasi-rigid fixation of movement sensors to the knee. In 1994 they came up with the prototype of a fixation system in which a motion detector could be firmly attached to a patient's lower limb.

Their next task involved describing the knee's motion so they could design software that would compute the mechanical stresses to the ACL. That allowed de Guise to show the surgeon the best way to perform orthopedic surgery.

Once they had the hardware and software to record the kinematics — the movement of the knee — de Guise and his students undertook the next phase of research: looking at normal kinematics versus abnormal kinematics.

The funding for the initial research came from several sources. They included NSERC (the National Sciences and Engineering Research Council of Canada) and FQRNT (The Quebec Fund for Research on Nature and Technology). De Guise also secured a grant from the Canadian Institutes of Health Research to study patients with osteoarthritis of the knee.



### Red Light Leads to Green-Lighting of Project

What happened next put the project on a different footing.

De Guise was riding his bicycle one day in 2000 when a former engineering classmate, Francois Bastien, pulled up next to him in a car at a red light. When Bastien asked what he was up to, de Guise told his former classmate about his research. Bastien asked de Guise why he hadn't commercialized the invention.

The two quickly became business partners and created a new company called Solution YD3. On top of the grants de Guise had received, Solution YD3 obtained funding from INNOV, a special innovation-funding program from NSERC.

"A researcher is always seeking more money," de Guise says.

For a time, the project received adequate funding. And over the course of its development, more than 20 graduate students worked on the KneeKG.

L'Hocine Yahia, a professor at ETS, and Nicolas Duval, a surgeon, worked with several students to help de Guise get the device into clinics and show how it could work in a clinical setting.

However, economics eventually threatened to sideline the project.

Although some Solution YD3 employees were working on the KneeKG project full time, they were not drawing a salary. And, without enough people to continue development, progress would grind to a halt.

So de Guise approached the two universities where he worked. Each had a technology transfer office.

Together, Valeo — the technology transfer agency for ETS — and Univalor — the University of Montreal's technology transfer organization — retired the original KneeKG license and found a new licensee, Emovi Inc.

Valeo and Univalor had asked Quebec-based Emovi to identify any barriers to commercialization for the device. When Solution YD3 gave up its rights to the license, Emovi president and CEO Michelle Laflamme expressed interest in acquiring the license. Emovi, which provides medical products to health care providers, obtained the license for KneeKG in 2007.

Jean Bélanger, director of the Centre for experimentation and technology transfer at the ETS, explains why the university was interested in licensing the technology.

"KneeKG offers a quick way to diagnose the mechanical causess of the knee problems," Bélanger says. "There are not too many techniques that assess the knee in dynamic and weight-bearing conditions, in fact, this is the sole product available for clinical settings. And, it's noninvasive."

Health care providers can use the KneeKG in settings such as doctors' offices, hospitals, clinics and rehab facilities. It helps health care professionals in several ways:

- Looking at whether the knee is functioning normally
- Diagnosing the cause of knee pain
- Allowing comparison of knee function before and after treatment
- Getting a baseline of the patient's knee function for comparison in case of future injury, damage or disease

The device is also much more user-friendly than other systems that analyze the knee while in motion, in a weight-bearing position. Although some laboratories in universities and hospitals can perform similar analyses, those systems are not available in a clinical setting.

What makes KneeKG different from other systems is that it accurately analyzes the function of the knee joint in a clinical setting. A technician performs the 15-minute test. Afterward the device generates an easy-to-read report about the findings.



### Licensee Offers a Leg Up

Emovi has been integrating the device into its care protocol at its Emovi Knee Clinic since 2008. According to Laflamme, Emovi invested in the project with two objectives: First, to develop software applications to make the results easily understandable. This technology then demonstrates its added value to the patient, the physician and the health care system.

Second, to develop a database of different knee conditions, diseases and abnormalities. This not only adds to the value of the technology, it also advances the science as it relates to the knee.

The software applications that have been developed cover different angles:

- Highlighting knee-function problems that are linked to known diseases or conditions, to help the investigation of symptoms
- Clinical scores enabling easy post-treatment followup
- Pre- and postsurgery information for total-knee and ACL surgeries
- Diagnostic applications for general practitioners

“Emovi aims to help physicians revolutionize the way they evaluate knee problems,” Laflamme explains. “This empowers doctors to provide top-notch knee care.”

### Working with Universities Allows Licensees to Put Their Best Foot Forward

Laflamme says her company first became involved with the two universities because Emovi wanted to license the technology. Now the company has developed a solid relationship with the universities.

“It’s something other companies should look at, when they want to innovate,” Laflamme says. “More companies should work with universities. They have terrific knowledge and are also aware of development around the world. Plus, they are

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“It’s something other companies should look at, when they want to innovate,” Laflamme says. “More companies should work with universities. They have terrific knowledge and are also aware of development around the world. Plus, they are the best spokespeople for the innovation because they know it by heart.”

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the best spokespeople for the innovation because they know it by heart.”

Emovi now focuses on two activities: developing and selling the KneeKG, and operating its knee clinics.

As of early 2011, health care professionals are using the KneeKG in two Emovi clinics in Canada. Emovi has also sold its first units for use in a hospital in Lyon, France.

In addition, Emovi has gotten approval from the Food and Drug Administration to sell the device in the United States. Laflamme says the company is targeting about 10,000 orthopaedic surgeons in the United States, specifically those at the country’s 2,000 or so orthopedic and sports-medicine clinics.

As for de Guise, he is continuing his work at both the ETS and the University of Montreal, thanks to grants from the FQRNT and the Fonds de Recherches en Santé du Québec. Due to his efforts to help patients with knee pain, people can get back to work, play with their grandchildren and even ride their bikes — perhaps providing someone else with a chance for a life-changing encounter at a stoplight, too.

— Kirsten Lambert



**Emory University, Atlanta, Ga.**

## Insect Catcher Lightens the Load for Researchers Battling Mosquito-Borne Illnesses



Emory University researchers are testing the ProkoPack in the underground tunnels of Atlanta, Ga., to reach mosquitoes located in the 15-foot-high ceilings.

The members of a research team from the Department of Environmental Studies at Emory University had one goal in mind when they began a project in Atlanta. They wanted to determine how the West Nile virus was transmitted by mosquitoes in an urban environment. Little did they know they would end up becoming known worldwide as inventors of the ProkoPack

mosquito aspirator, a novel, inexpensive and efficient way to monitor adult mosquitoes and the deadly diseases they carry worldwide.

Their work with this tiny insect is no small matter. According to the World Health Organization, each year some 500 million people are infected with mosquito-borne illnesses: dengue, malaria, yellow fever and various forms of encephalitis, including West Nile virus. More than 2.5 million die, many of them young children. Mosquito infestations can be particularly troublesome in the wake of natural disasters such as floods or earthquakes — environments in which the tiny pests thrive and plague victims during times of stress while hindering recovery efforts.

Therefore, monitoring mosquitoes is a crucial, life-saving step in the battle against mosquito-borne illnesses.

Enter the Emory research team. In 2008, Emory's Gonzalo Vazquez-Prokopec, Ph.D., a postdoctoral fellow working with Uriel Kitron, Ph.D., MPH, and chair of Emory's Department of Environmental Studies, set out to find if mosquitoes that harbor West Nile virus were overwintering — or hibernating — in the ceilings of 15-foot-high Atlanta sewer tunnels. However, they knew before they even began that reaching the mosquitoes was going to pose a challenge: The gold standard device for collecting resting mosquitoes for research and disease-monitoring purposes, the Centers for Disease Control and Prevention backpack aspirator (CDC-BP), had only a 6-foot reach.

Developed in the mid-1980s, the main principle behind the CDC device is to use air suction similar to a vacuum cleaner to collect mosquitoes that are resting in various habitats, including in homes' walls and under beds. CDC aspirators are commonly



used by researchers and public health technicians to collect certain mosquito species inside houses and determine their numbers and potential infection with disease-causing pathogens.

### Challenge Was to Remove the Bulk

In addition to not providing the correct reach, the CDC-BP, which resembles the bulky backpacks used in the 1980s by the Ghostbusters characters, weighs about 26 pounds. “I kept thinking, ‘Why do I need a heavy motor on my back when I need to get suction to go to the ceiling?’ That was the spark — we didn’t need to go so heavy,” says Vazquez-Prokopec.

“It’s not like we woke up one day and said ‘Let’s invent a mosquito aspirator,’” says Vazquez-Prokopec. “It grew out of our needs during field research.”

The research team, with technical support from William Galvin (an undergraduate student at Emory), began the design process by looking for the perfect lightweight motor. Using lab startup funds, they made numerous trips to local hardware stores to purchase and test different varieties of battery-powered motors to find the one that would provide just enough suction power to capture the mosquitoes, but keep them alive for analysis.

After deciding on the motor, co-inventor Kitron says their next concern was focusing on parts that could be found in a developing country. Kitron and Vazquez-Prokopec wanted the device to be cheap, easy to fix and simple to use. They found a painter’s extension pole to give the device the height they needed and attached a plastic container covered by a wire screen to the battery-powered motor using a plumbing pipe coupler. The resulting device weighs 2 pounds and is easily maneuvered by one person. “And, you don’t have to be taught how to use it,” notes Kitron.

### Collecting More Mosquitoes

In addition to reaching higher into ceilings and upper foliage, the “ProkoPack collects more mosquitoes than the CDC-BP,” says Vazquez-Prokopec. “Because it can reach into locations

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**“It’s not like we woke up one day and said, ‘Let’s invent a mosquito aspirator,’” says Vazquez-Prokopec. “It grew out of our needs during field research.”**

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where engorged females rest after a blood meal — such as under beds — more of the collected specimens are engorged with blood, so we can figure out in a lab where they are feeding from and whether or not they are infected,” says Vazquez-Prokopec. The ProkoPack “has broad potential, not only for getting more accurate counts of mosquito populations, but for better understanding mosquito ecology.”

For decades, public health officials in developing nations have relied on low-tech and low-price methods to conduct mosquito surveillance. One of the most popular methods is to spray the inside of a home with insecticide, and gather all the bugs that fall to the ground. Not only is the procedure time-consuming, but many of the mosquitoes are dead when they hit the ground. The ProkoPack takes only 10 minutes to make a collection and most of the mosquitoes are caught alive, allowing for better preservation of samples for future processing. Vazquez-Prokopec says better monitoring of mosquito populations makes it easier to take action against them.

The ProkoPack has outperformed the CDC-BP in field tests in underground tunnels in Atlanta and in indoor collections in Iquitos, Peru, during a dengue fever study. It was during the Peru field study that the Emory team named the device. “We wanted a catchy name, not just ‘the mosquito aspirator,’” says Vazquez-Prokopec. “We came up with a combination of my last name and ‘pack.’ As the inventor, I am very proud of the name ProkoPack.”

Kitron is most pleased with how the ProkoPack has been embraced by researchers. The key to exploring mosquito-borne





Caring for the ones in most need: The ProkoPack is being used to collect malaria vectors in coastal Kenya.

diseases, he says, is having a good understanding of the risk and the mosquito population in a particular area. Fellow researchers in Africa have embraced this alternative to the time-consuming spraying of houses, which requires more equipment and more technicians and is inconvenient for residents who must leave their homes. Because data can be collected by one person in only 10 minutes, it is much easier to target problem houses.

The device is currently being tested in different epidemiological settings including: Coastal Kenya, Zambia and Tanzania for malaria vectors; in Australia, Mexico, Argentina, Thailand and Peru for dengue fever vectors; and in Italy for West Nile virus.

Many institutions in the United States have purchased ProkoPacks to use in local settings. Public health offices in Virginia and Illinois are using the units to monitor West Nile virus mosquito vectors. Researches in Michigan, Illinois and Indiana have purchased units to perform research on different mosquito vectors, and the U.S. Department of Agriculture is interested in purchasing units to test with agricultural pests.

### **ProkoPack More Affordable**

Emory University is selling the ProkoPack for \$150 to cover production costs. By comparison, the CDC-BP sells anywhere from \$500 to \$750. Because of the affordable price and portability,

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The ProkoPack is a natural fit for Emory University's Office of Technology Transfer (OTT) licensing principles that focus on humanitarian use, says Chris Paschall, Ph.D., CLP, and licensing associate for the OTT. "Our license agreements include provisions that a device or drug has to be readily available to populations that otherwise could not be reached."

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more developing countries will be able to afford the ProkoPack, says Vazquez-Prokopec. "I come from a developing country, Argentina, so I know what it means to be in a place where you can't get something because of money," he adds. "We are making this technology available for people in places most in need.

"There is a great need for effective and affordable mosquito sampling methods," he continues. "Use of the ProkoPack can increase the coverage area and the quality of data collected. Ultimately, we hope it can help us develop better intervention strategies that are more effective than what we currently have."

### **Focusing on Use in Developing Countries**

That the device is a more affordable alternative to mosquito collection is something that the university supports as well. The ProkoPack is a natural fit for Emory University's Office of Technology Transfer (OTT) licensing principles that focus on humanitarian use, says Chris Paschall, Ph.D., CLP, and licensing associate for the OTT. "Our license agreements include provisions that a device or drug has to be readily available to populations that otherwise could not be reached."





Paschall, who helped develop the licensing strategy and payment procedure, says this has been a fun project to manage because so many researchers are excited about collecting mosquito samples with a device that is lightweight and easy to use, especially in hot and muggy tropical climates. “We have been thrilled to make available a device that is inexpensive and works better than anything else on the market and that has that lowered the bar for entry for countries around the globe,” he says. “It’s very exciting to be a part of that.”

The OTT staff contemplated two different licensing strategies to commercialize the ProkoPack. The first idea was to license the device exclusively to an existing company for manufacturing, marketing, sales and distribution. The downside of that strategy was that the company would charge a fee for the services, adding to the cost of the device.

“If the device was too expensive, it would be out of reach for many of the countries who need it most,” says Paschall.

To keep costs down, the OTT decided to employ a nonexclusive licensing strategy and manufacture and distribute the device directly from Emory. The device is sold at cost and users sign a click-through-type license and payment agreement. By utilizing this strategy, “the device is cheap enough for nearly anyone in the world, and we can distribute it very quickly,” says Paschall.

After the earthquake in Haiti, Vazquez-Prokopec sent three ProkoPacks to the CDC for collection of mosquitoes due to concern that conditions would be ripe for transmission of dengue fever. Co-inventor Kitron says that’s exactly the type of activity that fits with the Department of Environmental Studies’ mission to be a leader in global health. In addition, the scientists published simple instructions on how to make the ProkoPack in the *Journal of Medical Entomology*.

### Data Useful for Developing Mosquito Intervention Methods

“The ProkoPack is extremely effective in showing public health

## After the earthquake in Haiti, Vazquez-Prokopec sent three ProkoPacks to the CDC for collection of mosquitoes due to concern that conditions would be ripe for transmission of dengue fever.

officials how malaria vectors are distributed between houses and even within a house,” says Kitron, “which in turn will help them to reduce the transmission of the disease by collecting data they need to target mosquito intervention.”

Because mosquitoes and other vectors are such a worldwide public health issue, the device is being tested by scientific colleagues from multiple institutions including the CDC, Johns Hopkins Bloomberg School of Public Health in Baltimore, Md.; University of Torino in Torino, Italy; and James Cook University in Townsville, Queensland, Australia. Part of the licensing agreement requires the scientists to share feedback on the device, which Vazquez-Prokopec says his research team will welcome to make improvements.

Kitron hopes the simplicity and ease of the ProkoPack will lead public health agencies to not only address mosquito-borne diseases before and during an outbreak, but also after an outbreak to see how the control measures they applied are working.

“We did not cure a mosquito-borne disease, but we opened new doors in terms of mosquito research and surveillance at an affordable price,” says Vazquez-Prokopec. “We moved from building a tool to get to the ceiling to designing a tool that can be used worldwide to measure other vectors more effectively than traditional methods.”

— Susan Zelvin Weiss



Lawrence Berkeley National Laboratory, Berkeley, Calif.

## DNA Microarray Rapidly Profiles Microbial Populations

Photo courtesy of  
Lawrence Berkeley National Laboratory



The PhycChip technology provides an efficient and accurate way to identify and monitor microbial populations.

Microbial threats, it seems, might be anywhere — bioweapons in the air and water, pathogens in the food supply, diseases in the human population, and changes in microbial populations in the environment, whether the result of natural or human activity.

A number of government agencies and health and medical researchers would like to monitor microbial populations to help keep us safe, cure our diseases and protect the environment. But it's not that easy. In fact, until recently it's been hard — exceedingly hard — to monitor microbial populations with any kind of depth and accuracy.

Oh, sure, a researcher could grab a sample, try to culture it in a petri dish and see what's there. But when you culture bacteria, you're creating an artificial, unnatural environment for the bacteria, and only a small proportion of the bacteria will actually

grow under those conditions. If you want to do a more rigorous DNA analysis on the sample, the conventional techniques for preparing samples are tedious, finicky, expensive, error-prone and grindingly slow. Some labs have tried to use robots to automate the sample preparation process. It's rumored that the robots quit because the work was too boring.

Now, thanks to research at Lawrence Berkeley National Laboratory, efficient technology transfer and a startup company, there is a much faster, efficient and accurate way to identify and monitor microbial populations. It's called PhycChip technology.

### The Evolution of a Breakthrough

Gary Andersen, Ph.D., Molecular Microbial Ecology group leader at Lawrence Berkeley National Laboratory (LBNL), is not a man given to puffing himself up. He says, "To start, you have to realize that we have made our accomplishments only by standing on the shoulders of giants. The mid-1990s were a revolutionary time in biology, and my colleagues and I owe a lot to the achievements of those researchers.

"There are two keys that make PhycChip technology possible," Andersen says. "The first is the discovery that the 16S ribosomal gene — a 1,500-base DNA sequence that all bacteria have — is like a barcode for a bacterium. The 16S gene is used in the assembly of protein, and it's different for every species of bacteria. Researchers have built up a large database of 16S gene sequences from different bacteria, so that now if you have a new community of bacteria, you could identify it on the basis of the previously known 16S sequences."

The second key development, Andersen relates, was the use of DNA microarrays to identify DNA sequences. A DNA microarray is a pattern of microscopic DNA "probes" arranged on a chip. Each probe is a precise sequence of DNA, and it has



the capability to detect a specific DNA target. When a sample that has been treated with fluorescent dye is passed over a microarray, researchers can then tell, by looking at the glowing dots on the microarray, which specific DNA targets have been detected. Initially researchers were using microarrays to detect the expression of genes. At first it was possible to test only for 100 different DNA targets, but soon it was possible to test for thousands using more advanced microarrays.

“We were the first research team to figure out that this technology could be used to identify bacteria by looking for specific pieces of the 16S gene,” Andersen says. “Originally, I experimented with 98-well microtiter plates, and it worked. The first array in its present form that we used had 16,000 probes. That was a huge jump, and it paved the way for making much larger arrays and eventually analyzing them by computer.”

Andersen adds, “The other key things we did were to figure out a way to group the probes together to rapidly distinguish one set of targets from another, to make the probes smaller to increase specificity of identification and to use multiple probes to identify each bacteria, which greatly increases our confidence of correct identification.”

### Going Big Time

With funding from the Department of Homeland Security, Andersen continued to develop and refine PhyloChip technology. And he wasn't alone.

Todd DeSantis, software developer in the Molecular Microbial Ecology group at LBNL, says, “We found out three important things. First, the technology is highly scalable. We started with 16,000 probes in an array, and now we're up to over a million.

“Second, our results are not just qualitative — that is, we can see which species of bacteria are present — but also quantitative: From sample to sample we can see which bacteria are growing in a population. It's tremendously important in ecological and clinical studies to see what the trend is over time.”

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It took, instead, a chance conversation to get PhyloChip technology licensed. One day Corey Goodman, who was between executive assignments and would ultimately become one of the founders of the company that licensed the technology, was chatting with a neighbor. The neighbor was involved in a water quality experiment involving PhyloChip technology and was raving about it. “You have to check this out!” he said to Goodman.

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Third, DeSantis states, the results are highly reproducible in tracking even the low abundance organisms. “That's critical to making sure the changes you are seeing are real and not some artifact of testing error,” he says.

He also notes that as the number of probes on a PhyloChip array has exploded, the ability to analyze the results by computer has become an absolute necessity. “If you were to try to analyze a million-probe chip by hand, it would be just as tedious, time-consuming and error-prone as the old DNA analysis techniques that PhyloChip technology replaces. The computer speeds and refines the process.”

### Licensing the Technology

Virginia de la Puente, senior licensing associate in Technology Transfer and Intellectual Property Management at LBNL, is the first to admit that the licensing history of PhyloChip technology is unusual. “This technology was the overall third-place winner for *The Wall Street Journal's* 2008 Technology Innovation Awards. You might think that would pretty much guarantee a



### The Realities of Bringing PhyloChip Technology to the Marketplace

In April 2009, a company called PhyloTech was set up specifically to commercialize the PhyloChip technology. “In a very short time, we got the technology transferred and up and running,” says Rachel Steger, marketing director for the company. By July 2010, we started selling to customers. That speaks very well to the tech transfer process, which allowed us to commercialize very quickly. In 2011, we’re making money and paying royalties.”

Steger notes that there is a huge effort in the research community to understand the human microbiome — that is, all the bacteria that reside in and on the human body. She says, “It turns out that any individual has far more bacterial cells than human cells, so many in fact that it amounts to a second genome. This second genome is not well-understood, but our technology is uniquely useful in helping researchers to get a handle on it. Because of that, our company was recently re-named Second Genome.”

She adds, “We are selling a service. Customers send us raw or processed biological samples. We do laboratory processing using the PhyloChip technology and perform data analysis on the results. Most of our customers are doing research in academic labs, but we also have customers in industry and in specific applied markets involving waterborne detection. Using conventional techniques, it could take years to get the detailed data that we can provide in just weeks.”

PhyloChip technology has already been put to good use in detecting oil-digesting bacteria in the plume from the BP Deepwater Horizon oil spill, in profiling microbial populations in floodwaters from levee breaks following Hurricane Katrina and in assessing the health of coral reefs. When the next microbial threat or research question arises, it seems likely Second Genome and PhyloChip technology will play a significant role in keeping us safe, curing our diseases and protecting the environment.

— Jock Elliott

licensing deal, but it was not to be. We had three or four companies interested, but none of them came back with a proposal.” She adds, “There is a certain amount of tension in tech transfer. Big companies want a certain level of development, and small companies generally don’t have a lot of money. You have to find the company that’s the right fit for the technology.”

It took, instead, a chance conversation to get PhyloChip technology licensed. One day Corey Goodman, who was between executive assignments and would ultimately become one of the founders of the company that licensed the technology, was chatting with a neighbor. The neighbor was involved in a water quality experiment involving PhyloChip technology and was raving about it. “You have to check this out!” he said to Goodman.

De la Puente says, “Goodman did check it out and soon entered into a six-month option agreement for the PhyloChip technology. Then this agreement was extended for another six months. The team Goodman put together hired a pretty aggressive law firm and negotiated hard. Finally a license agreement was signed.”



**Massachusetts Institute of Technology, Cambridge, Mass.**

## New Device Offers Pain Relief to People Suffering from Chronic Bladder Condition

When Massachusetts Institute of Technology (MIT) professor Michael J. Cima, Ph.D., learned that the most commonly used treatment to relieve the pain of interstitial cystitis (IC) is ineffective and can cause severe complications, he thought, “I can do something about that.”

One aspect of MIT’s mission is to commercialize technology arising from the research conducted by its inventors. Cima fulfilled the mission by inventing a device to treat the pain of hundreds of thousands of people in the United States who suffer from IC, a chronic inflammation of the tissues of the bladder wall that causes patients to make as many as 50 trips to the bathroom every day.

Cima, who teaches material science and engineering and is the inventor of several medical devices that incorporate material science technology, assembled a research team in 2007 that includes peers from MIT and one from Children’s Hospital Boston. By the end of one year, the team came up with a drug-delivery system called LiRIS, which stands for lidocaine-releasing intravesical system.

Now in its first phase of clinical trials, LiRIS is “moving along rapidly and is expected to reach the market within five years,” says Tom Tachovsky, Ph.D., a technology licensing officer at MIT. The device, licensed by the MIT Technology Licensing Office and its licensing partner, Children’s Hospital Boston, is being tested and will be manufactured and marketed by Taris Biomedical of Lexington, Mass., which was founded in 2008 by Cima and others specifically to launch LiRIS.

“Big companies are not always willing to invest in new technologies such as this,” says Tachovsky. “So we felt licensing to a



Shutterstock: Dudarev Mikhail

startup, which is more willing to take some risks, would be the best way to develop this device.”

Plus, says Tachovsky, this approach benefited from another important asset: the innovator himself. “Michael is not only an academic, but he’s a serial entrepreneur so we were confident that, with him providing scientific guidance, the technology would be commercially developed.”

### How LiRIS Works

The current treatment for alleviating the pain of IC consists of infusing a “wash” of dimethylsulfoxide and lidocaine into the ureter through a catheter. Relief lasts about 90 minutes, at most. Patients often call their urologists an hour later in dire pain.

LiRIS, however, delivers an extended-release dose of lidocaine, which lasts about two weeks, directly into the bladder through a





tube designed by Cima that is made of elastomers, which are a type of polymer. Both the current treatment and the one using LiRIS are performed in a doctor's office.

Cima says LiRIS uses shape memory technology that allows it to “fold up into the shape of a pretzel so it stays inside the urethra” — the canal that empties from the body the urine that collects in the bladder.

LiRIS is less invasive, greatly reduces the chance of infection and can be easily inserted and removed. Also unlike the current system, the device isn't at risk of damaging the bladder or causing possible side effects.

### The Heartbreak of IC

According to the National Kidney and Urologic Disease Information Clearinghouse, more than 1 million people in the United States suffer from IC, a disease of unknown origin. IC is sometimes called overactive bladder, a term that belies its severity, says Cima. In addition to constant pain, sufferers experience incontinence, urinary urgency, debilitation, depression and the reality that there is no cure.

In addition to the current treatment of douching the bladder through a catheter, other treatments — such as oral opioids, relaxation techniques, physical therapy and biofeedback — are used but with, at most, temporary success. When all else fails, doctors sometimes remove the bladder.

“But even then, patients still have pain from the nerve damage caused by the repeated wash treatment,” Cima says.

To add insult to injury, as recently as 15 years ago “urologists thought patients who had all the symptoms of IC were crazy,” he says. “They did not think that IC was a real disease.”

But for those dealing with chronic pain and the decrease in quality of life that came with it, IC is very real. Cima says some of the clinical study patients have tracked him down at his office

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**“But even then, patients still have pain from the nerve damage caused by the repeated wash treatment,” Cima says.**

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because they're so desperate to get relief from the constant pain.

Only about half of IC sufferers have been diagnosed with the disease, Cima says, because the remaining half are too embarrassed to talk about their symptoms with their doctor.

Patients usually display symptoms for a long time prior to diagnosis. IC usually is diagnosed by ruling out other possible conditions. It is common for doctors to misdiagnose the disease as a bladder or urinary tract infection, and then to prescribe antibiotics, which do nothing to help. On average, it takes about 18 months to diagnosis IC, Cima says.

### Relief Is on the Way

LiRIS comes not a moment too soon, and no doubt it will be enthusiastically received, Cima says, not only by those who suffer from IC — predominantly women and older men — but also by urologists, because “there's a huge unmet need.”

The beauty of the LiRIS device is that “it's not rocket science,” says Cima, whose team is composed of MIT researchers Mario Castillo-Ortiz, Karen Danielle Daniel, Steven Froelich, Hong Linh Ho Duc, Grace Young Kim and Heejin Lee, as well as Jordan Dimitrakov of Children's Hospital Boston.

“Our objective is to keep the cost of care less than or equal to what it is now,” Cima says, “and to produce a more efficacious outcome. LiRIS is designed for flareups and episodic pain, which means that patients need to be treated three times a year. That means three office visits to put the device in and three visits to take it out.”





## The Benefits of Cross-Disciplinary Collaboration

LiRIS, Tachovsky says, is good example of collaboration among disciplines at MIT.

“Usually there’s little cross-talk between disciplines,” Tachovsky says. But that isn’t the case with Cima, whom Tachovsky calls representative of a “new era of investigator” who uses his expertise in material science and engineering to tackle medical problems and “come up with integrated solutions.” Cima does his research at the Koch Center at MIT, a facility designed to mix faculty, postdocs and students on each floor thus promoting interdisciplinary collaboration.

In the case of LiRIS, Cima and his team collaborated with MIT’s departments of biology and mechanical and electrical engineering, as well as with researchers at MIT’s David H. Koch Institute for Integrative Cancer Research. The various departments shared the expense of bringing LiRIS to fruition and also were funded by MIT’s Deshpande Fund, which was created in 2002 to help technologies and ideas developed in the institute’s labs make their way to the marketplace.

## Next Steps

At Taris, LiRIS is nearing the end of Phase 1, which is the developmental stage in which Taris’ scientists continue to work on LiRIS’ design, do human testing and collect data. The Food and Drug Administration then will review Taris’ protocols and determine if the company can move to Phase 2.

Upon FDA approval of the final version of LiRIS, which Tachovsky estimates could happen as soon as 2014 or 2015, LiRIS will be put to use in the offices of urologists in the United States and, Taris hopes, doctors’ offices throughout the world.

Last year, volunteers in Taris’ clinical study tested the LiRIS device without the lidocaine to see if they could feel it in their body. No one could sense it, Cima says.

“What we learned with an empty system is that the device is

highly tolerable,” says Julie Himes, M.D., who is one of Taris’ founders, its chief medical officer and its senior vice president of clinical development, as well as an internist in infectious diseases.

Not only is the device comfortable for users, Cima says, it’s also not harmful.

“We’re very confident that what we’re doing is safe,” Cima says. “Our data are clear on this. Now we’re building a case by conducting carefully controlled studies that show that LiRIS is efficacious.”

In addition to helping alleviate the pain of interstitial cystitis, Cima and his team believe that LiRIS eventually can be used to deliver chemotherapy to patients who have bladder cancer and to aid in the treatment of other diseases of the bladder. He says there’s also the possibility that LiRIS can be designed to provide pain relief for longer than two weeks.

“Urologists whom we work with in our clinical trials are very excited about LiRIS,” Himes says. “They’ve given us lots of feedback — all helpful and positive.”

One of the nicest things about LiRIS, Himes says, is that Cima and his team have invented a technology that “fits well with what urologists currently use in trying to treat interstitial cystitis.” This means that “doctors will find LiRIS easy to deploy,” she says, and that it will be adopted rapidly.

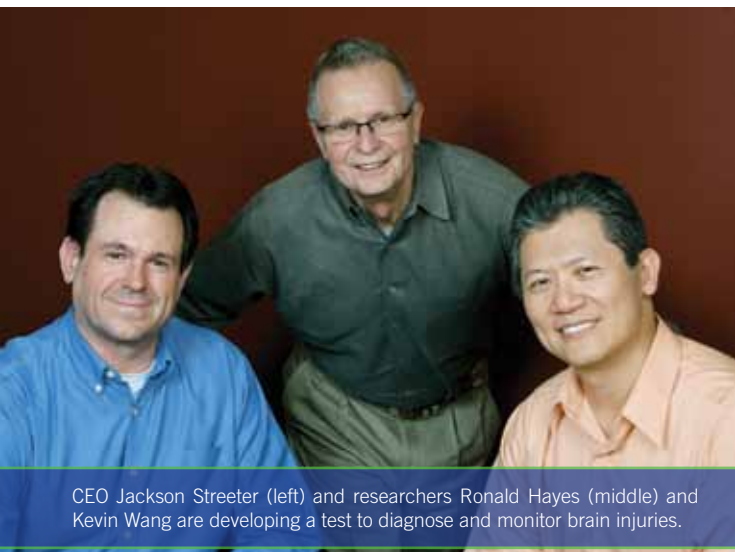
More importantly, says Tachovsky, this technology has the power to help millions of people recover from chronic pain and make huge gains in quality of life. “This device is offering hope to lots of people,” he says. “I feel fortunate to be part of that.”

— Deborah Leigh Wood



University of Florida, Gainesville, Fla.

## Florida Researchers Develop the First Blood Test to Diagnose Brain Injuries



CEO Jackson Streeter (left) and researchers Ronald Hayes (middle) and Kevin Wang are developing a test to diagnose and monitor brain injuries.

When actress Natasha Richardson died of an epidural hematoma after an accidental fall on a ski slope in 2009, many people were shocked. How could something like this happen? Why didn't the doctors *do* something?

The fact is, head trauma is frustratingly difficult to diagnose. Traumatic brain injury (TBI) creates a perplexing set of circumstances for medical staff for many reasons.

As was the case for Richardson, patients frequently remain conscious after a head trauma and underreport their discomfort because the injury can impact thinking, memory and objectivity. Emergency room personnel check vital signs such as heart rate and blood pressure but can easily misdiagnose whether it's

a brain injury, stroke or something entirely different. Medical staff may incorrectly prescribe unnecessary tests, fail to order a necessary test like a CT scan or recommend no treatment when it is required.

More than a million people suffer from TBI every year, resulting in more than 50,000 deaths. According to the Centers for Disease Control and Prevention, each year, 1.7 million people sustain a traumatic brain injury. Many more TBI-related disability cases are unreported. TBI contributes to a third of all injury-related deaths in the United States, and there was an increase in TBI-related ER visits and hospitalizations between 2002-2006.

Perhaps most disturbing is that after a natural disaster, children are susceptible to TBI inflicted by their parents as a consequence of the high level of stress. According to a study published by researchers in the Department of Social Medicine at the University of North Carolina in the *American Journal of Preventive Medicine* in April 2004, the incidence of TBI is higher for children living in areas recovering from severe, weather-related adversity.

### Making Patients Better by Better Diagnosing

With the number of traumatic brain injuries so large, why hasn't there been a better way to diagnose them?

This was the question that Ron L. Hayes, Ph.D., a tenured professor of neuroscience at the McKnight Brain Institute of the University of Florida, was asking in the late 1990s and early 2000s, almost a decade before Richardson's death.

"We weren't diagnosing brain injury very well," says Hayes, who



was the former director of the University of Florida Center for Traumatic Brain Injury Studies. “It occurred to me that in the 35 years I had worked in this area, I hadn’t done anything to make patients better.”

Hayes thought that, just as heart specialists revolutionized cardiology care by discovering protein biomarkers in people experiencing a heart attack, a similar biomarker could exist in an injured person’s blood, postinjury. His theory was that TBI wasn’t simply an immediate injury but a disease process, and the sooner it was diagnosed and treated, the better the outcome for patients.

With the help of his colleague, Kevin K. W. Wang, Ph.D., an associate professor at the McKnight Brain Institute and former scientific director of the Center for Traumatic Brain Injury Studies who also has a doctorate in pharmaceutical sciences, Hayes conducted research to assess proteins produced after a brain injury.

They found correlations between the degree of brain injury and certain levels of brain biomarkers. They were able to show that the levels of the protein UCH-L1 were 16 times higher in patients’ blood following injury to the brain than in noninjured patients. The results of these tests were published in *Critical Care Medicine* in 2010. The reliability rate was sufficient enough to provide an accurate diagnostic tool.

There it was: A blood test that could possibly have helped save Natasha Richardson’s life.

In addition to detecting certain biomarkers in the blood, Hayes’ and Wang’s research also focused on the potential treatment of brain injury using compounds that blocked two enzymes that cause additional brain cell death following injury.

“By blocking the action of these enzymes,” says Hayes, “subsequent tissue damage can be reduced or eliminated, which greatly improves patient outcomes.”

### A More Elegant Solution Surfaces

In the early 2000s, Hayes received funding from the Department of Defense and the National Institutes of Health to pursue the diagnostic biomarker. The Office of Technology Licensing at University of Florida entered into a licensing agreement with Hayes, Wang and Nancy Denslow, Ph.D., a University of Florida professor of biochemistry in the Department of Physiological Sciences and Center for Environmental and Human Toxicology who was also director of a Proteomics Laboratory at the university, for a development-stage company based on the biomarker technology. Denslow collaborated with Hayes and Wang to help discover the protein biomarkers of TBI.

By 2002, Hayes and Wang had left their posts at the university to build the University of Florida startup company that ultimately became known as Banyan Biomarkers, after the tree under which Buddha received enlightenment, says Hayes. The banyan tree, native to India, was first planted in the United States in Florida by Thomas Edison.

“The University of Florida is very supportive of startup biotechnology companies,” says Denslow. “We have a wonderful business incubator building in Alachua — the Biotechnology Development Incubator — that offers a great deal of support to startup companies, including shared instrumentation, computer services and meetings with prospective investors. It is a win-win situation for both the university and the startup companies. In the case of Banyan Biomarkers, the University of Florida has been a very helpful partner.”

Hayes became chairman of the board and Wang was named chief operations and scientific officer. Once the company was formed, Banyan was supported by congressional funding and secured two Small Business Innovation Research grants to continue their research efforts.

According to John Byatt, licensing officer at the Office of Technology Licensing at the University of Florida, the university has equity in Banyan and will earn royalties on sales of the biomarkers.



“It’s great that the university will earn royalties, but what’s more satisfying is to be a part of the birth of a new company and knowing that the research is making a real difference to the health and well-being of people everywhere,” says Byatt.

Located in Alachua, Fla., just 13 miles from the university, the company is focusing on the development of a simple, point-of-care blood test for use by physicians in the emergency room and hospital.

“[The financial support] gave everyone confidence to fund work in humans and get to work on a more elegant solution,” says Jackson Streeter, M.D., an experienced medical device executive who joined the team as CEO in 2010. To date, the company has received more than \$70 million in grants from the United States Department of Defense and the National Institutes of Health.

“With Hayes and Wang on board, funding from the U. S. Department of Defense and National Institutes of Health and 65 employees, the company is in a good position to continue to discover and commercialize,” says Byatt.

The company anticipates that three to five biomarkers will be used in detecting and monitoring patients sustaining TBI, translating into a potential market in excess of \$250 million in the United States alone, says Streeter.

Hayes is hoping that the diagnostic will ultimately be a portable device much like a handheld glucose strip. This small device would be optimal for testing not only in the playfields as a sports medicine application but also on the battlefield and be able to provide information within 20 minutes.

### **Athletic, Pediatric and Other Applications**

After Banyan completes clinical validation (expected in 2013), the company will seek Food and Drug Administration approval to market the biomarkers as an in vitro diagnostic test for detection and monitoring of TBI. Hayes says that the test will be used

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**“It’s great that the university will earn royalties, but what’s more satisfying is to be a part of the birth of a new company and knowing that the research is making a real difference to the health and well-being of people everywhere,” says Byatt.**

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for military personnel after blast injuries like those occurring from improvised explosive devices in Iraq and Afghanistan. The test will also be used for sports concussion injuries during athletic events. A future application also includes pediatric TBI, especially for shaken baby syndrome and for children who are victims of TBI inflicted by a parent such as in the stressful aftermath a natural disaster.

Currently, Banyan has three U.S.-issued patents and three patent applications broadly covering the use of biomarkers, and international patents have been filed. The firm has also secured grants to develop biomarkers for stroke and liver injury.

If this is the case, and a handheld device could be used on the slopes by ski patrol, head trauma patients would never again be solely responsible for identifying and communicating the severity of their condition. The chance for a definitive diagnosis could eradicate the question, “Why didn’t the doctors do something?”

— Ellen Blum Barish



University of Georgia, Athens, Ga.

## Biomedical Innovations: Changing Wound Care One Doctor, One Patient at a Time

Imagine the anguish that comes from receiving a severe wound, burn or skin ulceration. Aside from the pain, the mind will struggle with quality-of-life issues in the near future.

These worries are very real for millions throughout the world (see sidebar) who, without proper wound care, will suffer from devastating scars, disfigurement, amputation and/or social rejection. This problem is most acute in a wide variety of resource-poor settings, including sub-Saharan Africa, rural Asia, much of South America and areas impacted by natural disaster where there is a very high risk of infection — the primary obstacle to optimal wound care.

Open skin wounds such as burns, neuropathic ulcers, pressure sores, venous stasis ulcers and diabetic ulcers routinely heal via a complex multistep cellular-based process. But healing is often impaired when components in the process — individually or as a whole — fail to function properly for a variety of reasons, primarily infection.

### Young Girl's Hand Is Saved

This is the very position a young girl in Haiti found herself in after the hurricane of 2010. She received severe burns on her hands and arms from a cooking mishap. By the time she saw a medical professional, her hands had become badly infected. She likely faced a life without digits or possibly her hands due to the prevailing belief that amputation was the only solution.

As luck would have it, two new topical applications, with anti-microbial agents and marketing clearance from the U.S. Food and Drug Administration, were undergoing evaluation in Haiti as part of a multidrug therapy regimen for leprosy.



Photo courtesy of B. Flick

The gasoline burn on this firefighter's arm was cleansed with Silvakenz and covered with a bandage kept moistened with Silvion. The wound healed with very little scarring within two weeks.





### Wound-Care Costs

Each year, an estimated 5 to 7 million people in North America suffer with chronic, nonhealing wounds from burns, neuropathic ulcers, pressure sores, venous stasis ulcers and diabetic ulcers, according to the World Health Organization in a 2010 published white paper titled “Wound and Lymphoedema Management.” International statistics are difficult to acquire.

Collectively, chronic wounds cost the nation \$20 billion to \$25 billion a year, and acute or traumatic wounds add another \$7 billion to \$10 billion annually, according to Richard Ikeda, Ph.D., program director of the wound healing research portfolio at the National Institute of General Medical Sciences, National Institutes of Health. The problem is likely to become more costly with an aging population, because older skin heals more slowly and tends to have more problems in general. What is more, wounds often reappear even after expensive treatments.

Using compounds based on licensed academic research conducted at the University of Georgia (UGA) in Athens, the innovative topical technology “potentiates” — increases the effectiveness of microbial killing — in available antibiotics to fight dangerous infections, even drug-resistant microbes such as methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant *Enterococcus faecalis*, multidrug-resistant *Pseudomonas aeruginosa* and multidrug-resistant *Acinetobacter baumannii*.

These products work by generating physical holes in the microbe’s cytoplasmic membrane, or antibiotic-resistant biofilm, which provides a shield that effectively protects the integrity and functionality of the microbe’s cellular membrane. The holes reduce the bacteria’s ability to remove classes of clinically rel-

evant antibiotics and result in the death of the microbe.

“Microbes function very much like a boat because both are dependent on differential pressure,” says co-developer Branson Ritchie, D.V.M., Ph.D., a distinguished research professor at UGA and president and chief executive of the academic startup company founded in 2002, Molecular Therapeutics LLC of Athens. “If you punch holes in a boat or a microbe, they can’t work anymore.”

In Haiti, health care providers decided as a last resort to apply Molecular Therapeutics’ innovative topical treatments, Silvion and Silvaklenz, on the young girl’s severely burned hands. Remarkably, the pain rapidly diminished, the spreading microbial infection was stopped in a matter of days and the prospect of a future with the use of two hands became a reality.

This dramatic example is just one of many in which this biomedical technology is producing similar results, not only for those living in undeveloped areas, but also for those with access to wound-care gold standards practiced by the urban hospitals of major cities in the developed world.

“These products are just incredible. I see patient outcomes that are astronomically better than what I’ve seen using methods approved by WOCN [Wound, Ostomy and Continence Nurses Society],” says Donna Howarth, director of nursing, Medside Healthcare home-care agency in Sandy Springs, Ga. “Traditional wound care is focused at the tissue level, while these products work at the cellular level, which I think makes the difference.”

### Academic Research Provides Biomedical Foundation

Developed at the UGA College of Veterinary Medicine, these biomedical technologies are licensed to UGA startup Molecular Therapeutics by the University of Georgia Research Foundation Inc. (UGARF), which manages intellectual property developed by UGA employees. The startup company markets three antibacterial products based on the UGA portfolio: Silvion, a mois-





turizing solution, and Silvaklenz, a wound cleanser, both for humans; and Tricide, a veterinary treatment to prevent infection and promote healing in nonfood fish, such as koi.

“The wound-care market is quite crowded, but these products appear to be unique in their ability to significantly enhance the killing activity of a topical antimicrobial,” says Derek E. Eberhart, Ph.D., a senior licensing manager in the Technology Commercialization Office (TCO) at UGARF.

Eberhart was one of many in the business support team, including the university’s Georgia BioBusiness Center incubator, to help protect the innovations, prepare the technology for licensing opportunities and enable the eventual spin out of the academic startup company. The research was supported in part by UGARF’s Animal Health Fund, which fosters selected research initiatives in the UGA College of Veterinary Medicine. In addition, Molecular Therapeutics received seed funding from the Georgia Research Alliance, a partnership of state government, local industry and academia focused on facilitating new science and technology efforts with the potential to help people and have significant economic impact.

Two patents are issued to UGARF — one in the United States for aquatic applications and another in Canada for medical/human applications — and additional patents are pending in the United States and Europe. The inventors involved in various aspects of these technologies included Ritchie and his colleagues at UGA: Richard Wooley, D.V.M, Ph.D., a professor in the UGA College of Veterinary Medicine who is now retired; Victoria Burnley Vaughan, formerly in the department of Small Animal Medicine and now owner/director of Koi Lab LLC; Douglas T. Kemp, Pharm.D., formerly of the College of Veterinary Medicine; and Anthony Capomacchia, Ph.D., associate professor in the College of Pharmacy.

Ritchie embarked on antimicrobial research in 1998 with his mentor and colleague Wooley in an attempt to resolve the problems associated with multidrug-resistant microbes in burn

patients. The compound that enhances the effectiveness of antibiotics became the underlying foundation for the biomedical technologies for humans and animals that Molecular Therapeutics is using.

“This technology, which helps kill drug-resistant bacteria and fungi with compounds that cleanse wounds while also being gentle on the tissue, is a beautiful example of translational medicine,” Ritchie says. “We started with burn patients as our target, but it just so happens that it also works with wound care in companion animals.”

### **Veterinary and Pharmacy Sciences Come Together**

A real breakthrough came when potentiated antibiotics were combined with a bioadhesive following collaboration between Ritchie and Capomacchia on a nontoxic ointment to help burn victims. Capomacchia specializes in the formulation of drug-delivery systems.

Veterinarians soon successfully used the Tricide nonpetroleum ointment treatment on a burned dog in a high-profile animal cruelty case, followed shortly by Gasper, a beluga whale at the Georgia Aquarium in Atlanta.

These animal trial applications were soon followed by the first human patient — a firefighter involved in an explosion that caused first- and second-degree burns on his face and arms. Within 12 days of treatment with Silvaklenz and Silvion, the results were astounding. His skin is now back to normal.

In a short period of time, the researchers had come full circle: from designing a nontoxic ointment to help burn victims, to developing drug-delivery applications for aquatic animals and back to treating skin problems in humans.

### **Translation of Basic Research to Effective Products**

Initial attempts to license the basic science research by UGA failed to identify any companies that could translate it into effective clinical products.



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**“This technology, which helps kill drug-resistant bacteria and fungi with compounds that cleanse wounds while also being gentle on the tissue, is a beautiful example of translational medicine,” Ritchie says. “We started with burn patients as our target, but it just so happens that it also works with wound care in companion animals.”**

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“Our intent was to license these technologies for use with people and animals, but we couldn’t find anybody interested,” says Ritchie, who feels the existing licensing environment is “quite challenging” for academic biomedical research. “So, it came down to a decision: We either do this ourselves or let down the constituents who could most benefit and who we wanted to help.”

The self-described “entrepreneur by necessity” says it isn’t so much what he intended to do, but what he had to do.

Eberhart in the TCO at UGARF says existing companies that consider in-licensing academic opportunities — research that is often in the concept stage — tend to focus on risk assessment and the pathway to commercialization.

“Most inventions arising from university research are early stage and, thus carry a high level of risk and uncertainty,” Eberhart says. “Most academic labs are not set up to perform the extensive proof-of-concept experiments that many companies would prefer to see before licensing a technology. Sometimes,

a startup company is a necessary step in the commercialization process.”

Today, both Eberhart and Ritchie say that Molecular Therapeutics is starting to get some traction with nine independent sales representatives under a national sales director who are introducing more health care providers to the company’s Silvion and Silvaklenz products. “We’re making headway — one doctor, one patient at a time,” says Ritchie. “We’re OK with this approach because we’re helping patients who can really benefit from these products.”

### **People Are the Real Beneficiaries**

Even though Ritchie says he didn’t start out with entrepreneurship as a goal, he says he is “honored” to have worked with colleagues who started with a problem, developed a viable solution and now sees better quality-of-life prospects for people suffering from burn wounds, neuropathic ulcers, pressure sores, venous stasis ulcers, diabetic ulcers and even acne.

“I look at this as a blessing because we’re in touch with the user base,” says Ritchie, who sees merit in building connections between caregivers and the patients, such as those that exist between the young girl in Haiti and about a dozen patients under Director of Nursing Howarth’s care at Medside Healthcare.

“One of our patients suffering from cellulitis (a noncontagious spreading bacterial skin infection) was looking at having his legs amputated,” Howarth relates. “I’ll admit I was skeptical, but we used the topical applications on Day One. On Day Four, we took the bandages off and his toes were no longer black and he was pain free.

“We had been treating him for three months with traditional methods and little progress. Imagine, in four days seeing measurable progress. It was out of this world. It was so Star Trek.”

— Dave Perilstein



## University of Nebraska Medical Center, Omaha, Neb.

# New Medications Offer Hope for the Scourge of Malaria

The stakes are immense. Worldwide, more than 300 million new cases of malaria are diagnosed each year, and more than 1 million people die from it, according to the World Health Organization (WHO). Young children and expectant mothers are especially at risk.

An enormous problem: The parasites that cause malaria have developed resistance to long-effective medications. The best drugs currently available are derived from artemisinin, a Chinese herbal medicine that's extracted from the bark of sweet wormwood. It's costly, its supply is limited and it requires frequent doses.

Jonathan Vennerstrom, Ph.D., a professor at the University of Nebraska Medical Center, is hoping to change that by developing a synthetic version of artemisinin, one that can be more effective, easier to administer and manufactured in large quantities at lower cost.

In research supported by a small grant from WHO, Vennerstrom, Yuxiang Dong, Ph.D., and other Nebraska colleagues were able to synthesize a peroxide-based drug that acted like artemisinin by producing a chemical reaction that ultimately leads to the death of the parasite.

### Projects of the Year

With promising results, they approached Medicines for Malaria Venture (MMV), a nonprofit foundation based in Switzerland. MMV provided funding and formed an international team involving scientists at Nebraska, Monash University in Australia and the Swiss Tropical and Public Health Institute.

The first drug candidate, OZ277, was declared MMV's Project of the Year in 2002 and was licensed to Ranbaxy Laboratories in India for development. In 2004, the team published its results in *Nature*.



Jonathan Vennerstrom, Ph.D., is a member of an international team developing new medicines for treating malaria.

Still, team members thought they could do better. For one thing, OZ277 requires three doses over three days. For reduced costs, improved patient compliance and easier distribution, the researchers envisioned a second generation that could work in one dose.

OZ439, a potential single-dose drug candidate that remains effective for much longer than OZ277, became MMV's Project of the Year for 2006. The lead innovators include Vennerstrom and Dong at Nebraska; Susan Charman, Ph.D., and Bill Charman, Ph.D., at Monash; Sergio Wittlin, Ph.D., at the Swiss Institute; and Hugues Matile, Ph.D., at Hoffman-La Roche Ltd. The team published its results in the *Proceedings of the National Academy of Sciences* in February 2011.

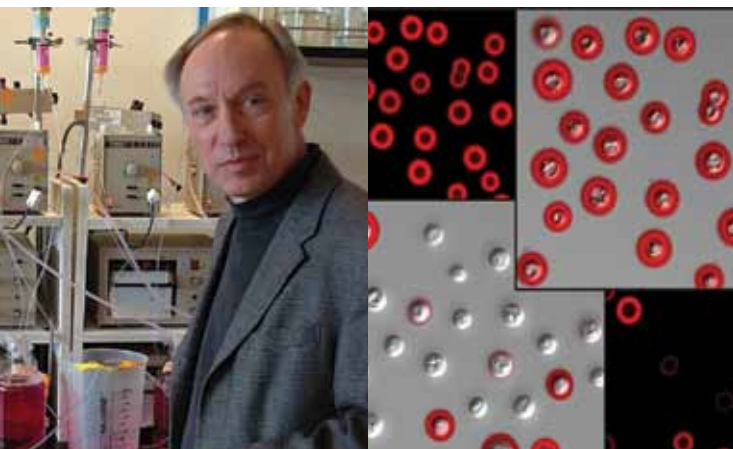
Vennerstrom tends to be cautious about predicting success. However, OZ277 could be available for use by the end of 2011. The new drug, OZ439, is in Phase IIa trials now in Bangkok and hopefully will be available in several years.

— Ralph N. Fuller



University of Nevada, Reno, Reno, Nev.

## Diagnostic Breakthrough Unmasks a Killer in Sub-Saharan Africa



Thomas Kozel's (left) work with antibodies (right) was a crucial component to the development of a test that will help diagnose fungal infections plaguing HIV-infected people in developing countries.

It's no secret that sub-Saharan Africa is being ravaged by HIV/AIDS. An estimated 22.5 million people in the region are living with HIV, accounting for about two-thirds of the world's total. Some 1.8 million died from AIDS in 2009, and an estimated 2.6 million became infected with HIV that year, according to the World Health Organization (WHO). WHO also estimates that 11.6 million children in the sub-Saharan region have been orphaned as a result of HIV/AIDS.

What is not so well-known is that another vicious killer — a fungus — is stalking those suffering with HIV/AIDS. Called *Cryptococcus neoformans*, it causes cryptococcal meningitis, an infection of the membranes covering the brain and spinal column. Found in various sites in the natural environment

around the world and inhaled by victims, *Cryptococcus neoformans* opportunistically attacks immunocompromised individuals — like people living with HIV/AIDS, rheumatoid arthritis patients and transplant recipients — whose immune systems are either compromised or suppressed. Left untreated, cryptococcal meningitis can cause swelling of brain, fever, sensitivity to light, stiff neck, headache, nausea and vomiting, confusion, disorientation, hallucinations and death. A study reported in the journal, *AIDS*, estimates that cryptococcal meningitis kills 500,000 people a year in sub-Saharan Africa. In sub-Saharan Africa, cryptococcal meningitis is estimated to cause more deaths among those living with HIV/AIDS than tuberculosis.

### The Crux of the Problem

Fortunately, there is a tool in the works that will help shrink this epidemic. “With early diagnosis cryptococcal meningitis can be treated with readily available and inexpensive medicine, although individuals with HIV/AIDS require long-term treatment to prevent reoccurrence. The question is: How do we rapidly diagnose cryptococcosis in sub-Saharan Africa?” says Sean Bauman Ph.D., CEO of IMMY (Immuno-Mycolitics Inc.), an Oklahoma company founded in 1979 to produce fungal diagnostic products.

For over 30 years, IMMY has been manufacturing diagnostic kits for cryptococcal meningitis. The current technology is simple but requires refrigeration and additional equipment to work. “I was in Tanzania almost a year ago doing product training, and it became clear to me that our current *Cryptococcus* test was not the right technology for the developing world,” Bauman says. “So we set out to do something about that.”

Bauman had known Thomas Kozel, Ph.D., of the University of



Nevada School of Medicine, part of the University of Nevada, Reno (UNR), as a leader in the field of *Cryptococcus* research since 1995. “So I gave him a call.”

### The Key to the Solution

With funding from the National Institutes of Health, Koziel has been investigating *Cryptococcus neoformans* for over 30 years, doing basic science studies on how the organism produces disease.

“We were interested in antibodies as a way to probe the structure of the yeast and for reversing the anti-immune-cell action of the capsule,” says Koziel. “So when Sean called and asked if we had an antibody that could be used for a point-of-care immunoassay for the diagnosis of cryptococcal meningitis in the field, I thought, ‘I know we do.’”

“I was sure because we had recently gone through our collection of antibodies, trying to develop a very sensitive laboratory-based assay that would pick up all forms of the diagnostic target globally. We had just completed that work when Sean called,” he continues.

It turned out that Koziel did indeed have an antibody that would fulfill IMMY’s requirements. Koziel had an antibody that increased and broadened the sensitivity of the test, brought it closer to the point of patient care and dramatically reduced the cost. “It’s an almost perfect antibody that can be made in tissue culture using techniques for producing hybrid cell lines so that it is always the same,” he says.

Koziel sent samples of the antibody to Bauman. When IMMY tested it, they had a “eureka!” moment, and, not long afterward, Bauman was applying to the UNR for licensing the antibody.

### Rapid Licensing

“The entire licensing process went very quickly — about four months from beginning to end,” says Michael Birdsell, director of Intellectual Property Marketing and Business Development at UNR. “The key to successful licensing is having the right

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Of the licensing process, Bauman says, “UNR has been wonderful to work with. We had a common vision — to help cryptococcal victims in the developing world. Big profits are not what IMMY is after. We are a privately held, family-owned company, and we are not beholden to shareholders, which enables us to develop and market products that meet the needs of both the developed and developing world.”

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partner,” he adds. “Although we generally like to work locally with licensing partners, IMMY had all the right stuff: key expertise including years of working with *Cryptococcus*, current access to markets, capital and a high level of commitment. With lives in the balance, we had an obligation to seek the quickest way to market for this technology.”

IMMY has been busy with the antibody developed by UNR. “We have already developed a test kit that will be useful in existing labs,” Bauman says. “It has recently been cleared by the FDA, has been approved in Europe and is already in use in sub-Saharan Africa. Kits are going out across the world, and momentum is starting to build for this product in the marketplace.” The kit has been evaluated or is in the process of being evaluated in the United States, South Africa, Thailand, Vietnam, India, Kenya, Uganda, Rwanda, Zimbabwe, Tanzania, Guatemala, Argentina, Brazil and Mozambique. Further, the test meets the WHO ASSURED criteria: affordable, sensitive, specific, user-friendly, rapid, equipment-free and delivered to those who need it.

### A Simple Test

IMMY is in the final stages of putting together a field kit that has all the necessary components to run the test in the back





University of Nevada, Reno, researchers have been studying *Cryptococcus neoformans* for more than three decades.

of a truck or in a crude rural clinic in sub-Saharan Africa. The test is almost as simple as a pregnancy test: (1) place a drop of diluent that comes with the kit into a tube, (2) add a drop of patient specimen (urine, plasma or whole blood from a finger stick), (3) add the dipstick containing the antibody to the tube, (4) wait 10 minutes and (5) read the results: two lines, positive; one line, negative.

Delivering the test to places where it is needed is also easy to do, says Bauman. “We can FedEx stuff nearly anywhere in the world,” he says. “In addition, we look for distributors in country to partner with. Some countries also have ministries of health where material is warehoused, and they are responsible for making sure it gets to where it needs to be.”

Bauman says, “It’s a really simple test, and the simpler the test, the lower down the health care chain we can go with it. You have to realize that in many areas of Africa, health care infrastructure is very limited.” He notes that the new test will appeal to health care providers in developed countries as well because it is so easy to use.

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derful to work with. We had a common vision — to help cryptococcal victims in the developing world. Big profits are not what IMMY is after. We are a privately held, family-owned company, and we are not beholden to shareholders, which enables us to develop and market products that meet the needs of both the developed and developing world.”

Ryan Heck, director of UNR’s Technology Transfer Office agrees: “One of the stipulations in our agreement for the licensing of the antibody with IMMY is to have this crucial test available at low cost. Dr. Bauman has already begun to make this happen.”

### A Big Impact

The upshot of this new technology promises to be very significant. “With the new point-of-care diagnostic test, a health care provider can give the test, observe the results and administer the first dose of oral medication, all within a few minutes,” says Kozel. “Studies have shown that early identification and treatment are essential to beat cryptococcal meningitis. A late diagnosis means that antifungal therapy will likely fail in resource-limited countries. Most patients in that setting are not diagnosed until they are very sick, and then it’s too late.”

Bauman adds, “Antifungals used to treat cryptococcal meningitis are available for free or at low cost in regions such as sub-Saharan Africa. In countries with limited infrastructure or resources, as many as 1 in 10 AIDS patients may develop crypto. If we can diagnose early and begin treatment, we can save an amazing number of lives.”

Bauman estimates 1,700 people die every day from cryptococcal meningitis. Thanks to Tom Kozel’s research and rapid technology transfer from the University of Nevada, Reno, the new diagnostic test from IMMY promises to help sub-Saharan Africa respond to the adversity of the AIDS epidemic by significantly reducing the death toll from cryptococcal meningitis and preventing thousands of sub-Saharan children from becoming orphans.

— Jock Elliott



**University of Toronto, Toronto, Ontario, Canada**

## Microchip Diagnostic Revolutionizes HIV Monitoring in Developing Countries

An HIV-positive woman living in a remote African village walks 37 kilometers, six-month-old baby in tow, to the nearest health clinic for a simple blood test to determine if her disease has progressed to AIDS. She will have to make the same arduous journey weeks later for her results, and if the test reveals that her immune system is weak, she'll need to return to the clinic again and again — if she's able — for antiretroviral drugs and continual monitoring.

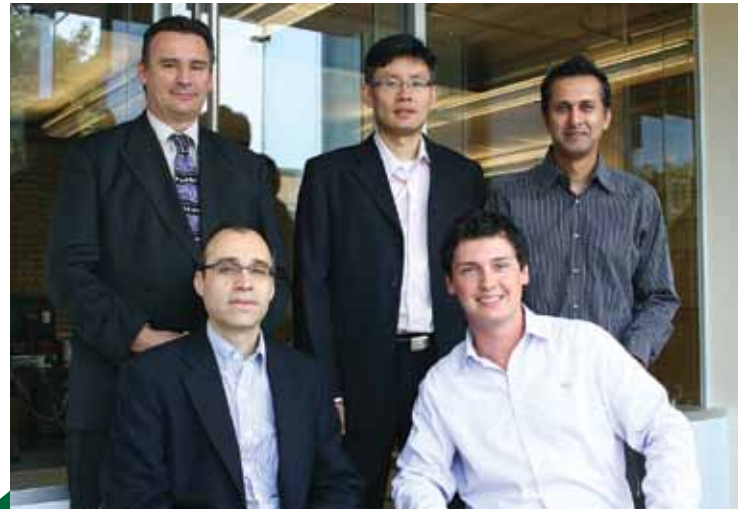
She is just one of the millions of men, women and children living with HIV in sub-Saharan Africa that James Dou, a doctoral student at the University of Toronto (U of T), hopes to reach with his new invention: a portable lab on a chip that makes blood testing more accessible, efficient and affordable.

### HIV and Sub-Saharan Africa

The World Health Organization (WHO) considers the human immunodeficiency virus (HIV) a worldwide pandemic, but sub-Saharan Africa is disproportionately affected. According to the WHO, more than 22 million people with HIV live in that region, accounting for nearly 70 percent of the global total.

As HIV progresses to AIDS, the infection weakens the body's immune defenses by destroying CD4 (T-cell) lymphocytes, a group of white blood cells that help guard against bacteria, viruses and other germs. When CD4 cell levels decrease, the body becomes vulnerable to a host of opportunistic infections that invade when the body's defenses are low.

"When people are infected with HIV, they are more prone to other infectious diseases such as malaria or tuberculosis, which can become lethal," says Dou.



The team behind a patented and portable lab-on-a-chip that can test for blood-related ailments such as AIDS includes, from left to right, back to front: University of Toronto Professor Stewart Aitchison; doctoral student and inventor James Dou; Rakesh Nayyar, CEO of the ChipCare Corp.; and Lino DeFacendis and Kurtis Scissons of the U of T's Innovations and Partnerships Office.

A critical component of HIV care is monitoring CD4 levels and administering antiretroviral treatment when they decrease. Antiretroviral drugs help suppress the HIV virus and strengthen the immune system by inhibiting the HIV replication cycle. But such drugs must be given only when the disease progresses — and discontinued once CD4 cells return to stable levels.

### Counting Blood Cells

CD4 cell counts are measured by a flow cytometer, a machine the size of a photocopier that is standard equipment in clini-



cal labs — at least in the advanced world. Because the typical flow cytometer costs up to \$100,000 and requires both sophisticated infrastructure and trained technicians to operate, it is beyond the reach of many developing countries.

“Flow cytometers are for the most part concentrated in first-world countries,” says Dou. “Many countries in the developing world simply do not have the facilities or infrastructure to offer HIV monitoring.”

The Toronto-based Dignitas International, an organization that supports people with HIV and AIDS in the African country of Malawi, has only one flow cytometer in its central health facility, which runs just 250 blood tests per week. Blood samples are collected from villages and transported to the facility for testing via an unorganized process involving motorcycles, buses and bicycles. Results can take weeks to produce and often never reach the patient at all. Dou’s invention would eliminate the need for patients to travel to a central facility for blood testing or blood samples to be collected and processed elsewhere. His portable, handheld cytometer, similar to the glucose monitor developed for diabetic patients, could provide rapid, point-of-care HIV monitoring in even the remotest parts of Africa. At a cost of \$5,000 to \$10,000 per device, Dou’s cytometer offers the potential for affordable, efficient HIV testing, providing results in a few minutes at a cost of less than \$10 per test.

### The Science of Flow Cytometry

Dou’s invention grew out of his work as a graduate student in the laboratory of Professor Stewart Aitchison, Ph.D., U of T’s vice dean of research in the Faculty of Applied Science and Engineering. With funding from the Natural Sciences and Engineering Research Council of Canada and Ontario’s Ministry of Research and Innovation, he created — and has now patented — a multitest particle detection and analysis platform that involves a plastic cartridge, an optical reader and software. Additional software can be easily added to the device to transmit results wirelessly to a central database.

A disposable cartridge is engineered with tiny channels, reservoirs and reaction chambers the size of a human hair. For the CD4 test, a dried reagent — an antibody designed to bind to CD4 cells combined with a fluorescent molecule — is placed in the reaction chamber. When the blood mixes with the reagent, the antibody/fluorescent compound binds to the CD4 cells and light up. As blood flows through the channels, the optical reader and software count the CD4 cells, and an LCD on the device displays the results within minutes.

### Going to Market

Dou designed his platform to be capable of executing any number of applications from counting blood cells and measuring air pollution to testing for food safety. To determine which application to pursue first — and for help bringing the invention to market — Dou and Aitchison turned to U of T’s Innovations and Partnerships Office (IPO).

Once U of T committed to Dou, the office suggested a startup company and facilitated the development of a business plan, with the help of U of T’s Rotman School of Management, a commercialization plan and patent filings.

“Most of our team has a technical background so adding Innovations and Partnerships brought us complementary skills in business,” says Dou. “They’ve been very helpful in helping us make connections, complete our market analysis and apply for funding.”

### Engineer Meets Biologist

Director of Commercialization and Business Development Lino DeFacendis and Commercialization Manager Kurtis Scissons introduced the engineers to Rakesh Nayyar, an expert in flow cytometry who had recently become aware of the need for HIV diagnostic equipment in the developing world.

“They were initially looking at testing for leukemia/lymphoma,” says Nayyar. “I advised them to look at doing the CD4 count because it’s a much simpler test and the immediate need is far greater.”



With valuable experience in biological testing, Nayyar joined Dou and Aitchison in forming the ChipCare Corp. to commercialize the portable cytometer.

“This is both a good business venture and humanitarian effort,” says Nayyar, who was recently appointed ChipCare’s CEO.

A bonus for the new company is U of T’s collaboration with the MaRS center, an innovation and commercialization hub situated in downtown Toronto’s discovery ecosystem. The IPO is physically housed within MaRS, which acts as a catalyst to commercialization by bringing together and supporting research institutions, startup companies, entrepreneurs and industry.

“We take a team approach and collaborate in order to leverage our complementary resources,” says DeFacendis.

### Getting into the Field

U of T also helped ChipCare establish partnerships with two organizations that are anxious to get the portable cytometer into the field: Dignitas in Malawi and the Camillian Social Center of Rayong, Thailand, which is dedicated to caring for orphans with HIV and AIDS.

“This proves how university research has a direct and positive impact on people’s lives,” says Professor Peter Lewis, Ph.D., U of T’s associate vice president, research, and acting executive director of the university’s Innovations and Partnerships Office. “Our team at IPO is having great success at working with U of T professors in taking their research to the marketplace for the good of society. Our work with Professor Aitchison and James Dou is an excellent example.”

Dou’s invention has impressed others as well: It beat out 200 entrants to win the *Canadian Business* magazine’s Great Canadian Innovation Competition in 2009. The top prize included nearly \$90,000 in engineering and business services, which the company used to refine its technology and develop its first prototype.



Camillian Social Center of Rayong, Thailand

Using the hand-held cytometer, or lab-on-a-chip, developed by the ChipCare Corp., the Camillian Social Center of Rayong, Thailand, will conduct much-needed blood tests on the orphans in its care to determine if their HIV infection is progressing to AIDS.

“They have de-risked the science,” says DeFacendis. “The blood flow is the tricky part. You need a clean, extremely discreet profile to count the cells.”

With additional funding, the company is set to shrink the current prototype, which is about the size of a breadbox, to the handheld version. ChipCare’s goal is to deploy 100 devices in Malawi and Thailand in 2012.

### Multiple Uses in Many Countries

Dou’s portable diagnostic device also has potential applications in North America and other advanced countries, where it could help reduce health care costs. The U.S. Centers for Disease Control and Prevention recommends routine HIV screening of adults, adolescents and pregnant women — and reports that each year, nearly 22 million Americans are tested for HIV.

“The portable cytometer is a nice complement to existing flow cytometers in hospital laboratories that have a lot of bells and whistles,” says Dou. “Many of the tests that run on flow cytometers don’t need to use all of its features.”



Dou says obtaining one CD4 blood count from a flow cytometer in North America typically costs between \$75 and \$100. He expects his portable cytometer to complete the same test for approximately a tenth of the cost. But the ChipCare Corp. won't stop with one blood test. The company has recently filed a second patent that covers the chemical processes involved in testing for other blood-related ailments, such as malaria. With one drop of blood, Dou's device could count CD4 cells and detect malaria parasites, providing two results from one test.

ChipCare's portable cytometer could also perform a simple complete blood count (CBC), a routine screening test used to check for anemia, infection and other diseases in patients all over the world. By performing CBCs in settings far removed from a hospital laboratory, the portable cytometer could make a huge impact on the delivery of health care.

For example, patients undergoing chemotherapy treatment for cancer must have their blood tested regularly to monitor cell counts (such as the number of white or red blood cells). The ChipCare cytometer would allow health care workers to perform blood tests in a patient's home, eliminating the need for extra trips to the hospital or clinic.

"Our technology has the potential to revolutionize medical diagnosis by providing less expensive, accurate blood testing with timely results while saving patients pain and inconvenience," says Dou.

ChipCare's portable cytometer could also be engineered to count bacteria in water — an application that would eliminate the need to collect and send water samples away for analysis and instead provide immediate, onsite detection of *E. coli* and other dangerous microorganisms.

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"It's very meaningful and rewarding to do this work," says Dou. "I am hoping that our efforts can allow technology to have a bigger impact on people's health and quality of life. That is my motivation."

— Mary Henderson





# Technologies to Replenish Water Supplies

Stellenbosch University, Stellenbosch, South Africa

## Tiny Teabag Filter Offers Tremendous Hope to World's Thirsty



When an earthquake and tsunami devastated Japan this spring, international aid groups raced to bring assistance to the beleaguered country. After their filtration plants were damaged, a key necessity was securing safe drinking water for the residents.

To this end, an aid group contacted South African businessman Tony Karsten hoping to buy thousands of inexpensive water bottles with built-in filters that his company, AquaQure, is developing for exactly such disasters. The bottle is still being perfected so Karsten couldn't send any, though he says, "They would be perfect for Japan."

The innovation grew out of research by Professor Eugene Cloete, Ph.D., at Stellenbosch University in Stellenbosch, South Africa. It uses a filter that resembles a teabag with a bacteria-killing compound spun into its fibers. Not only does it sit on top of a reusable water bottle, it's also an extremely economical and easy way to deliver potable water to regions that need it

most, namely those that have experienced a natural disaster, as well as poor areas around the globe that face a daily struggle for clean water. According to the United Nations, 2 out of 10 people in the world do not have access to safe drinking water, and millions of people, mostly children, die every year from related diseases.

Karsten said that his phone has been ringing off the hook since he signed a licensing agreement in late 2010 with the university to bring the teabag water filter to market. Much of the excitement and interest is coming from aid organizations, government ministers and international philanthropists.

"There is such a dire need," Karsten says. "We have created a spark of hope now that there's a clean option that they'll be able to afford."

### A Big Idea in a Little Package

The genesis of the filter involves a serendipitous conversation, some teabags borrowed from a university boardroom and a hair straightener.

Cloete arrived at Stellenbosch University in early 2009 to become the dean of the faculty of science. In his previous job at the University of Pretoria in Pretoria, South Africa, he had been working on integrating an enzyme into industrial water systems to keep filters from clogging.

A few weeks into the new job, he was on a tour of the science facilities and heard a short presentation by a recently minted doctoral student. The student had used a process called electro-spinning or nano-spinning to turn a polymer gel into silk-like fibers.

Cloete got so excited about the potential of this technology that

he couldn't stop thinking about it. Upon returning to his lab, he called his former colleagues in Pretoria and asked them to send him some of his enzymes. His idea was to use electro-spinning to integrate the enzyme into the filters instead of having to incorporate the enzyme after the fact.

But since he was too excited to wait the week for the enzyme to arrive, he said, "Let's try something else and put it in the fibers."

Cloete had some biocide, an antibacterial gel that he had helped develop with Karsten over the past eight years. The two had worked on integrating the biocide into agricultural water systems to combat algae.

He asked his two postdoctoral students, Michéle de Kwaadsteniet, Ph.D., and Marelize Botes, Ph.D., to try spinning the biocide into fibers. They started experimenting with ways to integrate the biocide fibers into industrial filters to prevent contamination from bacteria.

"When you test them, you don't test on an industrial scale," Cloete explains. "You test in the lab so you can demonstrate the principle."

The group needed a small-scale way to test the principle. They realized that teabags could act like a filter and provide a material onto which the biocide nanofibers could be spun. Cloete grabbed some teabags from the boardroom, emptied them of their leaves and they spun the biocide nanofibers onto the teabags. Then they filled the modified teabags with activated carbon — the same material found in your Brita water filter at home, which removes the water's impurities. To seal the teabags back up, they needed something hot — one of the students had her hair straightener with her and used it to complete the operation.

The researchers discovered that the prototype filters worked in the lab, but turned their thoughts to scaling up the approach for industrial water treatment. Then Cloete — who presses his

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**"How do you follow up with 120 organizations?" Cloete says, in explaining how grateful he is to Marais and his office for taking over the business side of the project. "They've played a very important role. You need people who can do that as a service to the scientists."**

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students to think about how changes in size and shape can improve innovations and was well-aware from his research that there is a massive global need for cheap, clean drinking water — had quite the reverse inspiration.

"We were cleaning 3 to 4 liters of water at a time" to test the filters, he says. "I asked myself, 'Why don't we design a filter for only 2 to 3 liters of water?' That's when it dawned on me that this was a very good idea."

### **The World Takes Notice**

The group switched its focus to smaller, water-bottle-size applications and spent the next year and a half laboring in the lab to perfect the technology.

At the same time, Stellenbosch University launched the Hope Project to mobilize its faculty to use its knowledge to solve the world's problems. The university decided to showcase the teabag water filter for local media in the summer of 2010.

After that, "Things moved pretty quickly," says Philip Marais, with considerable understatement. Marais is a business developer with InnovUS Technology Transfer, the university's technology transfer company.

A story about the filter in the local paper was noticed by media



Michèle de Kwaadsteniet, Ph.D., of Stellenbosch University holds a used and unused teabag water filter.

around the world, and the teabag water filter was suddenly the subject of articles from China to Europe to the United States.

Cloete was flooded with inquiries from 120 organizations on six continents that were interested in licensing the technology. He passed each person along to Marais.

"How do you follow up with 120 organizations?" Cloete says, in explaining how grateful he is to Marais and his office for taking over the business side of the project. "They've played a very important role. You need people who can do that as a service to the scientists."

For his part, Marais says he's learned an enormous amount about the marketing potential of leveraging the media when an exciting innovation comes along.

"It's quite staggering the value of that advertising that we've

paid nothing for," he says.

### Doing the Most Good Possible

Marais had already been in discussions with Karsten, who was interested in licensing the technology, before the media frenzy. Despite the 120 other interested parties, Stellenbosch University decided to stick with Karsten's AquaQure and signed an agreement with the company in November 2010.

"Tony is the perfect champion for the product," Marais says, noting his "passion for the product and determination to see it go to market."

AquaQure hopes to have full production under way at a Cape Town plant in the fall, with bottles on the market by the end of the year. He wants to keep the cost of the bottles as small as possible to provide access to the most people. The goal is that the bottles, which will come with a month's supply of filters and a pictogram explaining how to use them, will cost less than \$5 (U.S. currency). Additional filters, each of which can be used for a day, would cost less than a penny, Karsten says.

While the main focus is on providing safe drinking water to people who can't access or afford it, Karsten says there's an upscale version of the bottle being considered for hikers.

But, the main intention has always been to help those in desperate need.

Cloete said he has two big goals for the teabag water filter. He hopes it inspires other academics to use their knowledge toward solving humanitarian problems. And his main goal is chipping away at those massive problems himself.

"I want to see this make a difference in the lives of people who need it most," he says. "To bring hope to people in the world who need this technology, where children are dying of disease. That's my dream."

— Emily Stone



University of California at Los Angeles, Los Angeles, Calif.

## A Better Membrane Helps to Replenish the World's Fresh Drinking Water Supply

In April of 1961, at the dedication of a desalination plant in Texas, President John F. Kennedy said:

*No water resources program is of greater long-range importance than our efforts to convert water from the world's greatest and cheapest natural resources — our oceans — into water fit for our homes and industry.*

He went on to say that:

*Such a breakthrough would end bitter struggles between neighbors, states and nations.*

While there may be less hope for the end of struggles between nations, Kennedy's assertion that extracting freshwater from saltwater is one of the greatest scientific breakthroughs in history couldn't be truer today. More than 97 percent of the earth's water is too salty for human consumption. Water use has been growing at more than twice the rate of population growth in the last century.

The World Health Organization reports that as populations rise, urbanization grows and there is an increase in household and industrial uses for water, the world is running out of clean, drinkable water. Water scarcity affects 1 in 3 people on every continent. According to United Nations statistics, at least 1 billion people live in areas where water is scarce, and the numbers are reported to reach 1.8 billion by 2025.

Around the time President Kennedy made that speech, researchers at the University of California at Los Angeles (UCLA) were developing a new technology that forced water molecules across a semipermeable barrier at a much faster rate than salt



NanoH<sub>2</sub>O's reverse osmosis membrane element, QuantumFlux, increases desalinated water production with fewer energy resources than current technologies.

ions, producing a freshwater stream. The process became known as reverse osmosis (RO) and has since become the most popular method of separating salt water from seawater, a process known as desalination. Over time, the UCLA team developed this technology into tubular membrane modules that produced freshwater from ocean and brackish groundwater.

It was a watershed event in addressing seawater desalination.

Over the next 30 to 40 years, manufacturers improved membrane material as well as module and process designs and, as a result, the cost to produce freshwater from seawater was reduced by 400 percent between 1980 and 2000.



But there were two challenges. The first: The process remained energy-intensive and costly relative to traditional freshwater treatment processes. And second, modern RO membranes were prone to fouling when rejected particles and bacteria accumulated on the surface.

By early 2000, though it was only one of a few options available to address severe water shortages, the still-expensive process of RO seawater desalination was gaining global acceptance.

### Making over a Membrane

Eric M.V. Hoek, Ph.D., was in his first year as an assistant professor of environmental engineering at UCLA when he began working on a new RO membrane material envisioned to perform better in desalination applications.

“[I thought,] what if we could integrate a nanoparticle into an RO membrane to make it more productive and resistant to bacteria?” says Hoek. “I imagined the properties of such a material, and then one day learned in a presentation by a colleague’s student that something like it existed, but in a different form.”

That material, known as a zeolite, or molecular sieve, due to its internal molecular pores, takes up water like a sponge. The pores are just big enough to let water through but just small enough to reject salt. An extra advantage was that these materials could also be modified to exhibit antimicrobial functionality.

Hoek’s hypothesis was that synthesizing zeolite nanoparticles and embedding them within the RO membrane could reduce the overall energy demand in the desalination process.

That’s when, with startup funds provided by UCLA’s Henry Samueli School of Engineering and Applied Sciences, thin-film nanocomposite (TFN) membrane technology flowed from the tributary of great water desalination discoveries at the university.

When it worked, Eric Hoek had built a better membrane.

A second stream of funding came from the UCLA California NanoSystems Institute (CNSI) and from the company that ultimately would commercialize the technology, NanoH<sub>2</sub>O Inc.

The material was named, says Hoek, “for its unique structure where a 100- to 200-nanometer thin film contains both nanoparticles and polymers working together to produce a better material than either could alone.” It attracted water and rejected salt and other particles that can obstruct the flow of water.

Hoek says the TFN membranes he produced in the lab at UCLA demonstrated a 100-percent increase in permeability when compared to conventional RO membranes while maintaining the same level of salt rejection. It also inhibits the adhesion of bacteria and other organic materials that tend to foul up membranes over time.

All of this significantly reduces the cost of desalinated water, making it a more economically viable option to increase global water supply. In 1980, for example, the cost of desalinating water with conventional membranes was \$2 to \$3 per cubic meter. In 2010, with the new membrane, the cost was .50 to \$1 per cubic meter.

### A Sustainable Technology and a Company Surface

Discovery and commercialization came together in 2005 when Hoek met Jim McDermott, an experienced technology entrepreneur, and Bob Burk, Ph.D., a scientist with many years of experience in environmental technologies. Within weeks of their initial meeting, a deal was struck.

“It was an exciting agreement,” says Emily Loughran, director of licensing at the UCLA Office of Intellectual Property about the licensing. “I had heard from a colleague that there was an investor interested in clean energy and sustainable technologies. Our objective is to bring technology with a clear and demonstrable effect to the marketplace for public benefit. This project encompassed all the things we like to see. It’s very rewarding to be a part of a deal like this one.”

Jeff Green, who previously founded Archive Inc. and Stamps.com with Jim McDermott, was brought in as chief executive officer, and Burk was named chief scientific officer. The excitement of the union between Hoek, UCLA, Green and McDermott was further heightened by the fact that not only did the original technology come out of the UCLA, but Green and McDermott are graduates of the UCLA Anderson School of Management.

In late 2005, after receiving \$900,000 in angel funding, NanoH<sub>2</sub>O set up its office in one of the CNSI incubator laboratories. Two years later, a \$5 million investment came from Khosla Ventures and, in 2008, another \$20 million came from Oak Investment Partners and Khosla.

NanoH<sub>2</sub>O opened a 26,000-square-foot research and manufacturing and corporate facility in nearby El Segundo, Calif., in late 2009.

The company received an additional \$10 million in 2010 from PCG Asset Management and CalPERS, along with a \$400,000 research grant from the United States Office of Naval Research to explore military applications for this RO membrane technology now marketed under the QuantumFlux brand name.

“Eric’s membrane improves the economics and energy efficiency of desalination while it increases the world’s freshwater supply,” says Green. “The more productive the membrane, the lower the energy consumption of the desalination process. In retrofit installations, NanoH<sub>2</sub>O’s QuantumFlux membranes can significantly increase water production or drastically decrease energy consumption. For new system designs, utilizing QuantumFlux membranes can enable engineers to build smaller plants due to the higher efficiency of the technology.

“This will help improve the quality of life for drought-stricken areas of the world and ensures a potable water supply for future generations,” Green adds.

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### **Freshwater: A Continuing Flow**

NanoH<sub>2</sub>O was recently selected as one of top 100 companies for a Global Cleantech list out of more than 4,000 nominations. Global Cleantech 100 recognizes companies that offer solutions to the planet’s most pressing environmental challenges.

“I never intended to file a patent or start a company,” Hoek says. “The fact that our ideas have inspired other people is tremendous, and now there’s a company that is poised to lead the membrane desalination industry.”

First commercial sales for NanoH<sub>2</sub>O’s seawater RO membrane occurred in the fourth quarter of 2010. As of spring 2011, multiple desalination plants around the world are benefiting from this advanced technology.

NanoH<sub>2</sub>O continues to advance the research conducted at UCLA, allowing an expanded portfolio of products that will further lower the cost of desalination and directly address the worldwide water scarcity issues that President Kennedy foresaw so clearly.

— Ellen Blum Barish

University of Vermont, Burlington, Vt.

## Academic Filtration Innovations Aim to Solve What Ails a Perishable Resource: Water



Aleksandra Drizo, Ph.D., a research associate professor at the University of Vermont who developed a portfolio of filtration technologies licensed to startup PhosphoReduc LLC., inspects a residential waste-water treatment project in Taiwan.

Water quality is a growing global concern. Under stress from pollution, climate change and a surging population growth, the status of this important and perishable resource is propelling this planet toward a multifaceted crisis.

According to the United Nations Environment Programme's (UNEP) *2010 Clearing the Waters: A Focus on Water Quality Solutions*, "Every day, millions of tons of inadequately treated sewage and industrial and agricultural wastes are poured into the world's waters. Every year, lakes, rivers, and deltas take in the equivalent of the weight of the entire human population — nearly 7 billion people — in the form of pollution. Every year, more people die from the consequences of unsafe water than from all forms of violence, including war. And, every year, water

contamination of natural ecosystems affects humans directly by destroying fisheries or causing other impacts on biodiversity that affect food production. In the end, most polluted freshwater ends up in the oceans, causing serious damage to many coastal areas and fisheries and worsening our ocean and coastal resource management challenges."

Phosphorus and nitrogen loading from sewage and other agricultural, industrial and urban uncontrolled discharges is a major cause of eutrophication (excessive nutrients enrichment of water bodies) that triggers taste and odor problems in the public water supply and excess blue green algae that leads to deoxygenation and fish kills. The estimated cost of the excessive runoff into U.S. waterways of phosphorous, a valuable fertilizer used in farming, urban and industrial settings, is more than \$2 billion a year, according to the *Year Book 2011: Emerging Issues in Our Global Environment* by UNEP, "indicating that globally and annually the damage may run into the tens of billions of dollars." Also, phosphorous reserves are nonrenewable, with projected shortages to develop in less than 100 years.

### University of Vermont Academic Filtration Technologies Show Promise

Given the extent of this growing crisis and the need for environmentally and economically sustainable water-treatment options, numerous management strategies and technical innovations are starting to emerge, including a portfolio of filtration technologies for the removal of phosphorous from waste-water sources that were developed by Aleksandra Drizo, Ph.D., a research associate professor at the University of Vermont (UVM) and licensed by the college's Office of Technology Commercialization (OTC) to PhosphoReduc LLC, a UVM startup company located in Burlington, Vt.

Drizo has pioneered research in the use of various iron-, aluminum- and calcium-based materials — natural and industrial by-products that can be used to remove phosphorous from waste waters as a lower-cost alternative to other traditional technologies. The suite of UVM sustainable filtration technologies — two with patents pending and a third in the application process — is based on a plentiful and recyclable byproduct of steel manufacturing industry, steel slag. The sustainable filtration technology has been shown to reduce phosphorous, suspended solids and pathogens (E. coli) loads from sewage, agricultural and urban point and nonpoint pollution sources by 90 – 100 percent.

Apart from providing treatment for a variety of waste-water streams, Drizo and her UVM research team have adapted their technologies to an array of climatic regions, from subtropical to temperate regions, where large storms or snowmelts are common, but large areas of land to handle the high volumes of water from these events are scarce. They also have shown that once the lifespan of the system is completed, the phosphorus and minerals retained by the filtration material can be re-used, instead of chemical fertilizer, to enhance soils used for agriculture, horticulture and forestry.

Specifically, she and her research team at UVM have developed technologies for a simple filtration system that uses unique, but abundant, metal compounds as the filtration medium:

- An integrated, multistage constructed wetlands and phosphorus removal filter system
- Phosphorus removal and sequestration filters for treatment of agricultural, municipal and residential waste waters (point pollution sources)
- Simple “torpedo” system for phosphorus reduction from agricultural tile drains and urban storm-water outflows or in agricultural and onsite waste-water disposal drain fields for capturing and treating pollution originating from nonpoint, diffuse pollution sources and residential waste waters

As a leading researcher in filter technologies for phosphorus

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**The sustainable filtration technology has been shown to reduce phosphorous, suspended solids and pathogens (E. coli) loads from sewage, agricultural and urban point and nonpoint pollution by 90 – 100 percent.**

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removal from waste waters that can help solve the worldwide occurrence of algae blooms and eutrophication, Drizo has received grants and awards for her research from a variety of federal agencies and programs: the U.S. Department of Agriculture, the Natural Resources Conservation Service, the National Research Initiative and the Environmental Protection Agency.

Steel slag, available in different types, including electric-arc furnace, blast furnace, basic oxygen furnace and iron smelter slag, for various applications, including mining and road building, “shows real promise as filtration material, not just for phosphorous and suspended solids but also for the bacteria E. coli in waste-water treatment plants in smaller, rural communities, as well as in storm-water applications found in urban areas,” says Robert Slusser, a self-described champion of the UVM technology outside his official duties as a watershed field coordinator for the Virginia Department of Conservation and Recreation.

Slusser, who first learned of Drizo’s research with steel slag as a filter medium via an email exchange with a New Zealander, says the pollution threat posed by waste-water discharge from farm and rural activities justifies a closer look at sustainable filtration technologies like those developed at UVM. Today, waste-water discharges from 30 percent of the population that depends on septic systems, since they live in areas where it is prohibitively expensive and impractical to extend sewer lines, pose two water pollution concerns: Most of the onsite systems are not properly managed for lack of management skills and/or neglect, and they were installed decades ago and have long

### Fertilizer Pollution Is an Emerging Issue

According to the United Nations Environment Programme's *Year Book 2011: Emerging Issues in Our Global Environment*:

- Global use of fertilizers that contain phosphorus, nitrogen and potassium increased by 600 percent between 1950 and 2000. This helped to feed a growing world population, but excessive or inappropriate fertilizer use has also led to significant pollution problems in some parts of the world.
- In the last half-century, the phosphorus concentrations in freshwater and terrestrial systems have increased by at least 75 percent, while the estimated flow of phosphorus to the ocean from the total land area has risen to 22 million tonnes per year.
- In aquatic systems, too much phosphorus and other nutrients results in eutrophication, which promotes excessive algal and aquatic plant growth, along with undesirable impacts on biodiversity, water quality, fish stocks and the recreational value of the environment. Algal blooms can include species that release toxins that are harmful to humans or animals, while decomposition of algae can lower dissolved oxygen levels, causing mass mortality among aquatic creatures. Scientists have warned that human-induced nutrient overenrichment can push aquatic ecosystems beyond natural thresholds, causing abrupt shifts in ecosystem structure and functioning.
- The estimated annual cost of eutrophication in the United States alone is as high as \$2.2 billion. This problem is exacerbated in large urban centers, where phosphorus from excreta and detergents is concentrated in waste-water streams and discharged along with nitrogen and other nutrients. If local authorities do not invest in facilities to remove these nutrients, they will be discharged with other effluent into rivers and water bodies. This is frequently the case in the megacities in developing countries, where more than 70 percent of waste water enters surface or groundwater untreated.

since passed the recommended replacement dates. Examples of septic systems failures typically include holes in the pipes or tanks, clogs that cause tanks to overflow and back up solid waste into buildings or leach fields and soils that either become saturated with nutrients or ill-suited for removing the pollutants.

"When I talk to state and municipal officials, planning consultants and farmers about waste-water issues, I always have the steel slag story in my back pocket," says Slusser, who has befriended and introduced Drizo to various public and private individuals who are interested in her filtration technologies.

### UVM OTC Helps Innovator Launch a Startup

"These filtration innovations represent more of a platform technology where we see several application and market opportunities," says Todd Keiller, director of UVM Ventures and UVM OTC, which was instrumental in obtaining patent protection for the UVM intellectual property and establishing the startup company. "We could have taken the nonexclusive licensing approach with multiple entities, but it became clear that a better strategy was to license the technology to one entity that would have exclusive rights to target multiple applications and markets."

Keiller and his UVM OTC team decided it was worth helping Drizo and her partner, Hugo Picard, a Canadian entrepreneur with experience in small-company business development and operation management, start their own company based on the UVM-licensed technology.

So, in 2007, Drizo and Picard established PhosphoReduc, with seed funding assistance from UVM Ventures.

"In the early stages, we helped PhosphoReduc bridge the gap between early stage research and angel, early seed ventures," says Keiller. "Our activities included conducting a thorough market assessment, as well as working with them to develop a prototype and a business plan."



In return, UVM Ventures holds an equity stake in the company with a royalty agreement.

“I certainly had envisioned owning a business because my partner has been a successful entrepreneur for about the past 10 years,” Drizo says looking back on the decision. “I saw how well it was working so it gave me the strength to go into business.”

Drizo credits the UVM OTC and the UVM College of Agriculture and Life Sciences (CALS) for playing a pivotal role in the expansion of her academic innovations beyond university laboratory and field settings.

“In 2006, the UVM OTC funded our first patent application for System and Method for Removing Phosphorus from Non-Point Pollution. Then we received the necessary funding through the UVM OTC and CALS Dean’s Office Agricultural Innovations Fund to establish our small-business venture, PhosphoReduc LLC,” says Drizo. “Now we have broad applications in the United States, Canada and Taiwan.”

### Persistence Coupled with Desire to Solve Water Issues

Since 2007, when Drizo, Picard and the UVM support team first established PhosphoReduc, the startup has had to overcome several hurdles in its drive to create pilot, demonstration or full-scale projects. The startup was confronted by various regulatory challenges, from state-to-state, within U.S. agencies and around the world, as well as expensive certification requirements that were made even more challenging during the global economic recession.

“Despite these challenges, the desire to help solve a crucial water-quality issue was what encouraged the PhosphoReduc team to persevere,” Drizo says.

Today, the PhosphoReduc custom-designed systems consist of one or more filter units filled with iron- and/or calcium-based filtration material derived from slag. Phosphorus and other pollutants are removed from waste water by capturing it within the



Three parallel treatment lines have consistently reduced phosphorus and suspended solids by nearly 100 percent for nine months of operation at a residential waste-water treatment project in Taiwan.

filtration material at the specific hydraulic residence times. The filtration media is packed, arranged and integrated in specially designed modules that form a modular composite filter. This method developed by PhosphoReduc allows users to replace the modules as needed and also extend the overall lifespan of the system, ensuring the effluent meets water-quality targets.

“Our technologies are showing to be highly efficient, not only in removing phosphorus, but also other pollutants including suspended solids, pathogens and various metals and minerals,” Drizo says, citing to-date PhosphoReduc treatment performance data that shows on average: 95 percent phosphorus removal from point pollution sources (residential, municipal and agricultural effluents); 80 percent phosphorus removal from nonpoint pollution sources; 90 percent removal of suspended solids; 95 percent removal of E. coli bacteria; and 85 percent removal of manganese, iron, aluminum and zinc.

In addition to reducing phosphorus and diminishing blue green algae growth, Drizo says PhosphoReduc filters based on UVM technology require little to no energy, a small land footprint, and minimal operation and maintenance. And, since the filtration materials efficiently reduce phosphorus, they decrease the reli-

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**“In the early stages, we helped Phospho Reduc bridge the gap between early stage research and angel, early seed ventures,” says Keiller. “Our activities included conducting a thorough market assessment, as well as working with them to develop a prototype and a business plan.”**

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ance on costly chemicals and the amount of sludge accumulation and disposal in municipal waste-water treatment facilities, are simple to install with negligible land disturbance and provide a significantly longer lifespan compared to other passive treatment systems.

These innovations developed by Drizo and her research team are backed by years of testing and research. They are found in Vermont, Virginia and Taiwan, where demonstration and full-scale systems are contributing to the environmental sustainability of waste-water management in agricultural, urban, residential and municipal settings. Vermont is even considering adopting the technology as a “best management practice” for agricultural tile drains, pending evaluation on a test site in that state.

Meanwhile, in Virginia, Slusser believes that Drizo's steel-slag argument is going to get a much-needed boost when data becomes available from the residential waste-water treatment project that is being tested and considered in Taiwan.

“We need inexpensive, environmentally sustainable solutions, not only for waste-water treatment plants in smaller communities, but for expensive storm-water detention applications as well. This is a huge problem that is starting to be discussed in Virginia, the rest of the country and the world,” Slusser says. “If steel slag can come along as acceptable as we focus attention on water quality, then this filtration medium can be incorporated into more consistent regulations, and we can really achieve a significant reduction in pollution and bacteria in our planet's perishable resource.”

— David Perilstein

Includes  
Foreword by  
American Red Cross  
President  
Gail J. McGovern

The *2011 Better World Report*, published by the Association of University Technology Managers, celebrates real-world examples of technologies that are helping the world respond, recover and restructure in the face of human-made and natural disasters. And how humans can be more respectful in working with the environment to provide a sustainable, good life for all humankind.

Within these pages you will:

- Find out how cow manure can be used to clean up soil.
- Wonder at the ingenuity of a group of people using a teabag, activated carbon and a hair straightener to make the prototype of an inexpensive water filter that could mean the difference between life and death.
- Discover how years of anonymous, often-repetitive lab work built the foundation for a DNA microarray to monitor microbial populations — a scientific breakthrough that could help detect a number of threats, from bioweapons to pathogens in the food supply.
- Marvel at the creativity and cooperation of a group of students and their teachers as they use their architectural skills and sweat equity to build affordable, green modular homes and donate them to the community.
- And so much more...

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